energy design resources

design brief

SMART BUILDINGS

Integrating smart-building design features into a new construction project can significantly increase the energy efficiency of the building while also providing enhanced occupant comfort.

Summary

Smart buildings take advantage of information exchange to provide a flexible, productive, and cost-effective environment for building occupants. There is a high demand for smart buildings in the marketplace, with a majority of office tenants citing features available through smart buildings infrastructure as important features for their office spaces. Total life-cycle costs for smart buildings are generally lower than costs for conventional buildings due to large energy and churn cost savings to building tenants, as well as lower vacancies, increased lease income, and lower tenant improvement costs for building owners.

Information exchange in smart buildings occurs through a high-bandwidth cabling infrastructure that connects with all components of the telecom; heating, ventilation, and air conditioning (HVAC); lighting; fire, life and safety (FL&S); and security systems. A Building Automation System (BAS) with microprocessor-based controls in each building zone transfers information through this cabling system, providing the sensory functions, signal processing, and control responses that lead to smart-building operation. Building automation systems that include a "smart metering" component for electricity and other utilities further increases the energy management capabilities available with smart buildings, giving facilities managers the information necessary to make better decisions that can reduce overall energy use and costs.

To minimize the cost impact of providing smart-building capabilities, they should be incorporated into the design of new

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facilities from the beginning—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.

Introduction

In a "smart building," the systems, structure, and function of the building are optimized to provide a productive and cost-effective environment that adapts to the current and future needs of building occupants. Although smart buildings are diverse in nature and employ many different techniques to enhance productivity and drive down cost, most smart buildings share a set of characteristics that set them apart from other buildings. These characteristics include:

In a "smart building," the systems, structure, and function of the building are optimized to provide a productive and cost-effective environment that adapts to the current and future needs of building occupants.

- Advanced HVAC and lighting controls
- Smart metering capabilities, allowing central access to real-time utility data
- A structured cabling infrastructure with high bandwidth and connectivity
- Adaptability to changing technology and tenant needs

Is There a Market Demand for Smart Buildings?

The enhanced comfort, flexibility, and building responsiveness associated with smart building technologies are among the most important features building tenants expect to have in their workplace. The Building Owners and Managers Association (BOMA) published a survey in 1999 identifying the building features office tenants view as important for their offices.[1] The 1,800 companies across the United States who responded to BOMA's questionnaire were mostly represented by company principals, executives, office managers, and department managers.

The first section of the survey asked tenants to identify the level of importance of a number of building features and amenities. Office tenants overwhelmingly ranked comfort issues highly in this portion of the survey. A large percentage of respondents also asserted the importance of building management responsiveness and flexible suite layout (**Table 1**, page 4).

A smart building is capable of providing tenants with all of these desired building features mentioned in the BOMA survey. Advanced HVAC control systems enable greater tenant control of temperature, ensure more comfortable temperatures throughout the building, monitor indoor air quality, and give facilities managers the information and control they need to quickly respond to tenant complaints. Smart buildings are also designed to allow easy reconfiguration of suite layout.

The second portion of the BOMA survey focused specifically on smart building features. In this portion of the survey, 72 percent of respondents claimed that they would pay additional rent for at least one of the following features, ranked by order of importance:[3]

- Wiring for Internet access and for high-speed networks
- Energy-efficient HVAC systems with tenant control of temperature
- Security systems with controlled building access and camera monitoring
- Telecommunications capabilities ranging from fiber-optic cable to cable TV to videoconferencing
- Redundant power source

Both the first and second sections of the BOMA survey demonstrate high demand among office tenants for benefits achieved through smart buildings infrastructure.

Who Benefits from Smart Building Technologies?

A smart building brings a wide range of benefits to facilities managers, tenants, and building owners. As indicated in the

What makes a building smart?

BOMA defines 13 building systems and structural features often found in smart buildings.[2] These features are a combination of automated control of various building functions, fast and flexible telecommunication systems, and time-saving conveniences for building occupants.

- Fiber-optics capability
- Built-in wiring for Internet access
- Wiring for high-speed networks
- LAN and WAN connectivity
- Satellite accessibility
- ISDN
- Redundant power source
- Conduits for power/data/voice cabling
- High-tech, energy-efficient HVAC system
- Automatic on/off sensor in the lighting system
- "Smart" elevators that group passengers by floor designation
- Automatic sensors installed in faucets/toilets
- Computerized/interactive building directory

Table 1: BOMA survey responses

Importance of building features to tenants.

Building feature	Percentage of respondents to whom feature is important
Building management's responsiveness	99%
Comfortable temperature	99%
Flexible suite layout	92%
Indoor air quality	99%
Tenant control of temperature	96%

Source: BOMA International Foundation[1]

The information for all building systems ranging from the chiller plant to security systems can be accessed from one computer terminal.

BOMA survey, office tenants want to occupy buildings that provide a comfortable and flexible work environment. Therefore, owners and property managers of smart buildings can drive their occupancy rates up by marketing these features to prospective tenants. When marketed correctly, these features can lead to higher lease income as well as increased occupancy. When tenants move out of smart buildings or expand to adjacent spaces, owners and property managers benefit from the lower churn cost and faster completion of tenant improvements associated with smart building infrastructure.

Smart buildings give facilities managers the information and control options necessary to effectively manage their buildings. Through the use of digital controls at the zone level, smart buildings keep facilities managers well informed, providing large quantities of information about building systems and components. The information for all building systems, ranging from the chiller plant to security systems, can be accessed from one computer terminal. This centralization of information gives facilities managers the capability to simultaneously monitor multiple building systems and to respond rapidly to any system malfunctions. Further, the control options available in smart buildings allow facilities managers to change system operational procedures remotely. Therefore, smart buildings allow facilities managers to minimize occupant complaints through event and alarm management, and respond rapidly to any complaints that do get reported.

Building architects and engineers will also benefit from smart-building technologies by receiving feedback about building performance. This feedback will give the design team the information necessary to improve building systems design for future building projects. Further, engineers and architects can use this enhanced building performance feedback to provide the documentation required for collection of performance-based fees (see the Energy Design Resources Integrated Energy Design Brief for more information on performance-based fees).

Building tenants also profit from smart-building technologies. Smart buildings are generally able to provide a higher degree of comfort and indoor air quality (IAQ) to building residents due to enhanced HVAC and ventilation controls. Moreover, tenants in smart buildings have the technologies necessary for meeting their communication needs. The higher degree of comfort and IAQ inherent to smart buildings, paired with a modern telecommunications infrastructure, enhances worker productivity for building occupants. Tenants will also have lower costs due to energy cost savings and to the lower churn costs resulting from increased flexibility when expanding or reconfiguring office suites.

Smart buildings are generally able to provide a higher degree of comfort and indoor air quality (IAQ) to building residents due to enhanced HVAC and ventilation controls.

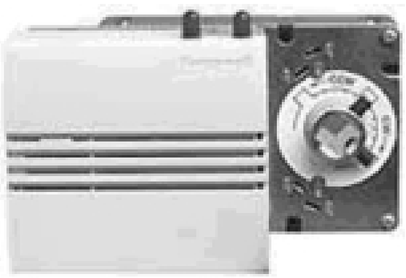
Advanced HVAC and Lighting Controls

Advanced HVAC and lighting controls are the “brains” behind the intelligent operation of smart buildings. Controls that improve the intelligent response of building systems include the following characteristics:

- Direct Digital Controls (DDCs) with electronic ancillary devices for both central equipment control and zone-level management
- Integration into one central BAS
- Interoperability achieved through an open protocol standard

Figure 1: VAV box DDC controller

DDC VAV box controllers vary airflow to a space and relay pertinent zone information to centralized building control systems.



Source: © Honeywell International, Inc.

Digital Controls at the Zone Level

Smart buildings use DDCs throughout the whole building to provide full facilities management and controls capabilities from a central location. DDCs are microprocessor-based controllers whose control logic is performed by software. Full DDC systems consist of digital controllers that work in conjunction with electronic ancillary devices (i.e., sensors and actuators) to control building systems. While many BASes use hybrid controls that combine pneumatic and digital components, smart-building BASes rely on full DDC systems for both central and zonal control. At the zone level, the smart-building DDC system generally includes:

- Digital temperature and CO_2 sensors that gather information about room temperature, supply air temperature, and indoor air quality
- Airflow sensors that determine airflow to the zone
- Electronic actuators to adjust airflow through variable air volume (VAV) boxes
- Terminal unit controllers that process sensor information and issue control signals to electronic actuators to vary airflow
- Digital occupancy and daylighting sensor controls that modify lighting levels

The BAS provides centralized control of all unit controllers, and integrates information received from unit controllers to make control decisions (**Figure 1**).

Full DDC BASes with unit controllers at the central and zone level offer many advantages over conventional, pneumatically controlled systems. First, DDCs gather and store much more information from sensors, allowing for automated diagnosis of problems, more informed decisions on the part of facilities managers, and greater integration between systems. Most BASes have software that notifies the facilities manager of a system malfunction and, when possible, provides an automated response to correct the problem. When each zone has full DDC controls, the BAS can provide specific information on the nature and location of the problem, and can often correct the problem through automated control sequences. For example, if a particular zone is too cold, the DDC-based automation system can identify the airflow to the zone, the supply air temperature, the temperature setpoint for that zone, and how the zone temperature compares with that of other zones. The BAS can use this information to identify whether the supply air is too cold, the air flow too high, or the temperature setting too low, and then modify temperature or airflow settings, either centrally or for that specific zone, in order to alleviate the problem. Problems that are quickly diagnosed and corrected will lead to increased building efficiency and enhance the overall functionality of building systems. The additional information available through digital zone controls can be used by facilities managers to make informed decisions regarding building control.

The information from digital sensors in each building zone also allows a much greater integration of the components in the HVAC and lighting systems. For instance, collective data showing temperature, airflow, and supply air temperature for all zones can be used by the BAS to analyze the appropriate volume of air that should be provided by the central air handling unit to meet building loads. Occupancy sensors can be used to turn off both the lighting and HVAC systems in an unoccupied zone.

The second major benefit of a full DDC system is its ability to either customize control sequences for a specific zone or to repeat control sequences in all zones of a building. Certain tenant activities or circumstances may require higher ventilation rates or customized heating, cooling, or lighting schedules. When DDCs for each zone are integrated into the BAS, all customized control sequences can be made quickly through the central software interface. This saves time for the facilities manager and greatly increases the adaptability of the leased space for various uses. The

Full DDC Building Automation Systems with unit controllers at the central and zone level offer many advantages over conventional, pneumatically-controlled systems.

The facilities manager has the ability to make universal changes to all zones through the central interface to the Building Automation System.

facilities manager also has the ability to make universal changes to all zones through the central interface to the BAS. In addition, when demand is high, buildings with DDCs can adjust setpoints and/or cycle equipment off to produce a 20 to 50 percent cost savings.[4] In buildings that do not have DDC systems in every zone, the facilities manager would have to walk to each terminal unit and make the change manually. Therefore, changes that would conserve energy and improve comfort are often not implemented in conventional buildings because of the inconvenience or added cost associated with such changes. In contrast, zone-level DDCs in smart buildings enable the immediate implementation of control measures that increase comfort and efficiency.

The third major benefit of full DDC systems is the increased precision and accuracy associated with digital controls. While pneumatic controls require routine maintenance and recalibration to preserve accuracy, DDC systems have far fewer moving parts, and therefore require significantly less maintenance. Once calibrated, DDC systems can also maintain temperatures and other building conditions with greater precision, and are capable of maintaining this accuracy for years without requiring recalibration.

Advanced Lighting Controls

Smart buildings minimize lighting energy use and optimize visual comfort through the use of enhanced lighting controls. Good lighting controls maintain lighting levels desired by building occupants by adjusting electric lighting illumination to supplement daylighting and by dimming or switching off electric lighting in vacant areas. As with HVAC systems, lighting control of smart buildings is accomplished through DDCs that are integrated into the BAS. In the best lighting control systems, each fixture, photosensor, and occupant sensor has a separate Internet Protocol (IP) address and is connected to a multicircuit digital control panel. Just as zone-level DDCs for HVAC systems allow for both customized control of each terminal unit and control sequencing applied universally to all zones, IP-addressed fixtures and sensors tied into the BAS allow both customized control of each fixture and building-wide lighting control. Building Automation Systems provide the following lighting control functions that help enhance energy use:[5]

Each lighting zone can be programmed with a lighting control schedule that is consistent with the tenant occupancy schedules for that area of the building.

- *Occupant control of lighting*. This is an essential feature for smart buildings, leading to increased productivity of up to three percent and a dramatic reduction in complaints about lighting. Some lighting control maximizes tenant control by giving each occupant the opportunity to control his own illumination level through a software program accessed through the workstation. In addition to increasing tenant satisfaction, occupant lighting control reduces energy use by allowing tenants to use lower illumination levels to meet their specific needs, rather than supplying enough light for the "worst-case" condition everywhere.
- *Scheduling*. Each zone can be programmed with a lighting control schedule that is consistent with the tenant occupancy schedules for that area of the building. In advanced lighting control systems, certain areas can follow schedules that dim lighting in vacant areas during the day, and turn it off after business hours.
- *Occupancy and Photosensor Controls*. When connected into the BAS, occupancy and photosensor controls can respond differently according to tenant preference. For example, occupancy sensor controls can either dim lights, turn lights completely off, or follow a timed sequence that employs both strategies. Photosensors can be set to adjust electric lighting systems to supply the illumination levels desired by the occupants.

Integration Through the Building Automation System

One of the most important capabilities available through a full-DDC BAS is integration. Integration refers to the sharing of information between building components and systems that leads to enhanced operation and efficiency of each building system.

Figure 2: Zone DDC-controlled lighting system

Zone DDC lighting control systems adjust artificial lighting levels based on daylighting and occupancy sensor inputs.

Source: © Ledalite

Building Automation Systems can provide information that allows for customized access, lighting, and conditioning of spaces.

As discussed earlier, integration of the HVAC components of the building through the BAS leads to a more rapid response to changing loads within a building, resulting in increased HVAC efficiency. The smart BAS further reduces energy use by integrating occupant sensor information for each zone into the HVAC controls. For example, cooling setpoints for an unoccupied space can be set slightly higher than those of occupied spaces. This allows for slightly lower energy consumption while ensuring that comfort conditions can be met quickly upon the occupant's return to the space. Some systems have been designed to shut off VAV boxes when the space is unoccupied.

In the smart-building BAS, FL&S and security systems can also be integrated with HVAC and lighting systems to improve the functionality of all systems involved. For example, FL&S systems can be integrated with ventilation systems to provide a redundant shutdown sequence during a possible fire.[6] Information from the FL&S system can also be shared with the security controls and video surveillance systems to enable faster response to emergencies and to initiate the more rapid collection of surveillance data necessary to identify the cause of fires or false alarms. At the most advanced level of systems integration, security systems can be integrated with HVAC, lighting, and elevator systems to ensure optimum security for all tenants while minimizing energy use and enhancing comfort. For example, when a person uses a security access card to enter a building after hours, the BAS can provide information that allows the elevator access to that person's floor and turns on the lighting and HVAC in that individual's office as well as the lighting in the associated corridors.

Although complete integration of all building systems into the BAS can increase the functionality of each system, there are several barriers that prevent it from becoming commonplace in new buildings. First, fire code requirements make it very difficult to integrate FL&S systems into the central BAS. Second, integration requires an engineer or team of engineers who understand the design of each system and how to integrate the systems. In the U.S., most building systems are designed individually by engineers specializing in a particular field of engineering. Systems integration requires an integrated design approach where design team members collaborate to design building systems that share information between systems. Third, systems integration is often not tested appropriately once the building has been constructed. All buildings that have complex systems or that integrate simple systems together should be thoroughly tested through the process of commissioning once the building is operational. Finally, data transfer between integrated systems has often been difficult due to proprietary communication languages used by building components.

Protocol Requirements for the Building Automation System

Although most modern buildings include individual controls that communicate some electronic data within systems, it has traditionally been difficult to allow access to this data from other building systems due to the proprietary communication protocols used within each building system. However, recent developments of "open protocol" (or "single standard") languages have allowed free information flow between systems. An open protocol is a standard of communication that is made available to the industry. Components that use an open protocol are capable of exchanging information with any other components using the same protocol, regardless of who manufactured the components.

An open protocol system lets building systems be expanded or changed without significantly altering the existing system infrastructure.

Systems designed with an open protocol have far more flexibility than those designed with proprietary standards. Open protocol offers an expanded choice of products for all building components. Further, an open environment allows a wider choice of installation and maintenance providers for building systems and components. Finally, an open protocol system lets building systems be expanded or changed without significantly altering the existing system infrastructure.

Two major open protocols are available for the purpose of facilitating communication between building systems. Building Automation and

Control Networks (BACnet) is a single standard developed by ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers, for more information see www.bacnet.org) to "achieve interoperability between HVAC&R controls and automation systems and other building systems." Although the BACnet system focuses on energy management functions, it does include capabilities for communications with FL&S, security, and power systems as well. LonWorks is a second open protocol developed for the purpose of integrating all building control systems.

In some cases, proprietary protocols are required to maintain building safety and security. For example, most FL&S systems rely on proprietary platforms. In these cases, an information gateway can be used to communicate pertinent information to other building systems. Communication gateways, such as the public Internet or private Intranet, are systems that translate from a proprietary language to a common language. Although gateways provide a viable alternative when open protocol systems are not available, they fall short of open protocols in several areas. The amount of information that can be communicated across an information gateway is limited, thus limiting the amount of communication between systems. When communication gateways are used, real-time monitoring or controls are nearly impossible due to the limited data transfer through gateways. Further, gateways must be altered every time components in the system connected to the gateway are altered. Finally, proprietary systems often require their own cabling infrastructure for transferring information, thus preventing the use of a single structured cabling system.

Smart Metering Technologies

Electronic submetering enables tenants and facilities managers to identify the energy conservation opportunities that will have the greatest impact on utility costs.

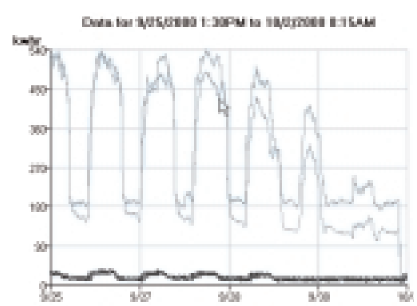
The term "smart metering" refers to metering technologies that record real-time energy data electronically and make the data available through a software interface. Electronic submetering is a form of "smart metering" that allows facilities managers and tenants to access real-time information regarding energy consumption and demand through the interface to the BAS. In commercial buildings, the BAS makes information available from submeters at each tenant distribution panel and from submeters for each chiller and air-handling unit. Electronic submetering enables tenants and facilities managers to identify the energy conservation opportunities that will have the greatest impact on utility costs and measure the actual impact of the energy conservation measures that are implemented. Data from submeters are especially useful in helping facilities managers implement control strategies that minimize peak demand. Submetering data also helps facilities managers identify performance problems and customize maintenance schedules based on actual equipment use. Therefore, submetering data can be used by both tenants and facilities managers to increase efficiency and minimize costs.[7]

Smart metering technologies also apply to whole portfolios of buildings, where information from multiple meters and submeters is displayed through a single Web interface. Nearly all Web-based energy portfolios provide real-time pricing information as well as options for viewing energy demand and consumption profiles for multiple buildings over a specified period of time. This information can be used to identify energy trends for individual buildings or groups of buildings. For example, the sample energy-use profile for two buildings in **Figure 3** can be used to identify the time of day when demand is likely to peak, and to evaluate typical daily building energy consumption.

Most Web-based portfolios also provide some data analysis capabilities that enable facilities managers to compare various rate structures and estimate future energy bills. The most advanced web-based building portfolios integrate information from BASes with metering data to generate complete energy analyses of multiple buildings from a single location. These systems generate separate reports for facilities managers, building owners, and building tenants, giving each of them specific information regarding energy costs, with recommendations for future strategies that will reduce costs. These systems also provide real-time diagnostics of energy use across multiple

Figure 3: Sample real-time energy use profile

Graph is shown in kiloWatts per hour/day.



Source: Demo at http://www.edisonamicos.com/

buildings, displaying alarm notifications for individual buildings or systems and following user-defined response strategies for dealing with alarms. While all Web-based portfolios can be used to estimate measurement and verification of energy savings projects, the more advanced Web-based portfolios are capable of generating precise calculations of the actual savings achieved through energy efficiency measures. Whether simple or advanced, Web-based building energy portfolios provide specific information about building energy use that enables facilities managers and tenants to minimize energy cost.

High-Bandwidth Communications Infrastructure

According to BOMA, truly smart buildings "are those with applications that take advantage of information exchange."[8] This information exchange is accomplished through the use of a structured, high-bandwidth, highly connective communications infrastructure that supports all desired voice, data, video, and control applications.

Bandwidth requirements in a building greatly increase as more people use the Internet and as the size of files transferred over the Internet continues to grow.

What Data Needs Are Forcing Higher Bandwidth Requirements?

Over the past 10 to 15 years, business success has become increasingly dependent upon rapid information transfer, which relies upon high bandwidth. Several factors have influenced the need for higher bandwidth within commercial buildings. First, increased processing speeds for personal computers have resulted in the overloading of cabling systems that connect the Local Area Network (LAN). Therefore, higher-bandwidth systems are becoming necessary to facilitate data transfer within buildings.

The explosion of the Internet as a tool for research, training, commerce, and communication is another key factor contributing to the need for greater bandwidth. The number of worldwide Internet users increased from 61 million in 1996 to 148 million in 1998, and estimates for the number of e-mails sent daily in 1998 range from 618 billion to 4 trillion.[9] As the Internet industry expands, Web design firms are incorporating large quantities of images, animations, and audio and video components into their Web page design. Most Internet users show a preference for these more content-intensive Web sites; over 75 percent cite high-quality content as the most important factor driving them back to a Web site.[10] E-mails are also growing in size as work products are increasingly distributed digitally rather than in paper form. Bandwidth requirements in a building greatly increase as more people use the Internet and as the size of files transferred over the Internet continues to grow.

Higher bandwidth is also required to support the structured cabling system that uses the same backbone for telecommunications and for data transfer between all components of the BAS. A structured cabling system transfers not only the Internet and local network data described above, but also telephone (voice) communications and data transfer between building systems. The data transfer between building systems can become very large in buildings where digital video surveillance is combined with the other digital signals transferred to and from the BAS.

High-Bandwidth Technologies

The cabling industry has expanded and changed almost as rapidly as the Internet, and now offers several viable alternatives for high-bandwidth applications (**Table 2**, page 16).

Wireless technologies transfer data through the use of infrared light or radio waves. Although wireless distribution technologies greatly increase flexibility for network access, they lag far behind copper and fiber-optic cable in bandwidth, supplying only 11 Mbps, and typically don't have the point-to-point range available through other technologies.

Unshielded Twisted Pair (UTP) copper wiring is the most common cabling used in commercial buildings. Unshielded

Data Transfer Rates

Data transfer rates are a measure of the speed at which data moves through a cable. The rates are measured in the number of bits (small amounts of digital information) that can be moved across a cable in one second. Current technology is capable of two different orders of data transfer rates.

Megabits per second (Mbps) — One million bits of data are transferred every second. One million bits is approximately the size of a 10-page text file.

Gigabits per second (Gbps) — One billion bits of data are transferred every second. One billion bits of data is approximately the size of a large software program.

Table 2: Comparison of data transfer media[12,13]

Fiber-optic cable has a longer range and higher bandwidth than other transfer media, but is still higher in cost.

Media type	Bandwidth	Range Across Backbone
Wireless	11 Mbps	500 – 1000 ft.
Category 5 UTP cable (24 AWG, 100 ohm + 15%, solid copper conductors)	100 Mbps	2624 ft.
Multimode fiber-optic (62.5/125 micron, graded index)	1000 Mbps (1 Gbps)	6560 ft.

twisted pair cabling that meets the most recent cabling specifications, Category 5E, transfers information at speeds of up to 100 Mbps, and is commonly used for data transfer both within a LAN and across the building cabling backbone. Although speeds of 100 Mbps are still acceptable for many applications, many businesses are beginning to demand even higher bandwidth applications. The copper cabling industry is working to meet those demands through the development of Category 6 and Category 7 specifications, as well as Gigabit Ethernet for Category 5 cabling.[11]

Fiber-optic cable is the fastest cabling technology currently available. It uses light rather than electricity to transfer information. Multimode fiber is now used for a large portion of cabling backbones due to its high bandwidth of up to 1 Gbps, its increased protection against tapping, and its ability to provide clearer, less distorted signals over long distances. Fiber-optic cable is now comparable in price to UTP, making it competitive for horizontal distribution, although the expense of terminating the fiber is still high.

Most building cabling systems consist of both horizontal distribution cabling that transfers data from the work area to the telecommunications closet and vertical systems or backbones that transfer information between telecommunications closets and telecommunications equipment rooms. Each system should be considered separately when evaluating the type of cabling to install in a building. For vertical distribution, fiber-optic cable is a wise choice because it is comparable in cost to copper, but has a higher bandwidth. Horizontal distribution is a more difficult choice due to the high cost associated with terminating fiber-optic cable at individual workstations. The volume of data transferred through DDCs is likely to remain constant over time, so Category 5 wiring is generally sufficient for these applications. However, bandwidth requirements for desktop applications are likely to grow as the Internet, video conferencing, and other communication technologies continue to develop. Therefore, fiber to the desktop should be a serious consideration for all smart buildings.

Fiber optic cabling to the desktop should be a serious consideration for all smart buildings.

Structured Cabling Infrastructure

Structured cabling systems (SCSes) integrate cabling for all applications, including voice, data, FL&S, security, and energy, into the same infrastructure (**Figure 4**, page 18). In conventional buildings, cabling for the various building systems is designed and installed in phases, resulting in a separate cabling infrastructure for each system. However, in smart buildings the design team must participate in an integrated design process in order to integrate building systems. This process enables the design team to collaborate on the development of a structured cabling system where one cable backbone supports all building systems. A structured cabling system that complies with the EIA-568 cabling standard offers numerous advantages over conventional distributed systems:[14]

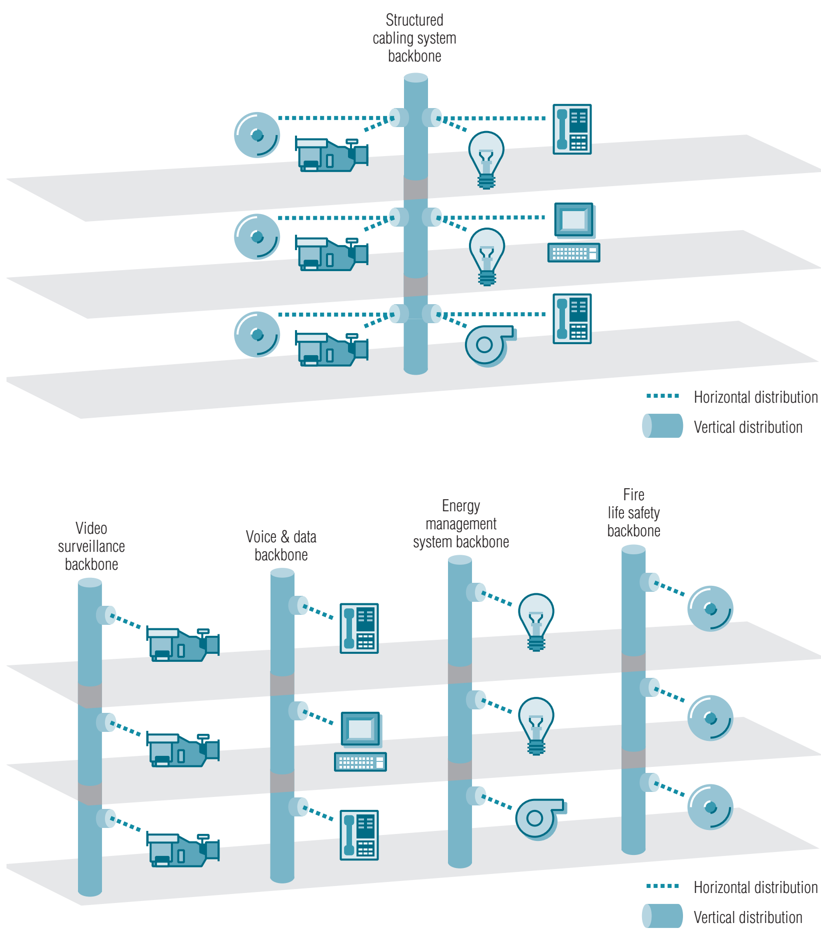
The flexible nature of the structured cabling system allows it to be easily configured for the needs of specific tenants.

- Up to 30 percent lower capital costs due to ease of installation, consolidation of installation processes, and lower number of equipment panels
- Greater flexibility for changes and upgrades, leading to lower operating costs
- Less time required for tenant improvements phase due to prior installation of horizontal cabling

One major objection to structured cabling systems is that the pre-wiring of horizontal voice and data distribution systems adds cost for the building owner and may not fulfill the telecom expectations of the building tenants. In conventional buildings, tenants are generally expected to provide their own telecommunications cabling to meet their own specific needs. However, a high-bandwidth telecommunications system can often be sold to tenants as an attractive added feature. The flexible nature of the structured cabling system allows it to be easily configured for the needs of specific tenants. Further, building tenants generally have to pay less money for prewired

Figure 4: Comparison of structured cabling system and distributed cabling system

The structured cabling system (top) uses a single backbone to distribute data for multiple building applications, while the distributed cabling system (bottom) requires a separate backbone for each major building application.



Source: CTG Energetics, Inc.

systems than to install their own cabling system because the owner recovers the incremental cost for the cabling from different occupants of the same space over time. Owners can receive additional profit from structured cabling systems by pairing with telecommunications service providers to offer service to their tenants. Telecommunications service providers are often willing to share up to 5 percent of profits for Internet services and two to three percent for telephone services with building owners who provide cabling to their customers.[15]

Smart Buildings Are Adaptable

The BAS and cabling systems in smart buildings are designed to be adaptable to changing technologies and tenant needs, and are therefore easy to modify, expand or replace.

Future Proofing

"Future proofing" is careful design of building systems that guarantees that the utility of building systems will persist over an extended period of time. Future proofing requires that systems meet the initial expectations of building occupants. To accomplish this:

- The building envelope, HVAC, and lighting must be designed efficiently.
- Control software for energy, FL&S, and security systems must be programmed accurately.
- Cabling systems must meet the bandwidth requirements of the building occupants, connect the appropriate building systems, and provide flexible telecommunications access from every space.
- All building systems must undergo a commissioning process to verify that the systems are operating as designed.

A building that is future-proofed will also accommodate growth and expansion for each of its systems. The expandability of the

A building that is future-proofed will accommodate growth and expansion for each of its systems.

BAS is heavily dependent upon the use of an open protocol standard, which allows the addition of components from multiple vendors without the hassle of adding communication gateways. Standard computer processors and a standard user interface should also be incorporated into the initial design of the BAS to facilitate further expansion and growth. Further, all building systems should be scalable, designed with the expectation that further components may be needed in the future. A structured cabling system will achieve the expandability goals for the cabling infrastructure, provide extra ports in initial building design, and simplify the process for installing additional ports when they become necessary. The cabling media should support the significant increases in bandwidth needs that are likely to occur over the first 10–15 years of occupancy so that the cabling system will not quickly become obsolete.

DDC-based BASes provide many more opportunities for customization than conventional pneumatic controls.

Systems in future-proofed buildings will also be easy to maintain throughout the life cycle of the systems. DDC-based BASes are vital to the maintainability of building systems, providing essential information about the building components that are not performing as designed and recommending routine maintenance timing based on actual hours of component operation. The open protocol standard also contributes to ease of maintenance, allowing the facilities manager to select a maintenance service provider from a variety of vendors. Service agreements for all systems are also essential to system maintainability, ensuring against premature system failure.

Future proofing adds substantial value to a building for tenants, facilities managers, and owners. First, it reduces the capital costs associated with replacing or expanding systems. Second, future proofing ensures better performance of systems over time, resulting in a more comfortable environment. Finally, future proofing significantly reduces the time required by facilities managers to maintain and operate the building.

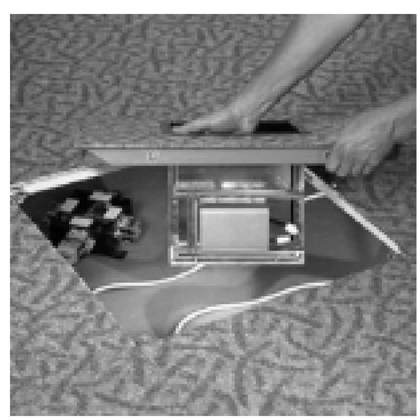
Adaptable for Tenant Needs

Although the term "smart buildings" often conjures up images of buildings making their own choices without regard for tenant concerns, the truth is that smart buildings adapt to the specific desires of building tenants, giving them much more control over their own environment. DDC-based BASes provide many more opportunities for customization than conventional pneumatic controls. For example, the DDC system gives tenants precise control over space temperature, and allows them to request customized HVAC and lighting schedules for their space.

The horizontal cabling and power distribution systems have traditionally been the least adaptable systems in buildings because the location of wiring changes every time the suite layout is adjusted. In smart buildings, it is imperative that these systems be designed in a way that allows flexible suite layout for all tenants. By far, the most flexible cabling distribution is accomplished in conjunction with a raised access floor system (see the Energy Design Resources Design Brief entitled "Underfloor Air Distribution" for more information). In raised floor systems, floor panels are elevated 6 to 30 inches above the slab floor to create a cavity between the slab and the raised floor where cabling and electrical wiring can be run. Outlets for power and jacks for voice and data are placed in some of the raised floor panels, which can be relocated from one position to another when workstations are relocated. Access floors can also be used as supply plenums for underfloor air distribution, which has the potential to further the comfort and energy savings associated with smart buildings and allow custom placement of air distribution terminals. The flexibility achieved through the use of access floor systems has tremendous influence on churn costs, significantly reducing the time and materials required for rewiring an office space (**Figure 5**).

Figure 5: Raised access floor

Access floors can be used for flexible cabling and power distribution as well as for air conditioning.



Source: Honeywell International, Tate, and York

Economics

Smart buildings are generally more expensive to build than conventionally designed buildings. However, the added value of smart building infrastructure results in much lower life-cycle costs and improved profitability due to the potential for higher rents.

Capital Costs

While some smart-building design techniques actually reduce capital cost through sharing of components, sensors, and networks, overall capital costs for smart buildings are generally much higher than those for conventional buildings. The following characteristics of smart buildings contribute to incremental capital costs.

- *Systems Integration Design*. Smart-building capital costs are generally higher due to the increased time devoted to integrating building systems. The integrated design process calls for several additional meetings between building team members, and many iterations of building design.
- *DDC-Based Building Automation System*. Incremental costs for full-DDC building control systems vary significantly based on a buildings complexity. As buildings grow in size and complexity, the incremental cost of digital control systems becomes comparable to that of pneumatically controlled systems.
- *Added Points in the BAS*. Smart buildings usually add control points not generally found in conventionally designed buildings, such as daylighting controls with dimmable electronic ballasts, occupant-sensing controls, and thermostats for all zones of the building. These non-standard controls lead to higher capital costs.
- *Structured Cabling System*. When designed correctly, capital costs for the SCS are comparable to those for distributed cabling systems. However, with SCSes, initial costs for

Architectural design for conventional buildings may not accommodate a structured cabling system or raised access floors.

telecommunications cabling are often paid by the building owner rather than by the tenant. The owner recovers these costs by augmenting lease prices.

- *Raised Access Floors*. Raised access floors cost approximately $4 to $7 per square foot to install.

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-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.

Operating Cost Savings

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. An appropriately designed BAS with smart-metering capabilities can be programmed to provide load management to minimize peak load. In the new deregulated energy market, peak demand charges are likely to escalate rapidly, particularly during summer months when buildings have the highest peak load. Therefore, smart buildings capable of controlling peak demand will have substantially lower demand charges. The BAS for smart buildings can further contribute to energy cost savings by lowering building energy consumption. Improved scheduling functions available through the BAS limit energy use by turning off unneeded equipment. The BAS also expedites the repair of malfunctioning components, thereby eliminating the energy losses that are prevalent among poorly maintained systems.

Additional operating cost savings are achieved through the reduced maintenance and facilities management costs associated with the BAS. Troubleshooting is accomplished through the BAS rather than by local testing of individual components of building systems. Further, consolidation of controls systems into one location reduces the labor required for monitoring systems and changing control parameters.

Churn Cost Savings

Churn costs are costs associated with adding, moving, or changing workspaces within an office. The flexibility of smart buildings reduces the time and effort required for adding or moving workspaces, thus significantly curtailing churn costs. Conventional buildings often provide cabling through ceilings and walls. Relocation of horizontal cabling in these buildings is very costly because walls must be torn apart, reassembled, and repainted. The access floor systems that are extensively used in smart buildings provide the means for instant relocation of cabling and electrical wiring as well as power outlets and telecommunications jacks. In cases where plenum-based underfloor air distribution is employed, air terminals can also be relocated quickly.

For More Information

Building Owners and Managers Association (BOMA)

BOMA publishes research showing the market drivers behind the commercial real estate industry. A survey entitled "What Office Tenants Want," and an article entitled "Integrated Building Systems: Increasing Building and Workplace Performance" are particularly informative resources available through BOMA.

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AutomatedBuildings.com

The Automated Buildings Web site provides monthly newsletters with constructive information and case studies about building automation.
www.AutomatedBuildings.com

Cabling Business Magazine

Cabling Business Magazine publishes a monthly magazine with many articles that focus on structured cabling systems.
12035 Shiloh Road, Suite 350
Dallas, TX 75228
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American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)

ASHRAE is organized for the sole purpose of advancing heating, ventilation, air conditioning, and refrigeration for the public's benefit through research, standards writing, continuing education, and publications.
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Fax: (404) 321-5478
www.ashrae.org

Building Automation and Control Networks (BACnet)

BACnet is a national standard created under the auspices of ASHRAE.
www.bacnet.org

Notes

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