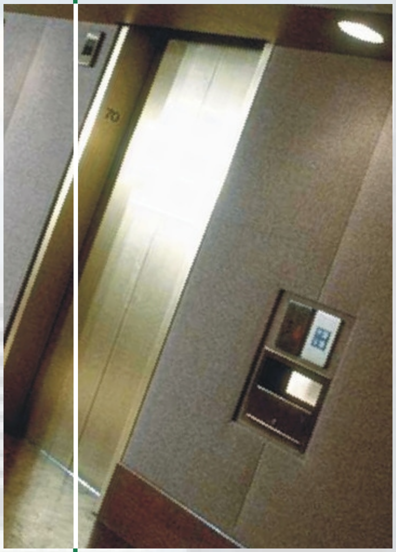
Technology Roadmap for Intelligent Buildings



CABA
www.caba.org

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BACKGROUND

In the fall of 1999, the Federal Interdepartmental Forum on Construction Technology, which has representatives from the departments of the Government of Canada with a major interest in construction innovation issues, identified the lack of understanding of the challenges and opportunities in the general area of intelligent building technologies as a significant national issue. This led to the proposal to create the Technology Roadmap for intelligent building technologies.

The Continental Automated Buildings Association (CABA) was approached by Industry Canada to determine if private industry would participate actively in such an initiative. CABA confirmed strong industry support, and offered to bring together major industry players in a steering committee. Assured of industry support, Industry Canada (IC), the National Research Council (NRC), Public Works and Government Services Canada (PWGSC), Natural Resources Canada (NRCan), and Canada Mortgage and Housing Corporation (CMHC) undertook to support the project.

The Steering Committee, facilitated by CABA with representation from industry and the sponsoring federal government agencies was formed, as follows:

McElwain, Kirk. IBM Canada (now Technical Director at CABA) Committee Chair, Technology Roadmap Project,

Barr, David. Technology Roadmap Project Manager, Continental Automated Buildings Association,

Wallace, Brian. Industry Canada, Contract Authority for Federal Government,

Balmes, Brian. Siemens Energy and Automation Inc.,

Balsamo, Sam. Tridel Corporation,

Choinière, Daniel. Natural Resources Canada,

Cuddy, David. Nortel Networks (now at Natural Convergence Inc.),

DelZotto, Andrew. Tridel Corporation,

Handfield, Louis. Hydro-Québec,

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Parent, Denis. Hydro-Québec,

Storie, Dwight. Siemens Energy and Automation Inc.,

Stylianou, Meli. Natural Resources Canada,

Zimmer, Ronald. Continental Automated Buildings Association.

Following a competitive bidding process, a contract was issued to IBI Group to undertake the Technology Roadmap project, managed by CABA staff under the guidance of the Steering Committee. The IBI Group assigned the following staff to the project:

Spitzer, Frank. Principal Project Research Engineer,

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EXECUTIVE SUMMARY

Introduction

This Technology Roadmap explores and explains the current status and imminent opportunities offered by the accelerating evolution and use of intelligent building technologies. The focus is on commercial, institutional and high-rise residential buildings, both new projects and retrofits, in a five-year time horizon.

Intelligent Buildings and their Technologies

Intelligent buildings apply technologies to improve the building environment and functionality for occupants/tenants while controlling costs. Improving end user security, comfort and accessibility all help user productivity and comfort levels. The owner/operator wants to provide this functionality while reducing individual costs. Technologies make this possible. An effective energy management system, for example, provides lowest cost energy, avoids waste of energy by managing occupied space, and makes efficient use of staff through centralized control and integrating information from different sources.

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. These systems are typically managed by personal computers (PCs) using data processing communication techniques. A heavy communications emphasis is essential, and both wired and wireless communication technologies are available. The key communications issues are redundancy, resilience, security and the assurance for all users that "their data" is secure. Integration considerations may be addressed through standards and conventions, or manufacturers' protocols. Since proprietary solutions permeate the industry, total interworking 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.

Optimized communications involve designs that use structured wiring standards with dedicated communications rooms, with equipment sharing a common space and a common backbone. This infrastructure will adhere to the OSI seven layer communications model (see Appendix C). Distributed equipment must be capable of operating when the communications infrastructure fails. Distributed control and distributed diagnostics will ensure that the functionality of all building systems is respected, and any single fault cannot invoke a generalized building failure. Among the candidates for wide adoption as standards, both BACnet and LonWorks currently exist and have widespread followings. However, even these available systems do not generally fulfill the requirements for interoperability.

The Benefits

Many of the concepts which are central to intelligent buildings are already commonplace, e.g., the ability to access a building independently and securely outside of normal working hours. The major benefits of intelligent buildings are as follows:

- standardized building systems wiring enables simple upgrade modifications of control systems;
- a higher value building and leasing potential can be reached via increased individual environmental control;
- consumption costs are managed through zone control on a time of day schedule;

- Occupants/tenants control building systems after-hours via computer or telephone interface;
- Occupant/tenant after-hours system use is tracked for charge back purposes;
- the service/replacement history of individual relay and zone use is tracked; and
- a single “human resources” (hire/fire) interface modifies telephone, security, parking, LAN, wireless devices and building directory, etc.

These useful benefits can be cost effective. Cost savings benefit primarily the developer/ owner/operator, while functional enhancements are mainly enjoyed by the occupants/ tenants. If improved comfort, security, flexibility and reliability can be achieved along with reduced costs and increased productivity, thus increasing return on investment, few would argue against the deployment of such technology.

The benefits from projects where these technologies have been exploited are often described. However, the Technology Roadmap has found a scarcity of reference projects that are fully instrumented and documented. Reference projects must apply equivalent technologies to new or retrofit projects and draw careful conclusions regarding the proposed investment and the projected return. These projects must identify and quantify the risks and the rewards. These evaluations must allow for appropriate substitution.

Many intelligent buildings projects have been showcase projects, demonstrating specific attractive examples but not seriously quantifying the costs and values. Without careful quantification, the economic case for intelligent buildings cannot be made, since the initial costs are often high. For example, energy cost is a key factor and rising energy costs can change the conclusion. The Technology Roadmap has studied published material and created a reference library on the CABA Web site <http://www.caba.org/trm>.

The Challenges

The financial impact is always significant, including capital costs, expenses and revenues. Financial implications must be correctly assessed, including the time value of money and tax effects. Low initial costs are attractive to developers, while the owners/operators and occupants/tenants are more interested in ongoing operational costs. Intelligent buildings offer major opportunities to increase revenue and offer more value, hence to sell/rent for higher prices and/or more rapidly. Financial decisions that compare alternative plans considering only initial cost will usually be wrong. If the revenue stream is the same, then ongoing expenses should be judged via the metric present worth of annual charges (PWAC). If the alternatives generate different revenue, (usually the case with intelligent buildings), the correct metric is net present value (NPV). The initial cost should only be the deciding factor when the metrics of alternative plans (PWAC where revenue is uniform and NPV where revenue varies) have similar results.

The improved value of intelligent buildings should encourage developers/owners/operators and the entire supplier community to take advantage of these opportunities. Intelligent building projects will affect the construction processes. The successful outcome requires an integrated design, with practical solutions with regards to divisional specifications, contracts and the interaction of the design, management and construction staff on the project. Changes in approach will be needed throughout the supplier community.

Intelligent buildings must react to component and system failures more reliably than “conventional” systems, using system design to ensure problem isolation and resolution that improves on “conventional” performance. Education, experience and changed practices will be required throughout the supplier community, including engineers, designers, architects, contractors, manufacturers, and those who manage and maintain the systems. Provision and use of common space, common infrastructure and shared resources are central to the economic effectiveness and advantage of intelligent buildings. A building and its infrastructure typically have a lifespan of 25 years or more between major retrofits. Intelligent buildings offer the ability to upgrade functional capability more often and much more economically, through upgrading components and equipment items without changing physical components, e.g., cabling.

Authorities having jurisdiction must ensure that codes, practices and conventions support and encourage the deployment of intelligent buildings, to gain the functional and financial value. The advantages of intelligent buildings highlight the need for the rules and regulations to encourage the use of intelligent building technologies while ensuring that public safety and public service are well addressed.

Future Directions

The most successful intelligent buildings indicate that the greatest advantages come from integrating communications and ensuring that the traditional systems have the ability to intercommunicate and interoperate. A single operator interface must recognize status and control information of all available systems. The primary benefit comes from the shared space, infrastructure and operating staff. Current trends to work from home encourage remote interaction with building communications and services.

These trends are being influenced by technologies and the current market situation. Construction methods and technologies are breaking down some conventional barriers. Increasing concern with environmental impacts and with security needs are market forces that influence intelligent buildings functionality.

Intelligent buildings depend on the increasing reliability of secure and resilient communication infrastructures. Mobile telephones are well established, encouraging mobile communications in many other forms. This technology has value for in-building applications. For the occupants/tenants and the operators, these technologies yield substantial efficiencies. These evolving concepts will lead to intelligent building technologies that are not yet on the drawing board.

Conclusions and Recommendations

The major “actionable” conclusions and recommendations to promote intelligent buildings are:

- Intelligent building technologies are generally available but are not yet widely adopted;
- there is reluctance by much of the development and construction industry to embrace them;
- many changes and initiatives must occur for these technologies to become widespread; and
- there is a need for promotion and education at all levels and in all segments of the industry.

This Technology Roadmap recommends many actions that require co-operation, as is typical of progress in technology applications in today’s world. The adoption of intelligent buildings offers major advantages, faces significant challenges, and is moving forward because of the vision and dedication of individuals and organizations.

INTRODUCTION

This section indicates the background that led to the preparation of this Roadmap, and the process and key players that were involved in its preparation. The definition of intelligent building technologies as used in the document is provided, and the relevant stakeholder groups are identified and described.

Developers/Owners/Operators

Traditional solutions to constructing, owning and managing buildings are evolving. This report is designed to describe and encourage readers to take full advantage of this evolution.

Occupants/Tenants

The demands for functionality and services by those who occupy buildings are increasing. The technology can deliver what is wanted.

This Roadmap provides a view of intelligent building technologies, including an evaluation of the current state of these technologies and a five-year view of how they are expected to evolve. Intelligent buildings have been made possible by the use of microprocessors/ computers and networks which monitor and control every new or renovated building system. The role of intelligent building technologies has expanded as available technologies, operational tools and interoperability have provided effective and efficient alternatives to traditional building approaches. Data processing and communications technologies now impact many aspects of building operations including:

- fire and life safety systems;
- heating ventilation and air conditioning systems (HVAC) management;
- elevators and escalators;
- access control systems and security systems;
- lighting management; and
- communications available to occupants/ tenants.

> *"...improvements in building technologies will enhance the daily environment of occupants, increase maintenance efficiency and increase return on investment for owners."*

The advantages of these applications are highlighted by the increasing costs of building ownership and operations. Changes include:

- rising energy costs (averaging about 3% per annum);
- increased labour costs; and
- changing work patterns.

Intelligent building technologies have become economically attractive, reliable and affordable.

This Roadmap presents the concept of intelligent building technologies and provides the basis and interpretations needed to appreciate these concepts. The primary objective of this project is to promote and encourage the use of intelligent building technologies in commercial, institutional and high-rise residential buildings. While intelligent building technologies are evolving rapidly, the design and construction cycle for real estate is long. The Roadmap objective has a five-year horizon, noting that a construction design planned for five years hence will be frozen well ahead of time. Some aspects of the Roadmap recognize the longer-term nature of the intelligent building technologies industry.

The emergence of the intelligent building technologies industry is encouraging building owners, operators, managers, designers and occupants to reassess their respective roles, and how they relate to the buildings in which they hold an investment. As this innovative industry evolves, improvements in building technologies will enhance the daily environment of occupants, increase maintenance efficiency for building managers and increase return on investment for owners. This Roadmap has been structured to help each of the stakeholder groups evaluate their roles, and to suggest appropriate steps to take best advantage of the opportunities offered by intelligent building technologies.

The Roadmap document has assembled intelligent building technologies information so that stakeholders may easily find the information related to their interests. The topic outline is:

- the definition of intelligent building technologies;
- intelligent building technology systems;
- the benefits of intelligent building technologies;
- the challenges facing intelligent building technologies;
- the future direction of intelligent building technologies; and
- conclusions and recommendations.

The Roadmap is structured to enable individual readers to explore those intelligent building technology topics that interest them. Each reader can identify and review his/her own interests and opportunities within the intelligent building technologies industry.

What are Intelligent Building Technologies?

For the purposes of this report intelligent building technologies have been defined as:

The use of integrated technological building systems, communications and controls to create a building and its infrastructure which provides the owner, operator and occupant with an environment which is flexible, effective, comfortable and secure.

The advent of the personal computer (PC) with its many applications now makes it possible to integrate systems. An Intelligent Building can provide communication among automated building systems. The building operator can enjoy a single interface capable of controlling lighting, security, heating ventilating and air conditioning systems (HVAC), fire and other building systems communicating over a single broadband infrastructure, which also supports the occupants/tenants' voice and data communication needs.

To cite an example, the building administrator can allocate a new building location to an employee in a single process that also provides network access, phone access, security access and parking access. As a result, the new employee could find the office automatically lighted and heated after using a personalized access card at the parking lot or in the elevator.

Identification of Stakeholders

The intelligent building technologies industry involves a wide range of stakeholders, which bring with them a great variety of interests, concerns, requirements and potential opportunities. To provide structure in considering these stakeholders, they have been grouped in four categories, based on somewhat common interests and needs. These categories, and examples of the groups included in them, as follows:

A. Developers/Owners/Operators

This includes all who have an ownership and ownership-type interest and role in construction projects and in the ownership and operation of commercial and large residential buildings which use or could use intelligent building technologies.

B. Occupants/Tenants

This includes all who occupy space in the building, whether as tenants or as employees of the building owner, e.g., building occupants, tenants and end users of all kinds, including retailers and restaurants as well as those who occupy office space.

C. Suppliers

This includes all who supply anything within the intelligent buildings industry, both in new construction and retrofit, and in the ongoing operation of existing intelligent buildings, and including suppliers of both goods and services, e.g., the construction industry in all its aspects, architects, design engineers, all specialties, building products suppliers, building equipment and system manufacturers, researchers and developers within supplier organizations, support and maintenance organizations, teachers and educators.

D. Authorities Having Jurisdiction

This includes all who regulate, legislate or make rules that affect the intelligent buildings industry, including building codes, health and safety regulations, municipal by-laws that relate to land use and construction and buildings, and the requirements of fire officials and waste disposal officials, e.g., regulatory authorities; building code regulators, health and safety policy developers, all levels of government, and other industry agencies.

These groups will sometimes overlap, and they may often represent conflicting interests. Broader issues will often affect the stakeholders in intelligent building technologies, e.g., policies related to energy efficiency, social policies (e.g., low income housing) and sustainable development policies.

INTELLIGENT BUILDINGS TECHNOLOGIES SYSTEMS

This section of the Technology Roadmap provides the reader with an overview and understanding of the current and evolving intelligent building technologies. These systems primarily support and operate various aspects of the building and its infrastructure including lighting, heating, ventilation and air conditioning (HVAC), energy management, security, elevators, life safety systems and building condition monitoring. Integration will become more pervasive as these technologies evolve. This section also considers the sometimes conflicting, sometimes co-operative interests of the two main stakeholder groups, the developers/owners/operators and the occupants/tenants.

Intelligent building technologies seek to improve the building environment and functionality for occupants/tenants while controlling costs. Improving end user security, control and accessibility all help productivity and user comfort levels. The ability to measure the use of specific building resources enables individual users to be billed for the resources they consume. The owner/operator wants to provide this functionality while reducing individual costs. Such reduction is possible. An effective energy management system, for example, provides lowest cost energy, avoids waste of energy by managing occupied space, and makes efficient use of staff through centralized control and integrating information from different systems.

An efficient integrated system enables a modern, comprehensive access and security system to operate effectively and exchange information with other building systems. A fully integrated functionality will have 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 resulting energy usage. Life safety systems, notably fire systems, are heavily regulated by stringent code requirements. These requirements do not, however, prevent the information originating with a fire safety system from being provided to any other systems. This opportunity can be exploited to open doors and illuminate a building when fire alarms are received.

The use of transducers (detectors) provides the ability to measure and react to many building parameters, e.g., vibration, strain and moisture, to monitor the building's infrastructure condition.

If all the foregoing systems are to be integrated and exchange information effectively, there is a growing need for an ubiquitous and reliable communications infrastructure. Each of the independent building systems is managed by a personal computer (PC) using conventional data processing communication techniques. A heavy communications emphasis is required when an Intelligent Building is developed. Both wired and wireless communication technologies are available. The key issues when communications are integrated are redundancy, resilience, security and the assurance for all users that "their data" is secure.

Integration considerations can be challenging. Some may be addressed through standards and conventions, or protocols provided by manufacturers. Since proprietary solutions permeate the industry, total interworking is currently unattainable. The future will require full interoperability, whereby information from one system can be exchanged with others. Communication requirements suggest an opportunity for technologies that translate protocols and conventions so that systems are fully interoperable.

Communications may be optimized by designing buildings using structured wiring standards with dedicated communications rooms, in which communications equipment shares a common space and common backbone. This infrastructure will adhere to a standardized communications model, based on the OSI seven layer model. There is a key requirement that distributed equipment is capable of operating even when the communications infrastructure becomes inoperative. Such distributed control and diagnostics will ensure that the functionality of all building systems is respected, and any single fault cannot invoke a generalized building failure. Among the candidates for wide adoption as standards, both BACnet and LonWorks currently exist and have a widespread following. However, even these available systems do not generally fulfill the requirements for interoperability.

> *"...computer-based processing enables the automation of all basic building systems."*

Developers/Owners/Operators

The basic building systems are the major mechanical and electrical systems. All can be automated for better management and service, and lower operating costs.

Occupants/Tenants

The basic building control systems can allow the users to select service functions and custom tailor these. This will require an enhanced communication infrastructure. Improved services result in improved productivity and ease of use.

Basic Building Systems

Widespread use of computer-based processing enables the automation of all basic building systems. This, in turn, forms the basis for integration among systems. The value of intelligent building systems improves dramatically as more systems are integrated.

Lighting

Intelligent building technologies for lighting include many lighting types and functions. Lighting needs vary with each building. The functional goal is to furnish occupants of the building with the lighting required to complete specific visual tasks effectively and productively. Current lighting systems can:

- automatically turn on and off lights by photocell or computer schedule;
- modify lighting levels through the use of photochromatic windows;
- allow individuals to adjust their lighting through computer or telephone interfaces;
- link the lighting controller to a graphic user interface with icons, for centralized control;
- turn circuits on and off through computer control; and
- manage energy consumption by monitoring room occupancy and adjusting lighting to suit.

Voice and Data Communications

Voice and data communication capabilities are integral to the effective operation of a building and its occupants. In an intelligent building, data communication is vital to the integration of all other automated building systems, e.g., lighting, energy management and HVAC. Generally "data" in the context of "voice and data", refers only to end-user data, such as e-mail, Internet and database access. Voice and data in-building communications include:

- voice services, e.g., telephones, voice-mail and intercoms;
- building systems, e.g., paging, elevator music and kiosks;
- video and audio conferencing;
- local and wide area networks, e-mail, internet access, database access;
- ability to access building services remotely, e.g., when working from home; and
- television systems.

Heating, Ventilation and Air Conditioning, and Indoor Air Quality

HVAC systems are generally controlled by building automation systems that can:

- permit individual occupants to adjust workspace temperatures (within prescribed limits);
- monitor temperatures, and adjust according to a usage profile;
- adjust indoor air quality based on room occupancy and building standards;
- adjust humidity, temperature and air flow speeds; and
- use either variable air volume or constant volume air distribution designs. The former allows greater individual control.

Energy Efficiency/Energy Management

The objective of energy management is to ensure maximum efficiency and lowest operating cost. Opportunities for reducing heat gain in the summer and reducing heat loss in the winter will lower energy costs. Energy deregulation brings opportunities to select the most effective source of heat, be it steam, oil, natural gas or electricity. In some buildings, multiple fuels are used together, whereas in other situations, each source of heat generates warmth in a distinct manner. For example, baseboard electrical heaters may supplement circulating warm air. Furnaces capable of burning either natural gas or oil exist, and electric heater systems compete with the ability to purchase steam from external sources.

> *"...data communication is vital to the integration of all other automated building systems..."*

Management of these energy sources depends on the infrastructure that exists within the building, as well as the "spot costs" of each of these energy sources. Intelligent building technologies permit each of the following energy sources to be managed based on criteria that can include the fluctuating pricing of:

- traditional electrical generating and distribution sources;
- new electrical generating agencies;
- oil;
- gas;
- co-generation; and
- future opportunities that may involve photovoltaic sources and wind.

Security

Security systems are generally divided into three sub-components:

- access control;
- intrusion; and
- surveillance.

Effective security systems integrate these three areas, allowing the building mode, function and operation to be pre-scheduled or controlled by individual access requests. A typical system will involve:

- access card;
- elevator interface;
- door interface;
- intrusion detection;
- sensor detection, such as temperature, moisture, glass breakage, etc.;
- guard tours; and
- parking controls.

Many of the functions of an access control system are subordinate to the life safety system, which may deactivate parts of the access control system in an emergency.

Elevators and Escalators

Intelligent building systems can provide occupants with improved elevator service. Elevator control can be quite complex, particularly with multiple elevator groupings and incorporating traffic patterns into the system. Some elevators may be shut down for part of the day to conserve energy. Current designs frequently include communications within the elevators to permit the use of access control cards, and closed circuit surveillance is becoming widespread. An effective access control system can permit dynamic changes to user privileges so that, for example, certain floors may not be accessible even with an approved access control card, unless there are already people occupying that floor.

Escalators can save energy by slowing down or stopping when detectors indicate no traffic. This approach to energy savings also benefits the mechanical components that need not run continuously.

Life Safety Systems

Life safety systems, often called "fire systems", are typically driven by code considerations. Security systems are required to release doors per code constraints under emergency conditions. HVAC systems are also driven by life safety needs, e.g., smoke extraction, stairwell pressurization and elevator recall.

The advent of intelligent building technologies facilitates additional functionality. For example, in a fire, lighting can be turned on throughout the building, and networks can enhance information provided to individuals, e.g., the state of the fire system, emergency broadcast messages, etc. Paging systems, normally restricted to being part of the fire system, can be used in intelligent buildings to broadcast pre-recorded status messages, which can be far more informative than messages spoken by nervous staff.

Building Condition Monitoring

Intelligent building technologies facilitate monitoring of a building's condition. Since transducers or sensors can measure most building-related parameters, needs will drive their specific use. Under appropriate conditions, any or all of these may be appropriate:

- areas with heavy snowfalls may monitor the loads imposed by such snow on their roofs;
- monitoring the strain in key structural members may be important with regards to wind loads, suspension of exhibits, loud speakers, and crowd loading in stadiums;
- moisture detectors laid beneath membranes in a building can prevent significant damage;
- monitoring the temperature in fuse panels, electrical switchgear and transformers can warn of impending failure;
- monitoring current flow in conductors can identify trouble in lamps or other electrical devices;
- monitoring vibration on mechanical systems can identify bearings needing maintenance; and
- monitoring conductivity of lubricating oil can identify metal buildup due to wear.

All of these examples may be built into a building condition monitoring system via the security system.

Integrated Communications

The full benefits of intelligent building technologies are only fully realized through integration, such as:

- building condition monitoring depends on many parameters;
- occupancy monitoring can provide input for lighting, HVAC and elevators; and
- voice and data can be integrated for those who use telephones and computers.

The communications infrastructure must be designed and developed to support all possible applications in the building. These include voice and data systems, data processing needs, security systems, building automation systems, lighting systems and other systems that combine to create an intelligent building. Under current practice, many subsystems in a construction project, e.g., elevator monitoring and control systems, voice systems, and security systems, are covered by separate construction contracts. Each specialty in a construction project is a division within the overall contract. As a result, each sub-contractor installs its own communication system, with dedicated conduits, separate communication terminal locations and different staff pulling similar cables.

> *"The full benefits of intelligent building technologies are only fully realized through integration."*

The Technology Roadmap notes the initiative to form a separate division within the construction administration documents for a consolidated communications infrastructure. Such a division would be part of the master specifications or documents based on the divisions which are normally included in documents provided by the CCDC (Canadian Construction Document Committee) or by the AIA (American Institute of Architects). This initiative is often called Division 17, a term prevalent in the United States but not yet common in the Canadian marketplace.

Earlier in 2002, the Construction Specifications Institute (CSI) Executive Committee approved a concept for revising and expanding the existing 16-division master format specifications system. Although these revisions are based to a great extent on the Division 17 initiative, the actual implementation is quite different. For example, there will be two new divisions in place of the proposed Division 17 to address communications and life safety and facility protection. The current draft of the revised document can be found at <http://www.csinet.org>.

The effective use of remote, automated diagnostics helps facility managers and operators reduce the costs of operations and resources, while also increasing the comfort and safety of the building occupants. Probable causes of problems, recommendations for resolution and estimated costs of remedial measures can be provided automatically to support staff decisions.

Radio Frequency Technologies

Many wireless devices and protocols are currently being promoted. Burglar alarm systems for residential applications, patient wandering systems for hospitals and other applications of voice systems, such as Bluetooth™ or IEEE 802.11b, communicate without a hard wired infrastructure.

Wireless communications are particularly attractive where offices and partitions are frequently reconfigured, and applications change frequently. The wireless solution competes favourably with wired alternatives. HVAC requirements can be economically and efficiently met using wireless controls.

Evolving wireless technologies enable one antenna to serve a wide range of frequencies, so that a single antenna and wireless infrastructure can serve telephones, pagers, local area networks and signalling for building automation systems. The active components of these wireless systems should be installed in the centralized communications rooms alongside their wired system equivalents.

Communication Issues

The ability of a standard digital data transmission protocol, e.g., TCP/IP (Transmission Control Protocol/Internet Protocol) to transmit many forms of data enables a single infrastructure to transport multiple, independent data elements. Both analogue and digital data can be handled, serving, for example, security, voice and traditional data processing information. Bandwidth needs for voice and security applications are small compared to data processing, so network performance would not be prejudiced.

> *"The effective use of remote, automated diagnostics helps...reduce the costs of operations and resources..."*

Security and redundancy needs must be well addressed, within the network design. Appropriate protection is essential, to ensure security and to protect against viruses, hackers and other intruders. A very large number of individual IP addresses can be used to uniquely identify each device attached to the network while also respecting naming conventions.

Current Integration Technologies

This section considers trends in standards, protocols and practices that impact the integration of different systems. Some manufacturers are expanding their range of solutions, so that a manufacturer's building automation system or security system monitors and performs some of the functions on sub-systems, e.g., lighting, HVAC, fire, intrusion monitoring, etc. Total solutions are hard to find. Not surprisingly, vendors generally have the most complete solutions in their own historic speciality.

Another approach to integration is emerging where an umbrella software integration solution, sometimes referred to as middleware, provides communications between each of the subsidiary systems and the host integration system. No changes are required to the individual systems. The host integration system undertakes the appropriate conversions, communicating with each system in its own "native language". Thus, each subsidiary system, module and component can talk to any other system, module or component in the system. While this presents a theoretically ideal solution, the functionality is at the mercy of proprietary changes that may occur in any of the subsidiary systems. For such an implementation, the vendors must co-operate to ensure continuity of the required interoperability.

Experience indicates that the advantages of system integration, providing interoperability and functional transparency, accelerate as the interoperability becomes more extensive and pervasive. There is clearly a marketing opportunity here. Customer demand will drive the provision of the required capabilities. When customers insist on these features, there will be vendors who will provide what is required. This will not happen instantly, and the early stages will not be easy, but the required products will become available with the features and reliability that is required.

No doubt there will be a price differential to be paid, and this is what will encourage the vendors to provide the products. The competitive North American market will ensure that the differential is not excessive. There is already much evidence that the value to the developers/owners/operators and the occupants/tenants will far exceed the price differential of the products.

Currently, adherence to standards and protocols that ensure interoperability among diverse systems does not generally exist in the market place for intelligent building technologies. The ability to create interfaces among diverse systems is well established, demonstrating that systems can communicate with foreign devices. The interaction among systems does require licensing of the protocols and close co-operation among vendors. There is a significant market opportunity here.

Some important aspects of interoperability depend on networking that is resilient and reliable, to assure adequate bandwidth for data transmission. Advantages include the following:

- DDC (direct digital control) controllers make use of individual controllers for personal work spaces cost effective and result in energy savings which justify their use;
- digital sub-metering that allows charging energy utilization to the end user;
- “soft-start” techniques (e.g., gradual start-up of ventilation fans) reduces operational and maintenance costs; and
- building automation logs device utilization, providing data for maintenance needs.

Common Communications Infrastructure

Networking technologies enable multiple systems to share cabling. Data communications use digital protocols, e.g., TCP/IP. These systems can co-exist, independently and securely, on a common Ethernet backbone. For example:

- PCs control HVAC systems, lighting systems and security systems, and can co-exist on a single platform;
- fire safety systems are now addressable, e.g., an Ethernet links sub-panels, each of which monitors a limited number of devices;
- elevator controls are digital, and are often controlled by a single PC platform. A single vendor may provide a PC interface for all elevators in a building or campus, for security and operations staff to monitor and control; and
- there is much publicity on telephony over a data local area network using Internet protocols (voice over IP – VoIP);

> *“...the value to the developers/owners/operators and the occupants/tenants will far exceed the price differential of the products ...There is a significant market opportunity here.”*

The individual sub-systems are already available, and their penetration is increasing as new buildings are designed and old ones retrofitted. The widespread adoption of a suitable communication standard by the building control system industry would enable interaction and interoperability among these devices. Experience indicates that the adoption of such standards has helped all elements of the industry. Standards and agreed industry specifications for computer devices have helped users and the industry grow while ensuring competition. There is a significant marketing opportunity here.

Cabling

Separate cabling within a building is typically provided for each system requiring communications interaction, i.e., separate cables are provided for telephones, local area networks, building automation, fire systems and elevator controls, depending on the systems in the structure. The cabling required for intelligent building technologies applications should, to the extent possible, adhere to a number of basic criteria for integration. In the future, individual cables will not be needed because the communications systems will be integrated. Most integrated cable systems will:

- multiplex or otherwise consolidate the communication needs between different systems;
- use a single, common communications raceway or communications tray;
- locate all common equipment in shared communications rooms where the equipment can readily be interconnected as required;

- ensure that the communications rooms are secure;
- use the same type of cabling wherever possible, so applications and cables are interchangeable over the lifetime of the building;
- use the same kind of termination equipment for all cables;
- manage the cable infrastructure as a building resource; and
- follow a structured cabling design, as recommended by Telecommunications Industry Association Standard TIA 568.

The basic design objective is to develop and construct a building cable network plan that will be effective and efficient for the lifetime of the building, and that will enable additions, upgrades and changes in functionality and utilization to be implemented by changing/ upgrading only the electronic equipment that uses the cable network. The selection of communications technologies will depend on the expected communications needs, considering both capacity and quality. Candidate technologies include copper, coaxial cable and fibre cables, and wireless technologies, including combinations of technologies. The design task is not trivial, noting that optimal solutions will change over time as technologies evolve.

A key feature involves cabling from end-user locations to the shared communications rooms, where backbone facilities then provide interconnection to other communications rooms and central services.

OSI Seven Layer Communication Model

Frequent references have been made to the use of communications as a utility within an intelligent building. The open system interconnection (OSI) model is a widely recognized generic standard for communications that defines networking in terms of seven layers. This standard was developed and is supported by the International Standards Organization (ISO). Additional information on the OSI seven layer model is provided in Appendix B.

While the OSI model serves as a valuable concept for outlining network and communications systems, it should be noted that not all manufacturers have adopted this model.

Consolidated Communications

The concept of consolidated communications addresses the provision of a single communications backbone throughout a building that uses intelligent building technologies. With a single backbone, all communications requirements for the needs of the users and of the building can be co-located. The resulting single communications path will be smaller and much less costly than the aggregate of individual paths that would otherwise be needed, and ensures that spare capacity can be consolidated between all applications. This single, consolidated communications infrastructure will also use a limited number of different cable types. The need for specialized wiring types is applicable only to special applications. If all systems use the same wiring, spare capacity can be shared among all systems. In some cases, several signals will be consolidated on a single cable. In other situations, individual cables of the same type will each carry a single signal. Multiplex allows multiple signals to travel on a single communications link. This approach is far more cost and service effective when most data are digital packets on a single network. Whether the backbone is a single cable or a group of cables will vary from project to project.

A key aspect is the association with the communications rooms. These strategically located rooms must have sufficient space and services to securely accommodate communications equipment. This equipment will then bridge and link the distribution network feeding the end users and the consolidated backbone infrastructure of the building.

Current Implementations

Current integrated communications in intelligent buildings are single vendor sourced or provide universal translator solutions so that all connected systems may communicate interactively. Johnson Controls' Metasys, Honeywell's Enterprise Building Integrator and Siemens Technology's Insight products are examples of systems that provide extensive building automation capable of providing most control functions. Tridium and Frame Networks' products demonstrate universal translator products. These are becoming more valuable as additional products are able to communicate over an Ethernet backbone using an IP protocol. These trends are allowing individual components to be attached to the backbone directly or through a controller. The ubiquitous presence of the PC ensures that these changes are consistent with the stable data processing environment, which can be used for building automation.

Distributed Building Control

Distributed controllers can provide total building automation. These devices, which communicate using a dedicated network, allow the use of standard access control, intrusion monitoring and surveillance devices, and can include multiple switched inputs and outputs, analog and digital input and output controls. The communications network can interact seamlessly with associated video and audio switches, allowing the operator screens to be used to select and control many different device types. The primary benefit of a distributed control system is the ability of individual controllers to continue functioning when some elements of the network or main computer fail. These controllers often interact with audio and video switches and other building management systems.

Intelligent Controllers

As processors and memory are built into the controllers activating HVAC and other building systems, there are opportunities to provide closed loop control. In traditional controllers, no response confirms that the requested action has occurred, e.g., if the room needs heat and warm air is called for, it is assumed that the baffle has acted as required, which is not always true. Intelligent controllers would confirm the success or failure of the baffle movement, closing the information loop. The intelligent controller can perform self-diagnostics and report potential failures sometimes before they occur, e.g., the controller can report that the actuator needed to move multiple times before the baffle achieved the desired position, indicating a mechanical malfunction. These controllers also function in a degraded manner if the communications link fails. Intelligent controllers may be applicable to any of the systems contained in, and controlled by, an intelligent building system and can report status information to the central control system. The same approach also allows periodic diagnostic cycles in order to perform directed maintenance.

Standards and Protocols

Standards and protocols are an area of contention in the intelligent building technologies industry. The industry would benefit from universal or widespread acceptance of a small suite of standards and protocols. There are, at present, a number of different standards available, but no general consensus apparent. Adoption of a universal or widely accepted standard industry wide would be very helpful.

Standards define the arrangements under which devices and systems interact and communicate with each other. The terminology is complicated by the frequent interchange of the terms “standard” and “standard compliant”. Some vendors will certify that their products comply with other vendors’ implementations. Sometimes, vendors will publish their standards, allowing competitors to use a subset. Switch manufacturers typically employ a range of protocols, some of which adhere to published standards and some of which are only available through their own proprietary products. The following arrangements generally apply.

- a standard is normally written through a national organization. Organizations such as the American National Standards Institute (ANSI) and the American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) are among those writing standards. Such standards are developed in a public forum that generally includes representatives from a number of corporate organizations and manufacturers who participate in a carefully structured vote to ensure that the document represents all interests. Canada, sometimes through the Canadian Standards Association (CSA), writes some of its own standards and often participates in the U.S. process so that standards will be compatible between the two countries and may be issued simultaneously in both countries;

- an open standard may be owned by a company or a consortium of companies and disclosed to the public. In some cases, open standards require payment of a licence fee;

> *"Widely accepted standards and protocols are necessary for building automation and integration, to enable communication among different building systems and devices."*

- proprietary standards are generally owned by a company and may be regarded as "corporate secrets". In some cases, use of such proprietary standards may be protected by legal actions, and in other cases, part of a standard may be released for public use, e.g., EIA-709 is an Electronic Industries Association (EIA) standard which is a subset of a commercial protocol (Echelon LonTalk); and
- protocols are generally reflective of common practice. Such common practice in some cases will subsequently be adopted as a standard. Protocols in particular are often used within the communication and software industries to reflect the manner in which data is represented.

Widely accepted standards and protocols are necessary for building automation and integration, to enable communication among different building systems and devices. This would support the interoperability of different vendor systems and components, and make competitive procurement for system upgrades and expansion possible. Widely accepted standards and protocols reduce risk, because they result from rigorous evaluation involving public review by interested parties including end-users, vendors, manufacturers and government agencies and this also gives assurance that they will be kept "evergreen".

BACnet and LonWorks

Two standards-related concepts appear frequently in the building automation media;

BACnet and LonWorks. Those advocating standards frequently argue that these two represent the leading standards for the building automation industry.

BACnet (Building Automation and Controls Network) data communication protocol is a standard for microprocessor based devices used in building automation and control systems. It was developed by ASHRAE and adopted by ANSI. LonWorks, is a networking platform conceived by Echelon Corporation that uses the ANSI/EIA 709.1 (LonTalk) standard as its communications protocol. Most vendors in the industry have demonstrated support for either or both BACnet and LonWorks in their products.

The BACnet standard defines how automation and control systems may interoperate with other BACnet systems. Multiple BACnet systems may share the same communication networks and may inter-communicate to request various functions from each other. BACnet (and LonWorks) can be applied to any type of building system including heating, ventilation and air-conditioning (HVAC), security, access control, fire safety systems, etc. In principle, this standard is vendor independent and forward compatible with future generations of systems. The object oriented approach that is central to BACnet represents all communication information within each controller. BACnet can communicate over local area networks such as Ethernet, ARCnet, MS/TP, PTP and LonTalk.

The use of BACnet does not force all systems to be the same nor does its use guarantee interoperability. The transmission of messages across various transport mechanisms permits common messaging with co-operating devices to interoperate, if this is desired. As a standard, BACnet describes mechanisms that will enable products from different vendors to be interoperable. Each system must then implement the features of BACnet that the other systems require. This is an area where not all systems are fully compliant. The BACnet Manufacturers Association / BACnet Testing Laboratories (BMA/BTL) have established a test lab to support compliance testing and interoperability testing activities.

LonWorks describes products, software and hardware, that utilize or leverage ANSI/EIA 709.1 (LonTalk) in some way or another. It is an embedded networking technology that is suitable for most types of electronic devices used for automation and control. Typically, the communication processor found in LonWorks devices is a member of the Neuron® Chip family of microprocessors manufactured and marketed by Toshiba, Motorola and Cypress Semiconductor. Recently, the Neuron core has become available in Echelon's own line of twisted pair and power line smart transceivers. ANSI/EIA 709.1 (LonTalk) is embedded in each Neuron chip. Specifications for interoperability directly amongst LonWorks devices (common communications structures or applications) are publicly available and are defined, published, and certified by the LONMARK® Interoperability Association. Each vendor choosing to gain LONMARK® certification for their product must submit it for testing to ensure that it can be installed using the common tool and will interoperate correctly with other LONMARK® certified products. However, non-primary functions/features, value-add applications, and company specific intellectual properties are left to each manufacturer. LONMARK® interoperability is optional for manufacturers making LonWorks products.

Both BACnet and LonWorks generally operate on dedicated communications infrastructures that are used exclusively for building automation (exceptions; Internet (both) and power wiring (LonWorks only)). LONMARK® and/or LonWorks devices cannot, and do not, interoperate natively with BACnet devices. Gateways are available to facilitate information exchange between these two standards.

For more information please visit the websites ((http://www.bacnet.org/ and http://www.lonmark.org/).

Vendor Independence

The adoption of standards ensures that vendors have the opportunity to manufacture their systems to be compliant with generally accepted standards that usually ensure there is no requirement to purchase specific components from specific manufacturers. The choice of vendor will be governed by availability, functionality and price, expecting interoperability to follow from standards compliance. This will result in more competitive pricing, driving down the price and increasing the quality and flexibility of each of the candidate products. In any given project, initial sourcing may well come from a single manufacturer, but that will not control the products which must be used within that structure for its lifetime.

Integration of Systems

The most critical challenge in designing, building and operating intelligent building technologies is the effective integration and interoperation of the several different building management technologies, and of other technologies as well. The capability of fire, safety, security, surveillance and other building systems to be integrated and to be interoperable has been noted. Wide experience and ample evidence indicates that the value of intelligent building technologies increases sharply as the number of integrated and interoperable systems increases. The value of intelligent building technologies can be further increased by the use of communications for remote monitoring, control and access.

Internet command and control systems allow applications associated with home, utility, business and factory automation to be hosted anywhere on the Internet. These systems use visually based software to produce a simple, graphical vehicle for network and system definition. In so doing, they can readily control lighting, security, life/safety, HVAC, elevator and power systems. These systems give users the ability to monitor, adjust and reconfigure devices as needed, from wherever they may be.

> *"...ample evidence indicates that the value of intelligent buildings technologies increases sharply as the number of integrated and interoperable systems increases... The opportunities are virtually unlimited."*

Access and control monitoring systems are also used for a number of security purposes. These systems can provide a live video window, embedded paging and e-mail capabilities, Windows client support and increased system capacities. The use of broadcast paging can allow for fast and convenient alarm notification to off-site personnel, thus adding to the efficient running of a building with minimal staffing.

The opportunities are virtually unlimited. From a central location, the operator can monitor, in whatever detail is required, not one but many buildings, which may be in a campus setting, or spread across a city, but could in practice be extensive. As with many other new technologies, it is a characteristic of these building technologies to result in many valuable uses which may not have been anticipated when the technologies were introduced.

Do all these capabilities bring value, save operating costs, enhance productivity, and warrant higher real estate and rental prices? Of course they do, and there is much evidence that the use of intelligent building technologies is potentially quite profitable. The sections which follow address both benefits and challenges.

THE BENEFITS OF INTELLIGENT BUILDING TECHNOLOGIES

This section develops and describes the benefits that intelligent building technologies can provide for the various stakeholder groups. Experience indicates that these benefits are functionally desirable and can be cost effective. Cost effectiveness benefits primarily the developer/owner/operator, whereas the functional enhancements are mainly enjoyed by the occupants/tenants. If improved comfort, security, flexibility and reliability can be achieved with reduced costs and increased productivity, thereby increasing return on investment, few would argue against the deployment of such technology.

Many of the concepts which are central to intelligent building technologies have already become fairly commonplace, e.g., the ability to access a building independently and securely outside of normal working hours. In general, the dominant attractions of these technologies are as summarized here:

- standardized building wiring systems enable simple upgrade modifications of control systems;
- higher building value and leasing potential via increased individual environmental control;
- consumption costs managed through zone control on a time of day schedule;
- occupants/tenants control building systems after hours via a computer or telephone interface;
- occupant/tenant after-hours system use tracked for charge back purposes;
- service/replacement history tracking of individual relay and zone use; and
- single "human resources" (hire/fire) interface modifies telephone, security, parking, LAN, wireless devices and building directory, etc.

Some projects report a reduced overall cost because independent computer systems and independent control rooms have been merged into single systems.

The benefits in projects where these technologies have been exploited are often described. However, the Technology Roadmap has found a scarcity of reference projects that are fully instrumented and documented. Reference projects apply equivalent technologies to new or retrofit projects and draw careful conclusions regarding the proposed investment and the projected return. These projects identify and quantify the risks and the rewards. These evaluations must allow for appropriate substitution.

> *"...To date, many intelligent building projects have been showcase projects...without seriously quantifying the costs and the rewards ...it is difficult to know whether the costs and efforts involved can be justified..."*

To date, many intelligent building projects have been showcase projects, demonstrating the "glitz" and attractiveness of specific implementations without seriously quantifying the costs and the rewards. Obviously, the use of room occupancy sensors, which reduce lighting when rooms are not occupied, will save costs for lighting, lamp replacement and heating. Without quantification, it is difficult to know whether the costs and efforts involved can be justified, since the "start-up costs" may be high. Of course, energy cost is a key factor, and changes in energy cost can change the conclusion.

The Technology Roadmap has studied published material and assembled the resulting information into a reference library. It is available to the reader in Appendix A.

Developers/Owners/Operators

Costs of building operations drop significantly because of the ability to better manage utilities, staff and operations. Each stakeholder has a different and identifiable perception of these valuable changes.

Occupants/Tenants

The end users are stakeholders and are affected by all of these activities. Properly automated facilities provide enhanced services, usually at lower costs.

Building Operations

Building Developers

For the building developer, intelligent building technologies provide advanced functionality at modest cost, and integration provides more usable (and revenue earning) space. Intelligent building technologies also make it easy to customize building functionality for specific occupants/tenants.

Traditionally, developers create and construct a building complex and subsequently seek occupants/tenants, or the developers undertake customized construction to meet the established requirements of an identified customer. The developer generally seeks 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 office space. Also, current trends clearly indicate that occupants/tenants value the improved services and environment in the building. This produces a tangible and saleable improvement to the building, which is clearly attractive to any developer.

This improvement is very applicable in retrofit projects, which currently form a large part of construction activity. Partial occupancy is possible if building systems are based on a floor or partial floor control granularity, as intelligent building systems are. In fact, controls are often sufficiently granular to provide different lighting and temperature for each individual. Occupants/tenants can then occupy some areas of the building, while other areas are still being fitted out. This ability to complete the building on a partial basis is attractive to contractors who are typically paid based on the percentage complete.

> *"...advanced functionality...reduce operating and maintenance costs...differentiate premium office accommodation from commodity space... the result is a building that is regarded as superior, desirable and, therefore, more valuable."*

Building Owners/Operators

Intelligent building technologies reduce operating and maintenance costs, and allow for more effective and responsive building management. These technologies can also provide a single interface for the integrated building services. The inherent intelligence also allows the owner/operator to transfer some building control to the occupant/tenant, improve telephone services and accessibility for the end user and facilitate security management. All of these changes provide operational efficiencies and the opportunity for increased revenue. These systems also provide owners/operators with greater operational flexibility, e.g., the ability to operate several buildings from one control centre, improving effectiveness while reducing cost. Human resource departments of the occupants/tenants can control, via one interface, all staff needs for telephones, voice mail, network access, parking access control, office lighting, etc.

An effective intelligent building technology implementation can therefore be operated with fewer operational staff, using these capabilities to monitor conditions and resolve problems more effectively. For example, fixtures can be re-lamped based on actual utilization, not on elapsed time. Since occupants/tenants can adjust temperatures, lighting conditions and security requirements through suitable interfaces, operational staff need not undertake these activities.

Building Occupants/Tenants

Building occupants/tenants clearly prefer the up-to-date bells and whistles that differentiate premium office accommodation from commodity space. What they want and are seeking is what intelligent building technologies can provide. And they clearly perceive that these features bring enhanced value, although, like consumers the world over, they look for the best value at the lowest price. These premium features focus on two areas. One addresses a more comfortable environment (HVAC, lighting, access and security) and the other relates to services and features that will improve efficiency and effectiveness.

Examples include reliable, ubiquitous, flexible and highly featured broadband communications, and the ability to reconfigure office space quickly, easily and cheaply, independent of the owner/operator.

The more comfortable environment enhancements 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 office 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. Another feature, which is desired, is the ability to relocate employees within the building, without reference to the owner/operator, thus reducing the time, cost and disruption.

Building Practices

The developer/owner is 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. Automation reduces the cost of operating staff. Added building functionality results in increased rents and building value.

As an example, quoted figures indicate that supervisory and security staff needs have been reduced by 50 percent. Since each person in this capacity typically costs $100K annually, a reduction of five staff saves half a million dollars per year for the life of the building. Other economies come from reduced energy consumption, reduced theft and vandalism and more satisfied occupants/tenants.

Owner/Operator and Occupant/Tenant Information Exchange Opportunities

A well-equipped intelligent building enables the owner/operator to exchange information in real time with occupants/tenants. The owner can charge for use of HVAC and electricity, and occupants can check their respective accounts on-line. Security arrangements can be integrated between operator and occupant, 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 and their employees will enjoy the benefits of such an upgraded facility and are expected to be more productive. Staff will be more willing to work during off hours. Owners will benefit from reduced tenant turnover and increased revenue.

Ancillary Benefits - Suppliers

Design Engineers

For the design engineer, intelligent building technologies provide enhanced functionality, facilitate commissioning and reduce dependency on proprietary vendors. Furthermore, intelligent building technologies provide design engineers with better control of site construction, because of fewer subcontractors and ensure consistent infrastructure options and implementation.

If the infrastructure for intelligent building technologies is covered by a single contract, it is normally undertaken by a single contractor who is responsible for both the integration and the infrastructure.

Contractors

For the construction industry, intelligent building technologies allow interchange of vendors and manufacturers, ensure control of construction costs and make testing and commissioning easier. Intelligent building technologies can allow for building completion in stages, i.e., it becomes possible for occupation of those floors of the building that are complete rather than awaiting full completion of the building project before occupancy may occur.

Equipment and System Manufacturers

The intelligent buildings market provides promising new business opportunities for technology developers. The development of standards is also promoting co-operation among vendors. Many technologies initially developed for other markets are now finding applications in the construction sector.

For building equipment and system manufacturers, intelligent building technologies offer good marketing opportunities through vendor interoperability. Intelligent building technologies decrease costs and increase reliability through the sharing of a common communications infrastructure.

Where vendors adhere to a widely agreed standard, products of more than one manufacturer will be interoperable, and purchase decisions are based on performance, availability and price criteria. Standards permit appropriate substitutions and exchanges, benefiting the end-user community through more choice, better availability and more competitive prices.

Since an intelligent building system records all activities, service related issues, performance concerns and diagnostics are available for all users. This centralized data can be readily evaluated, and the productivity of contractors and users alike is improved.

Reference Projects

Demonstrating the effective integration of intelligent building technologies into projects is an important and very effective way of increasing widespread understanding of the benefits. There have been a number of projects throughout the world that include intelligent building technologies and provide practical examples of how new technologies are being used to benefit all parties. Twenty-four projects are summarized in Appendix A. The relevant intelligent building economics are not included in these charts, because the project economic information is variously reported, and comparisons cannot easily be made.

Many of the buildings in which intelligent building technologies have been deployed use technology to reduce energy costs, but not to provide any direct benefit to the occupants. In others, claims of cost savings are based on anticipated cost savings compared with conventional technology alternatives. Valid economic comparisons are therefore tenuous. Legitimate extrapolation of the savings requires a retrofit building in which the operational costs over a number of years have established a pattern, to which subsequent retrofits then make significant changes. In most retrofit situations, the inherent structure of the building is left unaltered, so that the building only changes from energy inefficient to energy efficient in the context of improved controls, allowing more effective use of scheduled environmental changes.

Published Documents

The Continental Automated Buildings Association Web site <http://www.caba.org/trm> contains a bibliography of some 600 reference articles relating to intelligent building technologies. These publications are largely in English.

The research addressed by these articles and the trends, which are evident, are essential to the development of the Technology Roadmap and to the ability to keep it current. This research will continue to serve the Technology Roadmap by providing:

- a reference source identifying current and future intelligent building technology players;
- quick access to information about many facets of the intelligent building technologies industry;
- information related to innovative products and systems; and
- information for use in the analysis of market trends.

> *"Standards permit appropriate substitutions and exchanges, benefiting the end-user community through more choice, better availability and more competitive prices"*

CHALLENGES FACING INTELLIGENT BUILDING TECHNOLOGIES

Challenges to the widespread introduction of intelligent building technologies arise from many diverse considerations. This section considers how best to create and develop intelligent building technologies projects in the face of these challenges.

A significant consideration is always the financial impact, including capital costs, expense costs and revenue. Good business practice requires that financial implications must be correctly assessed, taking into consideration the time value of money and the effect of taxation. Low initial costs are attractive to developers, while the owners/operators and occupants/tenants are more interested in long-term operational costs. Intelligent building technologies offer significant opportunities to generate increased revenue. Intelligent buildings offer more value, hence sell and/or rent for higher prices and/or more rapidly.

Financial decisions based on the comparison of alternative plans of action that consider only initial cost will inevitably be wrong. If the revenue stream of the alternatives is the same, then revenue can be ignored and the continuing expenses can be factored in using the metric present worth of annual charges (PWAC). If the alternatives are expected to generate different amounts of revenue, which will generally be the case when intelligent building technology applications are under consideration, the correct metric is net present value (NPV). The initial cost must, of course, be considered, but should only be the deciding factor when the correct metrics for the comparison of alternatives, (PWAC where expected revenue is uniform and NPV where expected revenue varies) are the same or very close.

The improved value of intelligent buildings should influence developers/owners/operators and the entire supplier community to look positively on such opportunities. Intelligent building projects will obviously affect the construction processes. The successful integrated outcome will require that the design be integrated. This will, of course, involve many practical questions regarding the divisional specifications, contracts and the manner in which design, management and construction staff interact on the project. Changes in approach and appropriate co-operation will be required throughout the supplier community.

> *“Financial decisions based on the comparison of alternative plans of action that consider only Initial Cost will inevitably be wrong”*

Intelligent building technologies require that the system design reacts to component and system failures more reliably then conventional systems. System design must ensure that problem isolation and resolution will improve on “conventional” overall performance. To achieve these objectives, there is a continuing need for education for all those involved. Education and experience, and changes in normal practices, will be required throughout the supplier community, specifically including the engineers, the designers, the architects, the contractors, the manufacturers, and those who manage and maintain these systems. Provision and use of common space, common infrastructure and shared resources are central to the value, and the economic effectiveness and advantage of intelligent building technologies.

Authorities having jurisdiction must ensure that codes, practices and conventions support and encourage the deployment of intelligent buildings, noting the functional and financial advantages they offer. The assessment of successfully completed intelligent buildings projects highlights the importance of ensuring that the rules and regulations encourage the use of intelligence in buildings to achieve maximum value, while continuing to ensure that public safety and public service are well addressed.

The challenge is to demonstrate the construction of intelligent buildings with low financial risk and high financial return. Property that is more valuable to the developers/owners/operators and is occupied by satisfied occupants/tenants over the long term is the goal.

The current view is that a building and its infrastructure typically have a lifespan of 25 years or more between major retrofits. Noting the pace of technological evolution, intelligent buildings offer the ability to upgrade functional capability more often and much more economically, through upgrading components and equipment items without a need to touch physical components such as the cabling infrastructure.

Developers/Owners/Operators

Changing the traditional development, design, construction and operations of buildings requires new methods and techniques. These methods and techniques need to be developed and managed.

Occupants/Tenants

There is the potential for major advantages. The building operation will change and end users need to be made aware of these advantages. Costs and savings must be managed.

Lowest Initial Cost

When construction projects are planned, the costs and budgeting necessary for construction tend to emphasize capital costs and budgets. Proper consideration of ongoing operating costs is more likely when the building owner is also the developer. Since intelligent building technologies bring significant value throughout the life of a building, it is important to evaluate this in the budget planning.

The cost of building intelligent building systems may be slightly higher than independent systems, but by a very low percentage of the total investment. The developer/owner benefits from reduced infrastructure space and reduced operating costs. This increases the value of the newly constructed project, benefiting the developer/owner as well as the occupants/ tenants.

Current Practices

The advent of intelligent building technologies impacts present building practices in many ways. An appropriate analysis highlights areas where knowledge and technology gaps call for improvement, development and evolution of existing practices.

Developers/Owners/Operators

Of necessity, owners influence every phase of the design process. The owners are key to every design team, and need to be educated by the design team in the considerable benefits of intelligent building technologies. The design team itself must therefore be well educated about these benefits. The owner's influence will, of course, involve budgeting and scheduling and, in most cases, functional considerations.

Design Processes

All projects originate from a design group led by the architect, involving the developer/ owner/operator and including the specialist engineering and design staff who will design, specify, manage and commission the project. Each individual on the design team normally contributes in a manner directly related to the existing master specifications, provided by the Canadian Construction Document Committee (CCDC) or by the American Institute of Architects (AIA).

The intelligent building technologies concept does not meet directly with divisional specifications, and the advent of Division 17 complicates the concept. Experience suggests that a design consultant must take responsibility for the entire implementation of intelligent building technologies. The integration designer will influence the detailed designs of each of the divisional specifications in the master contract. Success in this requires that all members of the team are committed to this approach.

Redundancy

An efficient and reliable system must be able to withstand the failure of any single point in the system. In communication and control systems, many different techniques are used. Ring topology ensures that a break at any one place provides continued communications in both directions, to the point of failure. Distributed communications ensure that all individual controllers continue at a high level of functionality, when communications with the main computer are lost. The system in all cases will detect and report the failure of the communications link.

The terms "resilient" and "redundant" are complementary. "Redundant" indicates that extra components will assume the load in the event of failure, while "resilient" indicates that an individual component can survive a failure. Both these concepts are necessary. In telecommunications environments, for example, alternative links provide redundancy, while extra components within each link provide resilience within that redundant link. In building automation, these concepts are very important, as the integrated nature of intelligent building communication infrastructure requires these systems to provide all these functions.

Lifespan Issues

The evolution of electronic technology is moving rapidly, with lifespans and life-cycle times in the range of five to ten years. Buildings typically have a lifespan between major refits of approximately 25 years, or two to three technology cycles. A significant advantage of intelligent building technologies is the ability to upgrade the electronics while continuing to use the cabling that is already in place. Equipment and system vendors have an opportunity to design graceful growth into their product evolution plans; to enable their products that are in service to be upgraded to add the most recently introduced features and functions.

Building automation depends on many systems and components. Existing solutions will continue to function with the current implementation and capabilities, when newer products in the market place have displaced the installed product.

> *"The traditional construction process requires each of the specialized construction trades to complete their task independently of all others..."*

Construction Processes

Building projects involve a broad range of participants. The construction process has evolved to co-ordinate design, specification, contracting and construction into a number of distinct areas. Projects now follow an established sequence that reflects this experience. The traditional construction process requires each of the specialized construction trades to complete their task independently of all others, following a strict sequence so that their work is integrated seamlessly.

Intelligent building technologies add a new dimension to the integration of these construction processes. The objective is to ensure good quality with no delay in the construction, commissioning and acceptance process. This validation will ensure that, on completion of the system, its operation is calibrated so that the entire system functions properly. The integration process may lead to some jurisdictional issues, and the union and training responsibilities will need to be appropriately addressed.

Responsibilities

The design process must allocate responsibilities to suitably qualified engineers and contractors who are responsible for the design and implementation of the:

- common infrastructure;
- infrastructure testing;
- infrastructure acceptance and commissioning;
- system selection;
- system interaction;
- system testing and commissioning;
- system verification; and
- documentation, servicing, maintenance and repair.

Most of these responsibilities are essentially unaltered from those in existing individual contract documents. In an intelligent building, these roles are now consolidated into a single series of responsibilities. The challenge for the architect as the primary contract manager is to select engineers and contractors qualified to undertake these activities. Since the involvement of more parties in the construction process could make it more difficult to assign responsibilities, early and clear resolution of disputes is important.

Implementation of an automation system that is different may present a concern. The absence of a communications infrastructure within a traditional contract for elevators, electrical systems and mechanical systems is a change from the currently familiar process for each of these contractors. For example, the elevator contractor now uses a communications system provided by a third party, rather than the system that has traditionally been installed directly under his/her responsibility.

These concerns can be minimized by ensuring that the requirements for all communication infrastructures are clearly defined. The definitions will normally include the testing process and criteria used by all parties to ensure that the system meets appropriate standards. This process is central to many aspects of contracting already prevalent in the construction industry. With the evolving complexities of communications infrastructures, the use of a single, experienced contractor to install this infrastructure may be in the best interests of all parties.

Ongoing service arrangements in an integrated system must be addressed. The interaction among formerly segregated systems may pose a challenge. It is important to increase the intelligence of the systems, so that servicing can be more efficient and fewer routine maintenance activities will be needed.

Supplier Dependencies

Current construction practice is to install distinct systems for fire, HVAC, building automation, lighting control and security. These systems are now becoming co-resident in a building's control centre, and an integration layer allows the information to flow between the systems possibly through an integration PC. However, the separate suppliers maintain the independent systems in such implementations. The owner/operator may end up dealing with more independent suppliers and maintenance contractors.

The lack of proven interoperability and widely accepted standards continues to be a major barrier to the adoption of intelligent building technologies. Some suppliers recognize this and have focussed on software solutions to achieve interoperability. Market pressure by developers/owners/operators is needed to encourage change in the product lines offered by the suppliers.

Multiple standards and protocols have impeded the implementation of easy solutions for integration. The communications infrastructure required for building integration is moving to a common backbone using various versions of Ethernet. Use of PCs has imposed a *de facto* standard, and the increasing use of these devices and the adoption of Ethernet will encourage movement towards this *de facto* standard.

Often, the electrical standards, e.g., RS-485 or RS-422, define the electrical interfaces through which the levels are interpreted and the lines signal the data. These standards do not address how the signals are interpreted and how data is managed. Those protocols would be more easily interpreted if Ethernet standards were used by the individual transducers. Virtual LANs provide the necessary security for a local area network to manage both building automation and user data. For very high security communications requirements, it may be appropriate to segregate building functions from end-user functions, by providing a small number of individual cables to provide the data transport for each system. A Division 17 style of building management would oblige all parties to address the consolidation of all communications including building automation.

> *"The availability of the necessary human resources...is crucial to the success of this industry."*

Development of Human Resources

The availability of the necessary human resources to design, construct, commission, operate and maintain buildings which make extensive use of intelligent building technologies is crucial to the success of this industry. Education, training, development and experience are required not only for the design engineers, the architects and the developers/ owners, but also for the construction, maintenance and operational staff. Training for these individuals will include formal education, continuing education at accredited engineering faculties and technical schools, and courses, seminars and workshops provided by individual manufacturers. Training and development may also fall into the domain of trade unions. Unions are a powerful resource in meeting the objective of increasing the individual capabilities of their members.

There are currently few contractors with sufficient knowledge and experience to undertake a project where total integration is the goal. Many in the industry believe that an intelligent building addresses only certain sectors of building operations and management, typically areas where they hold vested interests, e.g., HVAC, security or building automation. Other interpretations relate to a building with a comprehensive telecommunications network. For intelligent building technologies to be installed efficiently and effectively, a broad spectrum of the construction work force must be trained in their use. Work activities on the construction site must be a team effort where each member has his own speciality.

Intelligent building technologies involve many trades. Most trades will need at least some understanding and knowledge, and will have to interact with other trades responsible for the installation of intelligent building technologies. There will be a need for training and for the provision of appropriate test gear. This test gear is necessary so that components and sub-systems can be tested, exercised and calibrated during construction when the intelligent building system is not yet available.

Building Codes

Building codes with the "power of law" are defined authorities having jurisdiction and must be respected. Examples include:

- the National Building Code of Canada, and local codes and interpretations related to it;
- the Electrical Code; and
- the Fire Code.

Other relevant codes, conventions and standards are not legally binding, but are often very helpful, for example:

- ANSI/EIA/TIA 568 (Telecommunications Industry Association) standard for commercial buildings;
- corporate standards which may apply to individual projects; and
- certification requirements by cable component vendors, e.g., NORDX/CDT CSV requirements.

These codes may not be easily interpreted and sometimes present conflicting requirements. Each code has a specific mandate and can significantly affect the opportunities and the process for implementing intelligent buildings. The Electrical Code, for example, requires that only cables of the same voltage and classification can be co-resident in a particular conduit. However, the jurisdiction of the Electrical Code does not generally extend to the communication cables that are mainly of interest to intelligent building technologies applications since the power levels lie below the Electrical Code jurisdiction. Intelligent building systems are used to control lights, fans and door control systems which are also regulated by the National Building Code or the Fire Code. Additional confusion can arise over the codes when some are rewritten or interpreted at national, provincial and municipal levels.

Currently, the codes generally define what is permissible and how it is to be implemented. Updated building codes, which are objective-based, are in preparation. Objective based codes will ensure the needed functionality while providing flexibility in how it is achieved. In general, intelligent building technologies improve the safety of buildings, and a suitable negotiation mechanism will resolve any conflicts. Through enhanced monitoring, diverse incident reporting and logging, the industry has anticipated many of the requirements that will be incorporated within objective-based codes.

Risk and Liability

Venturing into intelligent building technologies requires a partnership between diverse interests. This venture must inevitably involve the recognition of risks. However, each partner expects the risks to be related to the gains. The potential risks in implementing an intelligent building system should be identified in advance. The discussion of risks should include:

- initial additional costs and delays;
- delays in construction;
- supplier dependency;
- hidden costs; and
- liabilities.

Use of a common infrastructure and an integrated system with a single interface interacting among multiple sub-systems raises questions of liability. If the communications infrastructure does not perform appropriately, for example, for the lighting control system, the logical question that follows is: who will be held responsible?

These issues are not new and are fundamentally unchanged from similar considerations in traditional systems. The integration of communications infrastructure adds a new dimension that must be addressed in appropriate contractual commitments early in the design and construction process. Such a contract will go far to address concerns, and ensure that any failures will not lead to disproportionate liability accusations.

Assessable Reference Projects

Currently there are a number of showcase projects that demonstrate the functionality of various intelligent building technologies but there are few reference projects that add objective measurements to these demonstrations. For intelligent building technologies to be viewed as clearly the best direction for new and retrofit building construction, it is essential that objective reference projects be available. These reference projects must differentiate between “retrofit” and “new construction”. For retrofit projects, it should be relatively easy to establish the original operating costs, staffing and problems. As the retrofit occurs, the changed experience of all these criteria and parameters can readily be established.

> *“There is a critical need to initiate assessable projects, and the evaluation must be handled not by manufacturers, but by independent agencies...”*

When constructing new facilities, obviously no contractor or developer will initiate two simultaneous comparative projects. Therefore, the detailed measurements must stand on their own, including heating, operating, comfort levels, operations and maintenance, and perceived/measured value to occupants/tenants. There is a critical need to initiate such assessable projects, and the evaluation must be handled not by manufacturers, but by independent agencies, e.g., institutes of research or academic learning.

Overview of Intelligent Building Technology Challenges

The ability to fully realize the benefits of intelligent building technologies is hampered by a number of challenges:

- the reluctance of developers/owners to implement intelligent building technologies due to the perception of increased initial cost and concern over unproven technologies;
- 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 difficulty of achieving agreement among the design team members to commit to the approach required for implementing intelligent building technologies;
- the challenge for the architect to select engineers and contractors qualified to undertake the consolidated activities needed to design and implement an intelligent building;
- the challenge of educating owners to influence the budgeting, scheduling and functional considerations required in an intelligent building technologies project;
- the unwillingness/inability of suppliers to depend on each other for system data inputs due to proprietary protocols that cannot communicate with each other;
- the challenge of ensuring adequate redundancy so that any individual controller can work with adequate functionality when communication with the main control system has been lost;
- the lack of contractors with the knowledge and experience to undertake a project where total integration is the goal;
- the need for extensive training of a broad spectrum of the construction work force in the implementation and use of intelligent building technologies;
- the concerns over liability issues and problem resolution with a common infrastructure and an integrated system where a single interface provides interaction among multiple sub systems;
- the need for updated building codes which facilitate the implementation of intelligent building technologies;
- the concerns of developers/owners/architects about liability and insurability for integrated systems;
- the lack of proven interoperability and lack of universally accepted standards;

- the need to achieve co-operation and agreement among the stakeholders and their interests;
- the development of the procedures needed to implement an integrated communications system, that differ from those that have traditionally been used;
- the lifespan issues posed in making investment decisions for an intelligent building technologies construction project; and
- the ongoing service arrangements required by an integrated system.

FUTURE DIRECTIONS OF INTELLIGENT BUILDING TECHNOLOGIES

This section addresses the future directions of intelligent building technologies. The most successful introductions of intelligent building technologies indicate that the greatest advantages come from integrating communications and ensuring that the traditional systems have the ability to intercommunicate and interoperate. A single operator interface needs to recognize status and control information from all available systems. The primary benefit comes from the shared space, infrastructure and staffing. The current trend of working from home encourages interaction with building communications and services.

These trends are being influenced by technologies and the current market situation. Construction and technology are breaking down some conventional barriers. Increasing concern with environmental impacts and with security needs further influence intelligent building functionality.

These facilities depend on the increasing reliability of secure and resilient communications infrastructures. Mobile telephones are well established, encouraging mobile communications in many other forms. This technology has value for in-building application. For the occupants/tenants and the operators, these technologies yield substantial efficiencies. These concepts will lead to intelligent building technologies that are not yet on the drawing board.

> *"Rapidly evolving electronic technologies are encouraging both owners and occupants to reach for the latest technologies, yet the building and construction industry seems strangely reluctant to respond."*

Developers/Owners/Operators

Developers are recognizing that integrated and intelligent buildings provide a greater return on investment. Knowledgeable occupants recognize that such buildings are desirable, and investors are prepared to reward the development of these buildings with increased values, long term occupancy and recognition that those who create these buildings have a vision and a commitment to the "latest and greatest".

Occupants/Tenants

End users want to occupy buildings with excellent communications, personal workspace control and secure environments. The ability to deliver these is attracting end users to those buildings which best satisfy their demands.

Rapidly evolving electronic technologies are encouraging both owners and occupants to reach for the latest technologies, yet the building and construction industry seems strangely reluctant to respond. A very big part of the building and construction activity is retrofit, providing an excellent opportunity to introduce intelligent building technologies into existing "sticks and bricks" fabrics, and upgrading old buildings, in prime locations, into premium office space. Architects, building engineers and contractors are relatively conservative. Those moving to embrace the latest technologies do so only after they are thoroughly convinced of the value of systems and products that have been significantly endorsed.

New technologies provide both opportunities and challenges. Building systems can now be managed using automation, with less dependence on humans. Examples include monitoring doors and windows remotely (surveillance cameras, glass breakage detectors, etc.) and monitoring the building fabric (moisture, temperature, vibration, strain, etc.). Communications infrastructures allow knowledge workers to work where and when it is convenient. The concept of the mobile worker has led to new concepts where acoustics and lighting are automated, and this has also changed the configuration of offices. One must note the significant role played by the construction industry in the national economy. These activities represent a very significant part of the gross national product (GNP) of our economy.

Intelligent building technologies will promote the integration of control systems that enhance building and end-user functionalities. The increasing use of PCs and related technologies in the control of the target applications enables these systems to be interconnected and thus inter-related. The ability for computer networks to share information is the basis of almost every office function today. Use of e-mail has become commonplace and the ability of computer systems to exchange messages is now familiar. Within the building of the future these technologies will enable building functions, building management and end-user applications all to improve as a result of control and messaging techniques.

Trends

This project's literature review indicates that the current trends in intelligent building technologies are:

- to integrate communications, providing an overall or umbrella integration solution;
- to ensure that the existing systems are capable of operating independently, i.e., standalone;
- to move toward a single software front end which communicates with a single console;
- to gradually phase out separate control rooms for different functions;
- to change from project development based on lowest initial cost to development based on highest value, correctly reflecting higher revenues and operational cost savings; and
- to encourage suppliers to develop intelligent, self-diagnosing, fault tolerant controllers.

Market Drivers

Market drivers of intelligent building technologies include the owner/operator's desire to achieve a competitive advantage through more cost-effective and featured locations and the occupant/tenant's need for space that is comfortable, secure, versatile and productive. When office hours vary, the control of lighting and HVAC for individual offices becomes attractive for cost control. Security and reduced operational staffing are key elements in controlling rising costs while enhancing end-user services. Intelligent building technologies can provide better bandwidth and easier relocation for staff through the enhanced communications infrastructure. These functions are generally possible, individually, with traditional systems, but intelligent building technologies can provide them through full integration more effectively and at substantially lower cost. The dominant market drivers therefore are reduced cost, greater ease of operation and greater reliability.

Societal Impacts

Society continues to change dramatically, partly as a result of, and partly through the continuing evolution of technologies. These changes will continue. Trends to longer working hours, fewer support staff and portable wireless e-mail are examples of the intersection of technology and society. Intelligent building technologies are well positioned to more economically permit workers to control access to their own offices and related facilities, and to control the office environment. It has become possible for staff and firms to become tolerant of convenient working patterns, and to take whatever action is needed to complete job requirements with very challenging deadlines. The expectation that staff respond to their office e-mail whether they are in their office or elsewhere is now commonplace.

> *"It is common for technology to be introduced to reduce cost, while its greatest value turns out to be the added value capabilities that it brings."*

Future Technology Impacts

As technologies evolve, there are temptations to use technology because it is there, not because it solves an existing problem. Conversely, the introduction of new technology often leads to its use for valuable applications that had not previously been thought of. It is common for technology to be introduced to reduce cost, while its greatest value turns out to be the added value capabilities that it brings.

The introduction of smart cards, magnetic encoded stripe cards with read/write memory, has enabled many applications, e.g., medical records, passports, transportation fares, telephone cards, etc. As the following examples indicate, some technologies are also able to move the bounds of "intelligence" forward in their application to buildings:

- fibre optic communications can be used to recognize vibration, intrusion, etc. as well as to provide broadband, secure communications;

- security requirements are now, more than ever, constrained by the imagination of the user (or intruder), not by technological limitations. Use of biometric technologies ensures that recognition is unassailable, e.g., retinal scans, voice patterns, fingerprints etc. Such patterns may be stored on smart cards and used for many purposes;
- technologies are being sought which, in the view of responsible individuals, will reduce the risk of terrorism following the major tragedy of September 11, 2001;
- sensors are becoming available which perform multiple functions through a single transducer, including temperature, air quality, light and occupancy;
- software and interface devices are available to permit individual end-users to control their personal environment to achieve a comfortable and effective work space;
- improved communications and tools, e.g., e-mail and voice mail, have made the concept of working hours dynamic, allowing convenience for staff and avoidance of rush hours;
- improved security has ensured the safety of staff and equipment and dramatically reduced theft;
- high-rise apartments can now use technologies allowing dramatic improvements in convenience;
- because technological solutions are available, residents and workers demand access to them. End-user environments are attracting occupants to any type of building, i.e., the technology drivers are leading to technology implementation; and
- the concept of a home office has become widespread. Many companies accept the benefits of allowing staff to work at home. The necessary communications infrastructure for such home offices is a low investment for a significant productivity benefit. This approach is also contributing significantly to reduced environmental pollution and lowered staff stress.

Overall System Reliability

As intelligent building technologies become more pervasive, the need for them to become extremely reliable will increase.

Central Control

To maximize the benefits of intelligent building technologies requires systems integration and central control rooms. Staffing and training for the control room personnel will require very broad skills. An intelligent building system provides operation of all aspects of the integrated environment from a single control centre, which should have an alternative location, a backup facility, for use in the event of failure. The central control ensures the observance and interaction of all aspects of system operation. A central control facility has reduced total staffing needs and provides the resources to log, control and manage a large number of individual components. Staffing can be better managed and trained in such an environment than in many smaller, distributed facilities.

Wireless Dispatch

Wireless systems are options to consider in designing a building. The transition from wired to wireless systems is recommended to promote mobility and ease of access. Staff using notebook computers and personal organizers expect to be able to move about with these devices. Wireless communication also addresses the issues of dynamic offices and the travelling worker. Numerous competing technologies are being promoted.

The needs of end users who move between offices and sit with colleagues exchanging data and working on projects have stimulated wireless technology. Issues of confidentiality, bandwidth and incompatible operating systems are rapidly being addressed. In intelligent buildings, there is an obvious requirement for security and maintenance staff and others to move within the building. Available technologies enable pagers, cellular telephones and personal organizers to communicate with this mobile staff.

Communications systems use various technologies, protocols and infrastructures. Wired communications systems make use of a variety of twisted pair technologies. Communications systems comparable to these wired systems have now become available through various wireless technologies, usually utilizing packet data. Wireless technology uses a variety of mechanisms to comply with the requirements for security, reliability and power requirements. These evolving technologies are working together to provide a portable communications environment for many building applications.

The new digital wireless technologies can co-exist with the older analogue technologies and provide mobile services to both end users and building operations staff. Typically, wireless coverage is a major concern. For reliable coverage within buildings, technologies have developed to provide “repeater” or “internal antenna” functions. The latest trend is to mount antennae on the back side of ceiling tiles in suspended ceilings so the antennae are invisible and users do not perceive that they are using an antenna-based distribution system. Environments, such as hospitals, large buildings and sports arenas, can provide their occupants with continuous service for pagers, wireless local area networks and cell phones.

99.999% (Five “Nines”) Reliability

Electrical and telephone systems strive to achieve “five nines” reliability, i.e., operating without problem 99.999% of the time. Note that this does not imply complete reliability as even at this level of reliability there are 5.25 minutes of downtime per year.

For a building to operate with this overall level of reliability is a very demanding challenge. The PC does not normally attain this level of reliability, and dramatic steps are required to ensure that all systems included within intelligent building technologies can work together to achieve these levels of service. Initial steps to improve reliability are likely to focus on individual components capable of operating autonomously in the event of any central failure, and also of ensuring “fall back” or “diverse” functionalities. Common carriers, for example, normally provide secondary channels within communications systems that take the load if the primary channel fails. Reliability design requires detailed historical experience information about the intended components, i.e., mean time between failures (MTBF) and mean time to restore (MTTR).

Design principles to ensure system reliability will require the following:

- intelligence is distributed;
- standby power is continuously available to these distributed units;
- these distributed units are capable of operating without normal power or communications;
- the status of all control units and communication links is continuously monitored;
- the distributed controllers have local intelligence to report their status; and
- for critical applications, controllers have diverse communication paths.

CONCLUSIONS AND RECOMMENDATIONS

This report proposes actions to promote and advance intelligent building technologies. The conclusions drive the recommendations. There are two major conclusions and recommendations.

- Intelligent building technologies are generally available, but not yet widely adopted; and
- Many changes and initiatives are needed for use of these technologies to become widespread.

The Technology Roadmap recommends numerous actions, many requiring co-operation among organizations. This is the nature of progress in technology applications in today's world. The adoption of intelligent building technologies, like many other processes, faces significant challenges, and is making progress because of the vision and dedication of individuals and organizations. These visions need to be encouraged, adopted and exploited. The recommendations are designed to do this.

Developers/Owners/Operators

The key factors that need to be modified to encourage progress in the industry, and suggestions on how to undertake these modifications.

Occupants/Tenants

The changes that are needed to take more advantage of intelligent building technologies and how to make these happen.

Conclusions

The research that developed this Technology Roadmap led to the following conclusions.

1. There are a significant number of intelligent building technology products currently on the market that are capable of automating and integrating all major building systems.
2. Building automation systems can both reduce costs and increase productivity and comfort.
3. The degree of confidence in intelligent building technologies is inadequate largely because of a lack of awareness and understanding, of its value.
4. There is a lack of properly assessable intelligent building technology reference projects.
5. Reduced energy costs are seen as a major benefit of intelligent building technologies equated to HVAC. However, other benefits, e.g., reduced staff levels and improved occupant satisfaction, are often overlooked.
6. Economic analyses of intelligent building projects are often flawed. Typical errors: including construction cost increases but not savings, incorrectly reflecting operational cost savings over the project's expected life, and ignoring additional rent and sales revenues.
7. Many developers, owners, architects, engineers and contractors use only old, tried and proven products, methods and technologies, and show little initiative to consider valuable and economically attractive advanced alternatives.
8. Widespread use of the Internet and wireless communications improves worker productivity and increases the cost effectiveness and marketability of intelligent building technologies.
9. Air quality measurement and other sensors work well to control HVAC and other building automation systems.
10. There is a significant shortage of trained, knowledgeable and certified professionals in the design, installation and integration of intelligent building systems.
11. Intelligent building technologies require the co-operation of the entire design team including owner, developer, architect and engineers.
12. An integrated communications infrastructure is the essential foundation in the effective deployment of intelligent building technologies.

13. New and evolving technologies enable the gradual enhancement of functions and features, via upgrade of the electronics, throughout the life of an intelligent building.

Recommendations

The recommendations resulting from these conclusions follow. These recommendations are intended to increase the widespread, successful and valuable application of intelligent building technologies:

1. Increase awareness of the benefits of intelligent building technologies, to stimulate research and development and, most important, usage. Techniques to increase awareness include the following.
    - Document the substantial economic advantages of implementing integrated intelligent building technologies through well presented rigorous cost/benefit analyses, and circulate these studies widely;
    - Develop instrumented reference examples for both retrofit and new construction;
    - Stimulate demonstration projects, which must be properly managed, instrumented and monitored. The resulting knowledge must be useful for comparative evaluations of the benefits of these technologies, and widely available;
    - Economic results from instrumented examples must distinguish among the many technologies, the areas and disciplines, and short-term and long-term savings; and
    - Develop effective links with this technology in other countries and with all disciplines.
2. Emphasize the total benefits, the overall positive picture, of intelligent building technologies.
3. Education must be provided and promoted at all levels. This includes architects and engineers, developers, owners and all those involved in the construction, operation and maintenance of intelligent building technologies, and also the real estate industry. Education will include traditional universities and schools, and information, workshops and seminars provided through manufacturers and suppliers. On-site training and union participation are also required.
4. A disciplined approach to standards and protocols is needed, to ensure system interoperability, and maintenance and operation without proprietary information.
5. Develop partnerships among knowledgeable design engineers and traditional electrical and mechanical designers. This follows the practice of the architect selecting electrical, mechanical and other design and engineering groups.
6. Develop partnerships among suppliers to promote intelligent building technologies, e.g., utility companies partnering with intelligent building technology manufacturers, service providers and systems integrators to extend high value functionality to the customer.
7. Design intelligent building technologies systems to include redundancy and resiliency, with no single points of failure. Systems operate in redundant or degraded mode after a failure.
8. System integration should evolve gradually, i.e., evolution and not revolution.
9. Standards and protocols must evolve to promote interaction and interoperability among the multiple computer-controlled systems common within modern buildings.
10. The controllers and electronic components must incorporate diagnostics and reporting capabilities, to report failures or performance degradation before users become aware of them.
11. Protocols used by suppliers in proprietary solutions must be available to contractors, engineers and service personnel as required. These protocols must enable the required interoperability.

12. Warranty-related recommendations include the following:

    - Warranties must ensure that individual systems interoperate with other systems. Other vendors' components and sharing data among devices must not void warranties;
    - When commissioning or validating systems, suitable test procedures must be documented which are acceptable to all parties; and
    - Authorities having jurisdiction and building codes must recognize that integrated systems can and do provide improved safety and functionality. Appropriate Certification of these systems must be acceptable for authorities having jurisdiction and for warranties.

13. Contractual recommendations include the following:

    - Service and maintenance contracts must permit interoperability, non-exclusivity of service requirements, sharing of communication facilities, and provision of parts and service documentation to third parties;
    - Service contracts and maintenance agreements require non-confidentiality agreements so that vendors may share and distribute needed proprietary information;
    - Responsibilities among service organizations may be shared but must avoid competitive or conflicting requirements, e.g., transducers and communications facilities may be shared among more than one system;
    - Service agreements must guarantee overall system reliability and availability in terms that are both measurable and enforceable; and
    - Service and maintenance agreements should recognize the need to upgrade systems and avoid obsolescence. Exchange of service records among suppliers ensures proper functionality of integrated systems.

14. A key recommendation is the adoption of a single communications infrastructure with an integrated design. This requires a new division within the construction administration document process, commonly referred to as the Division 17 or the Division 25 initiative. Key elements include the following:

    - recognize that the communications infrastructure is a utility within the building comparable to the electrical risers or the plumbing infrastructure;
    - have a single contractor install all communications infrastructure;
    - certify the communication cables and infrastructure against demanding and common criteria;
    - co-locate equipment within communications rooms in order to provide versatility when additional devices, e.g., paging amplifiers, security systems, etc., are added to the common communications backbone; and
    - remove all Class 2 type services from all construction administration document divisions except in designated divisions, such as Division 17.

15. The construction divisions, which are normally included in documents provided by the CCDC or the AIA, are beginning to move to a Division 17 – Communications Infrastructure. The well-proven benefits to the developer/owner/operator have been:

    - a single, common, universal infrastructure;
    - lower costs because of the single communications utility;
    - an ongoing ability to easily relocate equipment as and when required;
    - a reduced number of different cabling options since a proper cable design allows use of a single cable type or low variation in cable types;
    - established pathways which eliminate unsightly and costly conduits dedicated to particular applications; and
    - identification of responsibility for cabling and end-to-end communications problems.

In Closing

This Technology Roadmap reflects the state and status of the intelligent building technologies industry, primarily in Canada and the United States, in mid-2002. The activities involved in developing the Technology Roadmap have resulted in a great deal of enthusiasm among some practitioners who recognize a tremendous opportunity for the expansion of related activities. In many cases, these will occur by evolution and not by revolution as the technologies are gradually placed into service and more people come to understand the benefits and opportunities that can be exploited from using these technologies.

We thank all of those who have contributed to date and look forward to further, exciting contributions from readers in the future.

A complementary document to the Technology Roadmap, has been developed by the Continental Automated Buildings Association (CABA) under contract to Industry Canada and Public Works and Government Services Canada. This document is a checklist of intelligent building technologies intended as a guide for all of the major stakeholders in IBT projects. It is available at <http://www.caba.org/trm>.

For further information and investigation, and to contact those who were involved in the development and preparation of this Technology Roadmap, please refer to the following appendices. Comments and suggestions will be most welcome.

APPENDIX A

Reference Projects

Reference Projects

British Columbia

Name	Date	Type	Location	Implementations	Cost	Savings/Benefits	Comments
Crestwood Corporate Centre, Building 2	March 1998	Commercial Office New Construction	Richmond	▪ intelligent HVAC systems; ▪ day lighting schedules; ▪ building automation system; ▪ photocells; ▪ automated lighting control	$5.2 million	▪ improved air quality; ▪ efficient lighting; ▪ greenhouse gas emission reduction; ▪ increased energy performance; ▪ efficient building design	A project of the CANMET C-2000 Program for Advanced Commercial Buildings, Building 2 advocated building performance in a holistic sense – energy use, environmental impact, occupant health, comfort and productivity, functional performance, longevity, adaptability and operations and maintenance. At completion, they experienced no identifiable overall incremental capital cost premium compared to conventional construction methods. The increased initial costs were balanced by the long term savings.
Royal Inland Hospital	N/A	Health Care Facility Retrofit	Kamloops	▪ installation of an intelligent building automation system; ▪ entering into a 15-year, $6.3 million Performance Contract	N/A	▪ projected savings of $5 million to the taxpayers; ▪ a projected annual energy and operating cost savings of $600,000; ▪ improved indoor working environment; ▪ reduction in greenhouse gas emissions	The Royal Inland Hospital was founded over 100 years ago, has 260 beds, encompasses 150,000 square metres and employs more than 1,400 staff. The goals of the retrofit were: ▪ finance a major capital improvement project without increasing public debt; ▪ improve the comfort levels in the hospital;

Reference Projects

Name	Date	Type	Location	Implementations	Cost	Savings/Benefits	Comments
							▪ increase productivity; ▪ increase plant and systems efficiency; ▪ reduce greenhouse gas emissions
British Columbia Institute of Technology	N/A	Educational Facility Retrofit	Vancouver	▪ installation of a structured cabling system; ▪ integration of the intelligent building automation system	N/A	▪ fully enabled centralized equipment control throughout the facility; ▪ reduced costs using energy saving measures, such as occupancy sensors that regulated lighting control and temperature; and ▪ meeting the Vancouver Energy Utilization Bylaws and ASHRAE/IESNA 90.1-1989R standards.	The British Columbia Institute of Technology in central Vancouver, occupies 50,400 square metres. The goals of the retrofit were: ▪ create a high-tech educational facility doubling as a profit centre; ▪ integrate voice, data and building controls into a single communications network; and ▪ increase levels of efficiency and savings.
Canada Place	N/A	Commercial/Port Facility Retrofit	Vancouver	▪ installation of an intelligent building automation computer system; ▪ flexible system controllers; ▪ flexible lighting controllers	N/A	▪ a reduction in facilities management costs; ▪ increased energy efficiency; ▪ implementation of a cost-effective solution insuring future system upgrades; and ▪ increased staff productivity.	Canada Place is a 540,000 square metre facility. It serves as a docking station for cruise ships in Canada's busiest harbour. It contains a hotel, retail facilities, a convention centre and an IMAX theatre. The managers wished to upgrade the building operating system and integrate the existing system

Name	Date	Type	Location	Implementations	Cost	Savings/Benefits	Comments
							devices from a number of different vendors.
The Fairmont Hotel Vancouver		Hotel Retrofit	Vancouver	▪ installation of high efficiency lights in entire building; ▪ installation of high efficiency boiler, replacing conventional boiler; ▪ five rooftop HVAC units changed, fitted with economizers to provide optimum building ventilation; ▪ LONWorks computerized energy management system installed (controls guest room temperature between 19oC and 24oC according to guest requirements); ▪ wireless communication between building and parking garage.	N/A	▪ $52,000 cumulative energy savings in first seven months; ▪ $36,000 electricity cost savings; $16,000 natural gas cost savings (seven months); ▪ 35% energy savings ▪ increased night time visibility in parking garage; ▪ ability for indoor parking control using wireless communication system; ▪ increased guest comfort; ability for individual room temperature control; and more reliable lighting; ▪ reduced maintenance demands on staff to change lights.	The Fairmont Hotel Vancouver is a landmark in the heart of Vancouver. The current structure was built between 1928 and 1939. It is a 20-storey, 730,000 ft2 limestone and brick structure with a distinctive copper roof. Located in the centre of downtown Vancouver, the Hotel includes 556 suites, two restaurants, one lounge, conference facilities, shops, a health club plus office areas and back-of-the-house facilities. The aforementioned implementations were made with an aim to update and improve the hotel's building performance.

Reference Projects

Alberta

Name	Date	Type	Location	Implementations	Cost	Savings/Benefits	Comments
Autovalue Central Auto Parts	July 1999	Warehouse/Office Retrofit	Calgary	▪ effective integration of building systems ; ▪ HVAC system designed to inject 100% fresh air into building envelope areas free of vehicular exhaust; ▪ glycol run-around heat reclaiming system.	N/A	▪ use of the Model National Energy Code for Buildings; ▪ energy use reductions of 39 per cent; ▪ comfortable workplace environment for employees; ▪ heat conservation	This facility, consisting of a warehouse, sales centre and offices, covers an area of 6025 square metres.
Northern Gateway Regional Division No. 10	N/A	Educational Institution Retrofit	Edmonton	▪ building automation system, providing long-term energy efficiency while allowing system upgrades	N/A	improved environmental control; maximized comfort, health, and safety; increased operational efficiency; reduced greenhouse gas emissions, connected all buildings through communications network; reduced energy consumption for an annual savings of $150,000	This school division operates 22 different academic facilities, northwest of Edmonton. Total area is 231,000 square metres and the facilities serve 5,685 students. The upgrade efficiency results won the Division a $137,000 Energy Innovators grant.
Wolf Creek School Division No. 72	N/A	Educational Institution Retrofit	Alberta	▪ the installation of energy efficient lighting and controls; ▪ the installation of an intelligent facility	N/A	▪ reduction in operating costs of 20%; ▪ energy savings of $26,000 for the first year;	The Wolf Creek School Division educates 8000 students, has 25 facilities, containing over 300,000 square metres. The retrofitting goals were to:

Reference Projects

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				management system.		▪ a reduction in utility bills of 30%.	▪ minimize operating costs; ▪ maximize efficiency; ▪ provide a safe, clean and aesthetically pleasing environment; ▪ reduce maintenance costs; and ▪ increase custodial staff efficiency. The resulting savings allowed for the installation of facilities management systems at other school locations across Alberta.

Reference Projects

Ontario

Name	Date	Type	Location	Implementations	Cost	Savings/Benefits	Comments
Queen Elizabeth School	1999	Educational Institution Retrofit	Sioux Lookout	▪ water-furnace system integrated with a VAV system. ▪ occupancy sensors; ▪ energy monitors; ▪ water source heat pump controllers; ▪ VAV thermostats.	N/A	▪ increased energy savings; ▪ flexible system design; ▪ increased occupancy comfort levels; ▪ interoperability between different equipment suppliers/ manufacturers.	In 1999, the HVAC system at the Queen Elizabeth School was retrofitted to replace an outdated system. The goal was to provide efficiency and room for future growth. Another consideration was the simple and non-disruptive adaptability of the system to future requirements, multi-vendor options for additional products and functionality as well as energy and cost savings.
Condominiums at 77 Governors' Road	December 1999	Residential New Construction	Dundas	▪ high performance thermal windows; ▪ increased wall insulation; ▪ four pipe fan coil unit in each suite for HVAC; ▪ individual heat recovery ventilators; ▪ high efficiency lighting systems in garage and common areas.	N/A	▪ decreased energy consumption by 30%; ▪ improved quality of life and personal security; ▪ energy savings of $12,941 per year; and ▪ simple payback in 1.8 years.	Urban Horse Developments, with The Office of Energy Efficiency (OEE), equipped each residence with a combination space/water heating system, electronically commutated motors in each air handler to reduce blower electrical demand and a lighting system which uses 30% less energy than conventional systems for the same level of illumination.
Mother Teresa Elementary School	September 1999	Educational Institution Retrofit	Oakville	▪ constant volume fan powered boxes with individual reheating coils for space conditioning;	N/A	▪ 35% energy savings; ▪ a more comfortable environment; ▪ a $9,659 reduction in energy costs per year.	The Mother Teresa Elementary School consists of 5059 square metres, with a student population of 675 and 40 teachers and staff. In designing the school, the

Reference Projects

Name	Date	Type	Location	Implementations	Cost	Savings/Benefits	Comments
				▪ occupancy sensors to control heating and lighting			Model National Energy Code for Buildings was followed. The goal was to provide an improved learning environment for students and reduce operating and maintenance costs.
Wellington County Board of Education	N/A	Educational Institution Retrofit	Guelph	▪ performance contract was entered into; ▪ lighting and control retrofit was carried out; ▪ installation of facility management system	N/A	▪ a 21% savings in electricity; ▪ $360,000 in energy savings or $2.5 million over a seven-year timeframe; ▪ the resolution of indoor air quality problems	The Wellington County Board of Education has an enrolment of 25,000 students, located at 67 different buildings. The goals of the system retrofit were to: correct indoor air quality problems; maximize available resources for teaching and learning environments; monitor control systems at a number of schools for later analysis.
Four Points Hotel Toronto Airport	May 1998	Hotel Retrofit	Toronto	▪ installation of high efficiency lights in entire building ▪ installation of high efficiency boiler, replacing conventional boiler ▪ five rooftop HVAC units changed, fitted with economizers to provide optimum building	N/A	▪ $52,000 cumulative energy savings in first seven months ▪ $36,000 electricity cost savings; $16,000 natural gas cost savings (seven months) ▪ 35% energy savings ▪ increased night time visibility in parking	The Four Points Hotel Toronto Airport includes 296 rooms, 21 meeting and banquet rooms, a Restaurant Grill and Lounge, patio, pool and indoor parking garage. Beginning in May of 1998, and scheduled to May 2002, building managers decided to undertake a $700,000 renovation project in order to increase guest comfort while decreasing energy

Reference Projects

Name	Date	Type	Location	Implementations	Cost	Savings/Benefits	Comments
				ventilation ▪ LONWorks computerized energy management system installed (controls guest room temperature between 19oC and 24oC according to guest requirements) ▪ wireless communication between building and parking garage.		garage ▪ ability for indoor parking control using wireless communication system ▪ increased guest comfort; ability for individual room temperature control; more reliable lighting ▪ reduced maintenance demands on staff to change lights.	and operating costs.
Human Resources Development Canada- 4900 Yonge St.		Government Offices New Construction	Toronto	▪ automated HVAC system, “personal w/s” ▪ integrtared lighting and HVAC systems; ▪ HVAC system includes end user controls using “adjustable stat.” (personal adjustment for air-flow, etc); ▪ DDC system which allows for integration paths	N/A	▪ improved thermal comfort; ▪ increased worker productivity; ▪ decreased occupant complaints	

Québec

Name	Date	Type	Location	Implementations	Cost	Savings/Benefits	Comments
Hospital Rivière des Prairies	1999	Health Care Facility Retrofit	Montréal	The integrating technologies employed included: ▪ current monitor nodes; ▪ relay lighting nodes; ▪ lighting schedulers; ▪ lighting software; ▪ user interface nodes.	N/A	▪ wide variety of available hardware; ▪ flexible, expandable design; ▪ high level of functionality; ▪ better control and documentation of energy usage.	This hospital wished to upgrade the lighting control system with a flexible, cost efficient and expandable system. The varied number of activities and locations within the hospital required that the wide range of lighting technologies and fixtures be integrated into one system. They solved the problem by installing a low voltage lighting control system throughout the 65,000 square metre complex. The system is monitored from the security office using lighting control software.
Le Château Frontenac	1995	Hotel Retrofit	Québec City	▪ facilities management system connecting new boiler automation system and chiller control panels	N/A	▪ ability to provide guest comfort on demand; ▪ efficient management of work hours; ▪ increased response reaction time; ▪ savings of $250,000 through efficient energy use; ▪ decrease in boiler maintenance from 24	The Château Frontenac, with 613 guest rooms and 18 floors, serves 270,000 guests per year. In 1995, a hotel wide restoration was begun. This included a building automation retrofit. The goals of the retrofit were: ▪ to ensure comfort of the guest at all times; ▪ to maintain a response time of 30 minutes to all maintenance requests; and ▪ to provide a high level of

Reference Projects

Name	Date	Type	Location	Implementations	Cost	Savings/Benefits	Comments
						hours per day to just one.	service with fewer staff members.
École de Technologie Supérieure (ETS)		Educational Institution New Construction	Montréal	▪ management integrated emerging technologies; ▪ new system specifications were developed	N/A	▪ construction costs were kept under $40 million ▪ a highly technologically advanced building was created; ▪ an evaluation of current business needs was undertaken	ETS, an engineering school, opened its new campus in Montréal in December of 1986. The school specializes in mechanical and electrical engineering and needed the most current facilities. It allows students the opportunity to experiment and apply their lessons in a real environment. The 139,500 square metre campus is housed in a building, which once served as a Molson-O'Keefe Brewery and was built in 1912.
Molson Centre	1996	Arena	Montréal	▪ lighting; ▪ access control; ▪ security; ▪ temperature monitoring; ▪ parking; ▪ LAN; ▪ telephone; ▪ Division 17; ▪ Fire System; ▪ HVAC; ▪ fire paging; ▪ control of public area televisions; ▪ liquor dispensing;	N/A	▪ reduced operating costs; ▪ longer lamp life; ▪ reduced losses; ▪ fewer security guards; ▪ greater accountability; ▪ rapid response to food storage or water leakage problems; ▪ ease of reconfiguration.	▪ soft start leads to better mechanical service; ▪ reduced staff needs exceeded expectations; ▪ operating costs below previous building despite substantial increase in size; ▪ audio and video recording or same tape for archival; ▪ response plans for fire, security incorporated into single system.

Reference Projects

Name	Date	Type	Location	Implementations	Cost	Savings/Benefits	Comments
				▪ water leakage detection; ▪ photographic flash lights for photographers; ▪ access control by intercom or card; ▪ daily usage statistics; ▪ in-house broadcast facilities to augment CATV			
Famous Players Theatre		Entertainment/Retail	Ste. Foy	▪ Echelon based HVAC control with the following features: ➢ employs an optimal start strategy where algorithms calculate the ideal start time to precondition the theatre based on temperature readings taken 30 minutes before a scheduled show time. ➢ directly connected to the ticket sales system which works to monitor the number of expected patrons who select any given movie and	N/A	▪ substantial energy savings; ▪ reduced training costs; ▪ increased customer satisfaction and comfort; ▪ reduced demand on theatre operating management; ▪ staff movement between theatres made easy.	Famous Players operates 111 theatres across Canada. In an effort to allow for easier operation of the theatre’s (HVAC) systems, Famous Players decided to implement a standardized automation system.

Reference Projects

Name	Date	Type	Location	Implementations	Cost	Savings/Benefits	Comments
				subsequently predict the expected heat load based on those ticket sales			

Reference Projects

International

Name	Date	Type	Location	Implementations	Costs	Savings/Benefits	Comments
Miller SQA Building	N/A	Commercial/ Manufacturing New Construction	Holland, Michigan U.S.A	▪ passive solar heating; ▪ roof monitors, skylights and sloped glazing for maximum daylight usage; ▪ photo sensors regulating artificial light so as not to duplicate natural light; ▪ high-efficiency electric lights; ▪ natural ventilation/cooling; and ▪ motion sensors monitoring zone occupancy to regulate light usage	N/A	▪ energy savings over $35,000 per year; ▪ increased worker productivity and work quality; ▪ reduced energy consumption; ▪ 17% decrease in natural gas costs; and ▪ 18% decrease in electric costs	The Miller SQA building is an office, manufacturing, and distribution center. Among the desired design objectives were improved indoor air quality, maximum use of daylight and a workspace that would allow a high degree of worker interaction.
International Netherlands Group (ING) Bank	1987	Office New Construction	Amsterdam, Netherlands	In order to achieve the company's objectives, the multidisciplinary design team incorporated some notable features including: ▪ specially designed security system; ▪ individual end-user	N/A	▪ $2.9 million estimated energy savings; ▪ a three-month payback of the initial investment in energy efficiency; ▪ 92% primary energy reduction compared to conventional	The International Netherlands Group Bank is currently the second largest bank in the Netherlands. Formerly known as Nederlandsche Middenstandsbank (NMB), the bank needed a new image and decided that the erection of a new headquarters in 1987 would be the means with which they

Reference Projects

Name	Date	Type	Location	Implementations	Costs	Savings/Benefits	Comments
				climate controls; ▪ passive solar heating ventilation; ▪ cogeneration and waste heat capture; ▪ office spaces with daylight illumination; and ▪ a design which is flexible and adaptable to evolving technologies and functions		building of similar size; and ▪ increased employee productivity, including 15% decrease in absenteeism	would achieve this objective. The new building was to be designed with functionality and cost-effectiveness in mind, and this task was a joint effort put forth by a multidisciplinary design team that included architects, engineers, energy professionals and landscapers.
DNP C & I Building	N/A	Commercial Office New Construction	Shinjuku-ku, Tokyo, Japan	▪ individual control outlets for under floor air conditioning system ▪ day-lighting illumination including automatic controls; ▪ natural ventilation system for maximized outdoor air intake; ▪ seismic vibration control equipment; and ▪ emergency generator with 2 week lifespan		▪ 30% decrease in primary energy consumption; ▪ 28% reduction of CO2, 31% reduction of SOX emission, 92% reduction of CFC/HCFC consumption; and ▪ natural disaster security (i.e. earthquake, flood, etc.)	The DNP C & I Building is a commercial office building in Shinjuju-ku, Japan. The objective of the building's construction included improving building energy use and operation performance as compared to other traditional buildings.
Hong King Wanchai	August 1992	Commercial Office	Hong Kong	Some notable building features of the HKW	N/A	▪ increased energy efficiency;	Encompassing 78 stories and a total building area of 173,000m²,

Reference Projects

Name	Date	Type	Location	Implementations	Costs	Savings/Benefits	Comments
Central Plaza		New Construction		Central Plaza include: ▪ double glazed visual panels (silver or gold); ▪ all-air single duct air-conditioning with perimeter zone reheat VAV (Variable Air Volume) system; ▪ lighting system including low energy consuming fixtures; ▪ central energy management system (includes programmed on-off control for heating/lighting, air temperature reset, etc.); and ▪ 5 express non-stop shuttle elevators		▪ reduced solar radiation imposed on air-conditioning; ▪ ability to suit individual zone cooling/heating requirements; ▪ quieter operation of air-conditioning system ▪ ability to perform routine maintenance with minimum tenant disruption ▪ additional 80m2 usable floor area as result of elevator design.	the HKW Central Plaza is an office tower located at the Wanchai waterfront of Hong Kong. Two of the major building objectives were to design a building that is energy efficient and occupant friendly. The building project included three construction phases. The building was completed with the completion of phase 3 in August 1992.
Australian Parliament House		Government Building housing the National Parliament of Australia Built to last 150 years as Class A Building	Canberra, Australia Capital Territory (ACT), Australia	Honeywell Enterprise Building Integrator > 30,000 Points Controlling : ▪ HVAC ▪ Fire, ▪ EWIS, ▪ Security, ▪ Access Control, ▪ Video Surveillance,		▪ energy Savings >$1 Million US per annum ▪ operational Cost Savings of 40% ▪ Viewed as one of the largest Intelligent Buildings in the World ▪ met “Greenhouse Challenge” for	Building was initially completed with independent systems that were installed on a lowest-bid basis. Honeywell worked with the end user to migrate the site to an integrated Intelligent Building solution.

Reference Projects

Name	Date	Type	Location	Implementations	Costs	Savings/Benefits	Comments
				▪ Power Monitoring and ▪ Lighting.		meeting reductions in GreenHouse Emissions.	

APPENDIX B

OSI Seven Layer Communication Model

Frequent references have been made to the use of communications as a utility within an Intelligent Building. Little emphasis has been given to the mechanism by which the infrastructure is supported with the diverse systems and technologies implicit in an Intelligent Building. The OSI (Open System Interconnection) model is a standard for communications that defines networking in terms of seven layers. This standard was developed and is supported by the International Standards Organization, a United Nations agency located in Geneva, Switzerland.

Control in each case is passed from one layer to the next. This model allows layers to be tuned and modified without prejudicing the other layers. This theory does not work with all modern protocol implementations because not everybody adheres to all of the standards. In some cases, as noted below, some of the layers (5 and 6) are effectively bypassed. The concepts, however, are crucial to any form of network and communications system. The traditional seven layers are:

1. Physical Layer – this defines the hardware for sending and receiving data, including cables, cards and electrical interfaces.
2. Data Link – this handles errors in the physical layer, places bits into frames, packetizes the data and validates some error correcting protocols e.g., checksums. The Media Access Control (MAC) and the Logical Link Control (LLC) are sub layers of the data link layer.
3. Network Layer – this provides switching and routing technologies, including virtual circuits for data from node to node. Routing and forwarding, including addressing, internet working and packet sequences are included. Protocols such as X.25 and IP are part of this layer's responsibilities.
4. Transport Layer – this layer provides transparent transfer of data between end systems and does not deal with any lost messages, except for the provision of a reliable service. It may reduce the size of messages from higher level layers in order to ensure effective transportation. If packets arrive out of order (diverse routing) they must be re-sequenced. The most common internet protocol, Transport Common Protocol (TCP) mates with layer 3, IP protocols.
5. Session Layer – manages connections between applications and sets up, co-ordinates and terminates conversations. It is widely ignored in practical terms.
6. Presentation Layer – this provides independence from differences in data representations or encryptions by translating from application to network format and vice versa. It transforms data into a form that the application layer can accept.
7. Application Layer – this is a collection of miscellaneous protocols for high level applications, including electronic mail, file transfer, remote terminal access and terms such as SMTP, FTP, Telnet, HTTP are widely evident in this layer.

While the OSI model serves as a valuable concept for outlining network and communications systems, it should be noted that this model has not been adopted by all manufacturers.