If Buildings Were Built Like Cars—

The Potential for Information and Control Systems Technology in New Buildings

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ABSTRACT

This article compares the technology used in new cars with the technology used in new buildings, and identifies the potential for applying automotive technology in new buildings. The authors draw on their knowledge of both new cars and new buildings to present a list of sensors, computers, controls, and displays used in new cars that can provide significant opportunities for our new buildings. Methods for integrating this new technology into new buildings are also discussed. The authors hope that their use of new car technology as a model for new building technology will stimulate recognition of the potential for new buildings, and ultimately lead to the implementation of similar technological improvements in new buildings.

INTRODUCTION

A great deal of new technology is available for buildings. The labels "smart buildings" and "intelligent buildings" have been around for years. Unfortunately, this wealth of new technology for buildings exists in pieces and as products from many different companies, and virtually no newly constructed building utilizes a significant amount of this new technology. The operation of most buildings constructed today is essentially identical to that of the buildings of the 1970s. Even though new materials, design and construction methods, and new ASHRAE building codes have made major improvements in new buildings, these buildings still look and operate much as they did twenty years ago. While most new buildings do have new technology in the form of new equipment and better insulation, there is little new technology for the building occupants to see and use.

In contrast, every new automobile—regardless of its price—is filled with new technology compared to the automobile of the 1970s. A new car typically comes with eleven separate computers, has around thirty-seven sensors, and provides about twenty electronic display and control functions. It does this for as little as $20,000, and the new car information and control system commonly requires little or no maintenance or repair for a period of three to five years. This technology is often visible, can be used by the driver and passengers, is generally standard on new cars, and is inexpensive and reliable. There is much fancier technology available if you want to pay for it, but the majority of new automotive technology is found on every new car.

With all this new technology, today's cars are much more reliable and have significantly reduced maintenance requirements. In the 1970s, an automobile needed a tune-up every 10,000 miles. Today, a typical new car does not need a tune-up for 100,000 miles. Older cars needed new brakes about every 20,000 miles. Now it's every 50,000 miles. One of the authors bought a new minivan in 1998 and did not need to take it back to the dealer for any service for 40,000 miles! The vehicle had several oil changes in that period, but no mechanical or electrical work had to be performed.

In comparison, our buildings need maintenance people from the moment we start using them. We're not talking about janitorial work, but about maintenance of lights, air conditioners, switches, controls, doors, and windows. This is like the old days with our cars when we started making a list of things to be fixed as soon as we drove the car off the dealer's lot. Why can't a new building operate for six months, a year, or even several years without needing any maintenance? Our cars do.

What is the potential for using reliable, comprehensive, integrated, and inexpensive components in our new buildings to create a transparent and efficient information and control system? And what should we do in terms of buying new buildings? Clearly, progress in adapting and implementing technology for new buildings has a long way to go. Nonetheless, we should demand more technology—a lot more. Technological improvements should be standard features that come with every new building without question, rather than options that add significant cost to the building. The only question should be where to draw the line between standard features and additional new technology that we will pay extra for.

FEATURES OF AUTOMOBILES THAT WE COULD USE IN BUILDINGS

Individual Control Systems

One of the most noticeable features of new automobile technology is how it provides the driver and often the passengers with individual control systems. Compared to a building, a new car has far more sensors, controls, and displays for a much smaller space. There are individually controllable air supplies for the driver and the front passenger. Large vehicles often have air controls for the rear seat passengers too. Temperature ranges for heating or air conditioning are individually controllable, often for the front passenger as well as the driver. The air velocity is controllable with a multispeed fan. The outlet vents are easily reached and can be moved to direct the airflow onto or away from the person. The amount of outside air can be controlled by selecting fresh air or recirculation. Some lights, such as headlights and interior dome lights, are activated by sensors. Other lights are individually controllable. The driver or the passenger can turn on selected interior lights, can often dim these lights, and can direct the light to the area where it is needed. The moon roof can be opened or closed by the driver or front passenger. Both front seats are individually adjustable for horizontal position, height, tilt, and back support; many are heated, too. In addition, in some cars, these individual settings or preferences for functions like HVAC and seat positions are provided through a memory setting tied to an electronic key.

Compare this technology to the control systems currently available in a common new building. A typical room in a new building may have a thermostat with a control setpoint and a temperature display at that location. It also usually has an unseen VAV control function, and in a few instances a humidistat with a setpoint control and a display of the relative humidity at that location. Lighting is controlled with a single light switch or possibly a single occupancy sensor for lighting. Otherwise, the occupants usually have no other sensors, controls, or displays in that room.

In addition to these personal comfort controls, the new car also has a large number of automatic control systems to optimize and control its own operation. Engine control systems insure fuel efficiency and reduce air pollutants from the combustion process. Sensors for inlet air temperature and relative humidity allow optimum fuel flow control and optimum combustion. System computer modules also control the ABS, transmission, cruise control, and body controller.

Display Systems

New cars tell the owner about much of the maintenance and repair that needs to be done, and certainly notify the driver whenever one of the major systems is in need of attention. A new car has sensors that report tire pressure, unclosed doors, lights or other controls left on, unfastened seat belts, brake fluid status, and many other operational features related to the safety of the car and the occupants. Even a cursory comparison shows that our new buildings lag far behind the present use of technology in new cars.

Much of the information on car maintenance and safety is aimed at the driver. What comparable information does a building operator get about maintenance needs of the building or the various rooms in a building? Things that would be helpful to know include whether the air handling system filters are dirty, whether the refrigerant is at the proper level, whether sensors are working properly, whether lights are burned out, or whether the doors have been left open.

The present system in buildings is essentially a manual system. Filters are checked by maintenance personnel on a time schedule. Maintenance workers often depend on "human" sensors to notify them of burned-out lights, improperly functioning photosensors, or temperature problems in individual rooms.

Options

New cars have options, and new buildings have options—but these mean very different things. An option for a new car is an item or function that is already available and can be installed on the car, but at extra cost. For a building, an option is an item or function that an owner wants to add at extra cost, but expensive additional design, engineering integration, and testing work must usually be performed before it can be installed and operated.

Table 1 below summarizes many of the sensor control and display functions of new cars, and provides a model for desired technology in new buildings.

Table 1.
Sensor, Control and Display Comparison for Cars and Buildings

S=Sensor C=Control DI=Display
D=Driver FP=Front Passenger RP=Rear Passengers
CBO=Controllable by Occupant NCBO=Not CBO

Function	Cars			Buildings	
	All	Mid-cost	Luxury	All	Some
I. Comfort and convenience					
A. Climate Control (HVAC)				Yes	
1. Zone of Control					
Single Zone	D	D	D	Few	
Dual Zone		D, FP	D, FP	Very Few	
Multi-Zone			D, FP, RP	Most	Individual Zone, CBO
2. Temperature				Yes	
Lever setting (C, DI)	D	D, FP	D, FP	Some	
Thermostat (S, C, DI)	–	D, FP	D, FP	1 per zone	Individual Zone, CBO
3. Air Supply					
Directional Vents (C, DI)	D, FP	D, FP,	D, FP, RP	Partial	
		RP			
Multi-Speed Fan (C, DI)	D	D, FP	D, FP, RP	No	
Ventilation (S, C, DI)	D	D, FP	D, FP	Yes, NCBO	
Recirculation (C, DI)	D	D	D	Yes, NCBO	
4. Humidity (S, C)	–	–	Yes	Some, NCBO	Yes, CBO
5. Air Quality (S, C)	–	–	Yes	Yes, NCBO	Yes, On/Off
(CO, NO_2)					
6. Advanced Features					
Reheat Operation			Some	Most, NCBO	Yes, CBO
Window Fog Control			Some	No	
Air Filters			Some	Yes	
Sun Sensors			Some	No	
B. Seating BT=Back Tilt					
1. Basic – Mech or Elec (C)	D,	D, FP	D, FP, RP	Yes	–
2. Horiz Position + Back Tilt (BT)	FP		(BT)		
3. Six-Way (C)	–	D, FP	D, FP		Yes
4. Back Support (C)	–	D, FP	D, FP		Yes
5. Heated (C)	–	D	D, FP		No
6. Memory Function (C)		D	D, FP	No	No
C. Visual (Inside Lighting)					
1. Dome Light (C)	Yes	Yes	Yes	Yes	
With Occupancy Sensor (S,C)	Yes	Yes	Yes	No	Yes
Delayed Dimming (S, C)	No	Yes	Yes	No	No
2. Overhead/Task (C)	No	Yes	Yes	Some	Yes
Directional (C)				Few	Yes
3. General					
Door, Glove Box (S, C)	Yes	Yes	Yes	No	?
Visor, Map (C)	No	Yes	Yes	No	?
D. Windows					
Power Windows	No	Yes	Yes	No	
Power Sunroof	No	Yes	Yes	No	Yes
II. Normal Operation					
A. Speedometer (S, D)	Yes	Yes	Yes	No	*
Cruise Control (S, C, DI)	No	Yes	Yes	No	*
B. Odometer (S, C, DI)	Yes	Yes	Yes	No	*
C. Tachometer (S, DI)	No	Yes	Yes	No	*
D. Fuel (S, DI)	Yes	Yes	Yes	No	*

Table 1. (*Continued*)

III.Safety and Maintenance					
A. Engine					
1. Engine Control Module (S, C)	Yes	Yes	Yes		
Temperature, Oil Pressure, Check Engine					
Status Light (S, DI)	Yes	Yes	Yes		
Gauges (S, DI)	No	Yes	Yes		
B. Auxiliary Systems					
1. Electrical					
Generator (Charge)					
Status Light (S, DI)	Yes	Yes	Yes		
Voltage Gauge (S, DI)	No	Yes	Yes		
Lights					
Headlights (C)	Yes	Yes	Yes		
Backup Lights	Yes	Yes	Yes		
2. Brakes					
ABS (S,C)	No	Yes	Yes		
Status Light (S, DI)	Yes	Yes	Yes		
Brake Light Out (S, DI)	No	No	Yes		
3. Others					
Seat Belt (S, DI)	Yes	Yes	Yes		
Turn Signals On (S, DI)	No	Yes	Yes		
Headlights On (S, DI)	No	Yes	Yes		
Low WW Fluid (S, DI)	No	Yes	Yes		
Door Not Closed (S, DI)	No	Yes	Yes		
Exterior Temp (S, DI)	No	Yes	Yes		
IV. Pleasure & Entertainment					
A. Audio System					
Radio	Yes	Yes	Yes		
Satellite Radio			YES		
CD Player	No	Yes	Yes		
B. Video System					
TV	No	No	Yes		
VCR, DVD	No	No	Yes		
C. Computer	No	No	Some		
Internet	No	No	Option		
D. Communications					
Cell phone	No	Yes	Yes		
Internet	No	No	Option		
V. Advanced Systems					
A. Navigation Systems	No	No	Yes		
B. Collision Avoidance Systems	No	No	Option		
C. Rain Sensing Wipers	No	No	Option		
D. DewPoint & Glass Temp Sensors	No	No	Option		
E. Voice Commands	No	No	Option		

HOW DID THE AUTOMOTIVE INDUSTRY DO THIS?

We must understand how new automobiles can have so much new technology at such a low cost, and why they are so reliable in order to know how to utilize similar innovations in the building industry.

Engineering Analysis and Design

A significant amount of engineering analysis and design goes into both the structural and operational features of a new car. In addition, significant engineering analysis and design also goes into the manufacturing and production processes for assembling the new cars. A major benefit of this approach is that the car's entire system and subsystems, as well as each of the car's components, are carefully engineered. For example, the electrical power consumption of the components and systems in a new car are carefully analyzed, built, and selected to make sure that the total power demand is not greater than the capacity of the electrical power supply system, i.e., the 12-volt battery. Thus, with cars, the need for energy efficient electrical systems is built in from the start.

When a building is designed, the electrical load is specified first, and then a power supply system is specified that is big enough to handle the load of the building. Little or no thought is given to minimizing the electrical load itself because there are generally no constraints on the amount of power a utility will supply to the building.

Overall Quality Control Programs

A new car is reliable because a significant amount of engineering goes into both the car design and its manufacturing process. Quality and quality control start with the engineering design, and are strongly emphasized throughout the manufacturing and assembly of the car. Individual components are designed and made with quality and reliability as major goals. Subsystems and final systems –including the entire car—are similarly produced. Ordinary and accelerated life testing are conducted on the car's components, subsystems, and systems. These extensive tests include the effects of temperature, moisture, mechanical, and thermal stress, and other factors. As a result, most of the car's components and systems will last at least three years, or 36,000 miles. Warranties on some new cars are now available for seven years or 70,000 miles.

Quality control and warranties in building design and construction are very different. The auto manufacturer provides the warranty for the entire vehicle (with the possible exception of the tires); the systems in new buildings are likely to be under several different warranties. The HVAC manufacturer covers the HVAC system; the flooring manufacturer guarantees the carpet/flooring; the plumbing manufacturer guarantees the plumbing fixtures; etc. There is usually no centralized quality control or warranty for a new building as there is with cars.

Widespread Use of Microprocessors and Computers

Much of the technology and operational features of our new cars comes from the use of microprocessors and microcomputers. A new car may have as many as 50 separate microprocessors and 11 major computer-based systems. Some new luxury cars have up to 90 microprocessors. It is often said that a new car has more computer power in it than our first manned space capsule. Computer-based systems are found in the system modules for new cars, and account for much of the engine performance, reduced emissions, sophisticated diagnostics, and many of our comfort and convenience features. The engine control unit (ECU) is the most powerful computer in the car, and it has the demanding job of controlling fuel economy, emissions from the engine and the catalytic converter, and determining optimum ignition timing and fuel injection parameters. These computers, microprocessors, and system modules greatly simplify the diagnostic job of finding problems with the car and providing information on what kind of repair or replacement work is needed.

While a large new building with a sophisticated BAS, or building automation system, may well contain 50 or more microprocessors, this does not match the new car in terms of having equal computing power per room or per group of rooms with 2 to 4 occupants. The rooms and offices in our buildings do not have monitoring and self-diagnostic features. They could, because the technology, equipment, and systems exist, but they are not supplied as a standard item, and they are not available in the same way that options are available on new cars.

System Modules

As discussed above, the system modules are where the computer-based systems reside in new cars. These system modules are highly complex, and highly important systems in new cars. Many of our highly desirable performance and comfort features are provided by system modules. Typical system modules in a new car are: the engine control unit, the instrument panel module, the climate control module, the transmission control module, the power distribution box module, the airbag module, the driver's door module, the ABS module, the body controller module, and the cruise control module. These are the system modules on every basic car. Additional system modules are options for lower priced cars, or standard features of higher priced cars. These include navigation control modules, entertainment system modules, advanced comfort control modules and communication control modules for computers, cell phones and internet access.

Communications buses

Using standardized communications buses with these system modules makes both designing and building new cars much easier than it was in the old days. Two major services must be accessible to every area of a new car—electric power and the communications bus. All of a car's system modules must be able to communicate with each other, receive signals from most of the sensors in the car, and send signals to the control components, systems, and actuators. Using a communications bus greatly simplifies the wiring, reduces the number of data sensors, and implements additional features at very little additional cost. Without the communications bus, the job of wiring a car during the assembly operation would simply be too labor and time consuming to have a reasonably priced product. Also, the speed of communications is so important now that only a digital bus has the speed and capacity to handle the data collection and data transfer load for a new car.

The communications bus and the system modules work together to make the design and building of the car much easier. Information is sent over the communications bus in a standard communications protocol—usually the SAE J1850 standard, or the controller-area network (CAN) standard, although some manufacturers are using FlexRay, which is a faster and more sophisticated communications bus. Data are sent in packets with a standard structure—a label and some data. For example, an information packet with speed for the label and 52.5 for the speed data in MPH is picked up by the instrument control module, which refreshes the indication on the speedometer with this new data. The standard communications bus makes the design of the various system modules much more straightforward. In addition, the sensors in the car only need to send packets of data to the communications bus; therefore, the car maker does not have to deal with the problem of a particular sensor putting out a strange voltage or current signal that must be converted somewhere into a true physical parameter of the car's operation. In our example, the alternative is to tell the instrument panel module maker that the signal for speed was going to be a 4-20 mA current loop value, and that 10 mA was equivalent to 40 MPH.

The use of the standardized communications bus also makes it easy to use outside suppliers and sources for many of the components and systems in a new car. The car makers do not have to worry about how a specific sensor or module works internally; they only need to know that the data will be transmitted in a known, standardized manner, and that they will have a known, standardized structure. Much of the success with using modern technology in cars, and much of the reliability of that technology, comes from using the simplified approach of a standardized communications bus.

This same type of technology is essentially available for our new buildings. BACnet, LONWorks, and TCP/IP are the most common standard communication protocols. TCP/IP may be the ultimate answer, but another level of standardization is also needed to insure that data that comes across TCP/IP means the same thing to each different piece of equipment in a facility. Most buildings are wired for a local area network (LAN) with either co-axial cable or fiber optic cable. Thus, the hardware and software are available, but there is no organization responsible for requiring or enforcing the standardized interconnection of all of the building components, subsystems, and systems like the automakers have. Without a standardized communications bus running through the entire facility—together with accessible electric power—buildings will never have the kind of technology that cars have, and we will never have the cost benefit or the reliability that this kind of technology can bring to our buildings.

Smart Sensors

Most basic automobile sensors that were used in the past to read continuous physical parameters such as temperatures, pressures, flows, and levels operated on the principle of producing a voltage or current output proportional to the real value of the parameter. The output of these sensors was almost always nonlinear, and also varied with the temperature or other physical parameters. This resulted in poor measurements, or required using more equipment and processing power to correct the sensor reading for the nonlinearity and to provide temperature compensation curves to get accurate readings. Today, smart sensors are used to provide these functions and to output data to a microprocessor or system module. The sensor output is input to the microprocessor, and the sensor reading is digitized, corrected, temperature compensated, and sent out over the standardized communications bus.

These smart sensors interface directly to the communications bus, and provide fast and accurate measurements. Since the sensor package contains a microprocessor, much of the load is removed from the system module that the smart sensor is supporting. Designed and built as an integrated package, the smart sensor fulfills its mission reliably with a low initial cost.

The sensors for buildings are expensive, and many of them are not very reliable. They are certainly not reliable in comparison to those in cars. In particular, the relative humidity sensors and CO_2 sensors are notoriously unreliable, and require frequent cleaning, calibration, and general maintenance. That level of performance would be unacceptable for these sensors in a car. Why shouldn't the sensors in buildings work reliably for a period of three to five years before they need any significant attention?

Wiring Harnesses and Standard Connectors

The use of pre-assembled wiring harnesses and standard connectors has made the task of wiring up a new car much easier. It is important to use stranded, not solid, wire cable. Each length of stranded wire consists of a twisted bundle of very thin thread-like wires. Solid wire, on the other hand, is a single thick wire segment. The advantage of stranded wire is that it is much more flexible than solid wire, and also less susceptible to breakage. One thread of a stranded wire can break without affecting the performance of the connection, but if a solid wire breaks the connection is lost. Also, if there is one weak link in the reliable performance of any electrical or electronic system, it is the connectors. With this in mind, the importance of carefully and correctly built standardized connectors cannot be overemphasized.

Use of Skilled Assembly Workers

The auto industry has a large supply of skilled workers at its design, engineering, and assembly operations. These skilled workers receive training in their specific jobs as well as training in quality control and process improvement techniques. Many of the manufacturing and design improvements in new cars have come from the production workers themselves. In addition, skilled workers have made a great improvement in the overall reliability and quality of the new cars. Autoworkers are usually paid more than those working in other industries or services.

Problems with the construction of new buildings often come from the use of workers with minimal or insufficient skills for the job. Finding skilled workers may be difficult, and is certainly expensive. The nature of building construction often impedes the retention of skilled workers. As a result, there may not be a large pool of highly qualified building construction workers available when a particular building is being built.

One of the most common problems in building structures is the roof, which is the subject of the greatest number of lawsuits in building construction. Most roofs leak, and leak from the day the building is occupied. Roof leaks are the result of poor installation and construction rather than problems with roofing technology and materials. When a roof leaks, water leaks into the walls and may not be noticed until mildew and rot are visible; by then the building may be significantly damaged. Mold, mildew, and IAQ problems in the building will require more time and money to fix. Using sensors in new buildings to identify roof and wall leaks when they occur is a critical application of automotive-type technology in our new buildings. New cars use infrared reflectance sensors to identify rainfall on windshields and automatically start up the windshield wipers. These sensors, or other types of moisture sensors, if installed throughout our new buildings, would quickly identify leaks and moisture buildup and alert building operational people to this serious problem.

Poor workmanship can cause many other problems in buildings. Even the HVAC system can be affected since random testing has shown that many air conditioning systems are installed with an improper charge of refrigerant. In economic terms, the problem of workers with insufficient skills and quality training results in the need to commission buildings to check and see if the building components and systems work as they should (see discussion on commissioning below). This expense is clearly attributable to the lack of adequate engineering, the lack of quality control measures, and especially lack of highly trained workers.

WHY DOESN'T NEW BUILDING CONSTRUCTION INCLUDE MORE NEW TECHNOLOGY AS STANDARD EQUIPMENT AND SYSTEMS?

Automobiles are built according to a standard plan; building architects, on the other hand, reinvent the wheel each time they design another building. This lack of standardization in buildings impedes the introduction of new technology in new building construction. Other factors also influence this difference in approach.

Unlike new cars, most new buildings are site built, and are built

to "cookie cutter" specifications that emphasize lowest first cost of construction. Even "custom built" buildings are held hostage to the lowest first cost syndrome. Thousands of different construction companies build residential and commercial buildings. Hundreds of different companies build fairly large commercial buildings. These companies range in size from small businesses to major architectural and engineering firms and major construction firms. It is extremely difficult to implement standards of technology when this many individual companies are involved.

The fact that most buildings are site-built impedes the assembly line and systems approach to installing new technology that is used in the auto business. One area of building construction that is immediately amenable to the assembly line approach of the car makers is the construction of prefabricated or modular buildings. This manufacturing sector could easily incorporate knowledge from the automotive assembly sector to produce buildings with the same level of technology and reliability as new cars. The engineering and quality control functions are much more cost effective in this sector. This sector could easily use more computers, more microprocessors, more system modules, more smart sensors, and a standardized communications bus.

Cars are constructed in a factory assembly line and moved to their ultimate market and user. The factory environment makes it easier to train workers in installing the equipment in new cars as well as training them in quality control procedures. Buildings, however, are constructed at the point of use. Construction workers may work for a long time on a single building doing all types of work. Their training is not likely to be technology specific. Auto assembly workers typically specialize in some part of the assembly process, and therefore can be trained on this more limited work task. In addition, they become quite knowledgeable on this part of the assembly operation, and soon become able to add value to the company by suggesting improved methods of designing and constructing components and systems that they assemble. Quality control is more easily stressed in this environment, and many of the workers actually see the final result of their work drive off the assembly line, which serves to positively reinforce the need for a high skill level and the need to perform high quality work. In fact, these workers often own and drive cars produced by the company they work for. Few of these workers will willingly accept poor quality parts, components, systems, and assembly procedures as a result of their skill and training level.

More new cars are sold each year than new buildings, so there is a larger market for the technology and the price can be reduced due to bulk purchase of the equipment. This is certainly true at face value, but when the scale of use of technology for buildings is considered, the numerical superiority of the cars goes away. If we consider that the unit of interest in buildings is rooms, and that we are interested in having the same technology level in each room that we have in a car, we now have a very different perspective. There may very well be more rooms than cars built each year. Thus, the comparison of a room to the car, rather than a building to a car, will lead to a much greater economy of scale for new building construction, and should provide a strong economic incentive to move in this direction for buildings.

Cars have a shorter lifetime than buildings, so new technology can be introduced faster, and the customers can develop a faster appreciation for what it does. Cars do have a shorter lifetime than buildings, but most buildings end up being refurbished, or equipment and systems retrofitted, so there is still a lot of opportunity to use new technology in older buildings. Sensors, controls, system modules, and many of the other features of new car technology can be added to older buildings when they are needed. In general, the most cost effective way to build an energy efficient and functionally superior building is to do it right the first time, rather than retrofit it later. However, new equipment, and especially new information technology, can be added to rooms and to the entire building. It would have been easier and cheaper to install coaxial or fiber optic cable in a building when it was built, but we have still managed to find a way to get LAN cable and connections into our rooms and offices so we could network our PCs.

Purchasers of new cars are influenced by features they have seen on other cars. Therefore, consumer demand is important in increasing the marketability of new technology options. This is one reason we need to start installing some of this new technology in buildings. Once building owners, managers, and occupants start seeing what has been done in other buildings, and how much more enjoyable and productive it is to work in buildings with this advanced technology, they will start to demand more technology as a result. It is somewhat amazing that the people who drive cars with all this new technology will go happily to work in buildings that do not come close to providing similar comfort and operational features of automobile technology!

WHAT DOES THE BUILDING CONSTRUCTION INDUSTRY NEED TO DO?

Establish an integrated design-and-build engineering and management structure. The amount of engineering work that goes into a new building must increase significantly. The building structure should be designed with high technology use in mind, and should utilize new technology to deliver the performance and comfort features that we want in our new buildings. In addition, quality control and reliability should be designed and engineered into the building from the start of the project. Quality management techniques should be employed so the building is actually constructed to provide the quality and reliability features that we expect.

Build more modular buildings. The solutions to providing greater use of technology in new buildings and providing quality and reliable buildings are much easier for modular buildings with significant pre-site construction performed in a factory or controlled environment. High-tech components and equipment can be installed more easily in prefabricated and modular buildings within a controlled environment and with highly skilled and quality control trained workers.

Impose standards on equipment and system suppliers. Most major construction companies are already in a position to do this. They have the financial leverage to specify components and equipment that meet their exact requirements. The residential manufactured housing sector in particular could do this quite easily. The federal sector, states, and large companies also have excellent opportunities to set these standards. One of the most important standards is to require a standardized communications bus in a building with all sensors and controls interfacing directly with that communications bus.

Use equipment and system modules. This approach has facilitated the use of most new technology in new cars at a reasonable cost with extremely good reliability. However, the standardized communications bus has made the most dramatic difference. By using a standardized communications bus and system modules, car technology could be transferred to buildings relatively easily. Individual HVAC modules for occupants, individual lighting modules, other comfort modules such as for seating, and building operation and maintenance modules could all be used to greatly increase the performance and reliability of buildings and yet allow us to build them at reasonable costs. Again, certain sectors such as the residential manufactured housing sector, the hotel/motel sector, and many office buildings could easily adopt this approach.

Are codes, standards or legislation required to increase the use of new technology in buildings? Building codes and standards have been responsible for many of the improvements in standard buildings. With minimum equipment efficiencies, minimum thermal transfer levels, and minimum structural standards in place, companies that construct buildings must meet these minimum standards—regardless of whether it increases the first cost of the building. Without minimum standards such as the ASHRAE 90.1 standard, many buildings would still have inferior equipment and poor insulation, because it was cheaper to put in initially. The standards for utilizing new technology could be set voluntarily by large companies and big purchasers of buildings like the federal sector, states, schools, and the hotel/motel sector. Certainly the auto industry has incorporated many of the new technological features without needing government intervention.

Integrate new building technology with the desktop computers and BAS (building automation systems) that are already being installed in new buildings. The types of smart sensors, system modules, and standardized communications buses that the authors have been recommending for use in new buildings should be considered an integral part of the overall building automation system. All of these components, systems, and equipment must work together seamlessly to provide the expected level of performance and comfort, and all the desktop computers should be tied in to these systems through a local area network.

The desktop computer could be the equivalent of the car dashboard or instrument panel, and it should be the personal interface to an expanded BAS. It could tell what the space temperature is and how much ventilation is being provided. It should allow occupants to set their personal preferences for lighting levels, seat positions, window or skylight openings, etc. It should also let them enter new desired values of these space parameters.

BENEFITS OF STANDARDIZED COMMISSIONING OF BUILDINGS

Commissioning a building is defined in ASHRAE Guideline 1—1996 as: The processes of ensuring that building systems are designed, installed, functionally tested over a full range, and capable of being operated and maintained to perform in conformity with the design intent (meaning the design requirements of the building). Commissioning starts with planning, and includes design, construction, start-up, acceptance and training, and can be applied throughout the life of the building.

Commissioning a building involves inspection, testing, measurement, and verification of all building functions and operations. It is expensive and time consuming, but it is necessary to insure that all building systems and functions operate according to the original design intent of the building. Commissioning studies on new buildings routinely find problems such as: control switches wired backwards; valves installed backwards; control setpoints incorrectly entered; time schedules entered incorrectly; bypass valves permanently open; ventilation fans wired permanently on; simultaneous heating and cooling occurring; building pressurization actually negative; incorrect lighting ballasts installed; pumps running backwards; variable speed drives bypassed; hot and cold water lines connected backwards; and control dampers permanently fully open. And this is only a short list!

The process of commissioning a building constructed like a new car, and using the new car-type technology, would be far quicker and simpler, as well as much less expensive. The use of standardized components, subsystems, and systems could actually eliminate the need to check and test these items each time they are used in a new building. A factory or laboratory, standardized commissioning test could well determine their acceptability with a one-time procedure. The use of a standardized communications bus would dramatically shorten the time and effort of on-site testing of the building components, subsystems, and systems. Data from all sensors and controls would be accessible on the communications bus, and would allow a significant amount of automated testing of basic functions and complex control actions and responses in the building. A commissioning module could also be added to the building systems, and would further automate and speed up the commissioning process. This commissioning module would remain as a permanent building system, and not only aid in the initial commissioning process, but also the re-commissioning process, and the continuous commissioning process.

Presently, the cost of commissioning a new building is around 2 to 5 percent of the original cost of construction. The use of standardized commissioning tests, and the use of a commissioning module, would greatly reduce this cost. Although commissioning is a cost effective process—usually having a payback time of one to two years—many building owners do not want to spend the additional money for the commissioning effort. A prevailing attitude is "I have already paid to have the job done correctly. Why should I have to be the one to pay to check to see that it has actually been done correctly?" This is a difficult attitude to overcome, and it is often a hard sell to convince new building owners that they will actually come out ahead by paying to verify that their building does work as it was designed to work.

One final note on commissioning is from one of the author's energy audit experiences. Many problems found when conducting audits of existing buildings are clearly ones where the problem has been there since the building was constructed. For example, in the audit of a newspaper publishing company it was found that the cost of air conditioning was excessive. Further checking showed that the heating coil and the cooling coil of the major air handling unit were both active during the hottest part of the summer. The control specifications specifically called for that simultaneous heating and then cooling! Once that original problem was corrected, not only did the air conditioning bill go down dramatically, but the building occupants reported that they thought the air conditioning system was working much better since they were much more comfortable.

DO NEW BUILDINGS NEED "DASHBOARDS?"

The dashboard and instrument panel is the heart of the driver–car interface. Status information on the car's operation is presented there in easily understood form. A similar feature in a new building would make sense. Not the complex HMI or GUI from a BAS, but a simplified display for average building occupants, and maybe even one for the building engineer or maintenance supervisor. Each floor of a building could have a "dashboard" type of display. It could be located in a visible place, and occupants could see the status of energy use in terms of peak cost or off-peak cost, daily use of kWh and therms of gas. They could also see temperature and RH conditions at a glance, and could get red light/green light indicators for energy use and maintenance actions. Several of these "dashboards" could be provided to the operation and maintenance staff. These simplified "dashboard" type of displays could also be available on the PCs of the occupants and operating personnel. Cars provide a powerful model to use in many building technology applications.

ADDITIONAL CONSIDERATIONS

The increasing sophistication of information technology coupled with its rapidly falling costs is making possible “smarter” buildings with increased capabilities for customizing the workplace to the needs of the workers and their employers. Smarter buildings cannot happen without extensive use of the basic building blocks of sensors, actuators, and controllers. Many more are needed in new buildings. The economics of replacing existing structures with wholly new ones is daunting, so new technologies are especially desirable if they can be retrofitted into existing spaces, replacing existing infrastructures to support change.

Research opportunities exist at the interface of how people work, where people work, and how they can be made as effective in buildings as they have become in their cars. Much of the research agenda needs to develop a more quantitative evaluation of productivity gains brought about by innovations in information and control technologies in new buildings. We not only need to focus on general purpose commercial buildings, but consider special purpose buildings, such as schools or hospitals. They are significantly affected by the new information technologies, including cable TV and computers. These research needs in commercial buildings are certainly worthy of further investigation and continued development and application of new sensors, actuators, and controllers.

CONCLUSION

New buildings have not kept up with technological advances, especially when compared to automobiles. All we need to do is make one trip in a new car, and then make one visit to a new building to see this for ourselves. Comfort levels, safety levels, reliability levels, quality control levels, and automation levels are all much higher in new cars than in buildings. The imagination and creativity that goes into new car technology and manufacture should be harnessed for our new buildings as well. We really do need to start building our new buildings like we build our new cars.

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