Factors Affecting the Acceptance and Successful Implementation of Building Automation Systems

John D. Petze, Teletrol Systems, Inc.

Advances in technology have reduced the cost of building automation systems to be comparable in price to conventional (pneumatic and electric), control systems. With the increased efficiency provided by automation systems, they would seem to be a natural choice for all facilities. A number of factors affect acceptance.

The way that HVAC systems, energy and maintenance costs are viewed by management is an important factor affecting the acceptance of building automation. In manufacturing industries for example, automation is well accepted as a means of improving production efficiency, quality, and profitability. Because it has a clearly measurable effect on the process that produces the revenue of the business, it is easy to analyze its benefits. Viewing occupancy and tenant satisfaction as the product of the facilities management process, can help owners improve the overall performance of their facilities.

The familiarity of decision makers with the operation of mechanical systems can also affect acceptance. In process industries decision makers are typically familiar with the processes that produce the revenue of the business. Property managers, however, often do not have first-hand knowledge of mechanical systems. The result can be a lack of understanding of the role of mechanical and control systems. Accounting practices are another factor. Practices that do not take into consideration maintenance, energy, and other life cycle costs will make it more difficult to analyze the value of an automation system. Training of operators and the execution of the bidding process also have important affects.

INTRODUCTION

Advances in microprocessor technology (including greater integration of logic functions on a single chip and higher manufacturing volumes), have reduced the cost of building automation systems (BAS) to the point where they are comparable in installed cost to conventional (pneumatic and electric) control systems. With the promise of more efficient performance of mechanical systems, reduced maintenance and better information relating to the operation of the facility as a whole, they would seem to be a natural choice for all facilities. What factors prevent this from happening?

The way that HVAC systems, energy, and maintenance costs are viewed by management is the underlying factor affecting the acceptance of building automation systems. In manufacturing industries for example, automation is well accepted as a means of improving production efficiency, product quality, and profitability. Because automation has a clearly measurable effect on the process that produces the revenue of the business, management can see its benefits and analyze its value fairly easily.

This paper will look at a number of issues relating to facilities management practices and their potential effects on the acceptance of BAS.

VIEWING FACILITIES MANAGEMENT FROM A NEW PERSPECTIVE

Automation has been well-accepted in process industries because it can be shown to have a direct, quantifiable, impact on the performance of the process; better control of the process yields a better product at a lower cost. In today's sophisticated and highly competitive buildings market it may be helpful to apply a process-oriented viewpoint to facilities management. Viewing occupancy and tenant satisfaction as the product produced by the facilities management process can help owners and managers improve the overall performance of their facilities.

In a commercial office building the process is occupancy. Tenants pay money in return for a space that allows them to effectively carry out their revenue-producing business. In a tenant occupied building, if the environment is continually unsuitable, the tenant leaves and revenue is lost by the owner. In the case of a commercial office building, ''production costs'' are the expenditures for the utilities necessary to maintain the building environment and the wages of the facilities staff. Controlling these costs in relation to the revenue received from ''customers'' determines the owner's return on investment.

By looking at tenant satisfaction as the output of ''the process,'' building managers may be better able to make decisions that will optimize the performance of their facilities, improve occupant satisfaction through better management of Indoor Environmental Quality (IEQ) factors, and thereby enhance the overall profitability of the facility.

This viewpoint of facilities management is all the more important today because new techniques make it possible to measure the factors that affect tenant satisfaction in more quantifiable terms than ever before. Factors that affect overall IEQ include: temperature, humidity, CO2 level, (and the presence of other airborne contaminants), lighting, and noise levels can all be monitored in real time by the BAS. Monitoring these variables allows us to better evaluate expenditures related to modifying HVAC equipment, control systems, and the building structure itself.

INVOLVEMENT BY THE TRUE DECISION MAKERS

In most manufacturing businesses, the key decision makers are intimately familiar with the production processes that produce the revenue for their business. Often they have had first-hand experience with these processes throughout their careers. Property managers, however, often do not have first-hand knowledge of mechanical systems and their inner workings. Often the true decision makers in property-related businesses do not have a technical background, but a financial background. The result is that the mechanical systems that maintain the indoor environment, and the control systems associated with them, are sometimes viewed as an expense without an appropriate understanding of their role and benefits, and the detrimental results that can occur if they do not operate properly. If, for example, the management staff of a tenant could see how poor air quality was contributing to high absenteeism rates among their employees, they would most likely raise strong objections to the manager of the facility. If the facility manager or owner could see the direct correlation between the poor air quality and the fact that this tenant would not renew his lease, they would have strong motivation to respond proactively, i.e., identify the source of the problem, correct the problem, and monitor the effectiveness of corrective measures over time to insure success. Simply put, decision makers need to see the key role that mechanical and control systems play in the overall financial performance of their facilities. One method of providing useful information to managers is to use the data logging and reporting capability of the BAS to create reports that show zone temperature trends, energy consumption vs. environmental conditions such as degree days, or energy consumption vs. loading factors such as occupancy.

Another way of addressing this situation is to expose key decision makers to information that shows how automation systems have been successful, both financially and tactically, in other similar applications. Case studies are a useful tool for doing this, especially when they focus on the financial concerns of the building owner, how those concerns were addressed, and the final financial results of the project. Technically oriented case studies can also be useful when presenting the BAS concept to the facilities operation personnel whose interests are related more to mechanical systems.

While most manufacturers publish case studies to support their sales effort, other good (and potentially less biased) sources of case studies are the major trade journals. Another good source of information on the benefits of BAS are the yearly project awards given out by ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers), AEE (Association of Energy Engineers), and Energy Users News.

New challenges and changing perspectives

Beyond anything that can be addressed with brief exposure to case studies or similar information, long term education is the only solution. The real issue is, again, the viewpoint of managers in relation to the mechanical systems in their buildings. This is often a fundamental part of the culture of a management company and can take time to change. Today, a number of new factors are having a significant affect on the attitudes and understanding of facility owners and managers. Legislative issues such as the phaseout of CFC's, and recent litigation and media focus surrounding ''Sick Building Syndrome'' and Indoor Air Quality are involving owners in a series issues which are directly related to HVAC equipment and BAS.

It has been shown that BAS technology can play a key role in addressing IAQ issues, by making it possible to continuously monitor and control the air quality of a facility. Air quality sensors are available which can be placed in individual rooms and in air ducts and be connected to building management systems. Continuous on-line sensing via a building management system can offer a number of important benefits:

- Improved Comfort Results In Improved Productivity. An independent studies by researchers at Renssenlaer Polytechnic Institute, and reported in ASHRAE Journal, July 1992, has shown that proper environmental conditions have a direct and quantifiable impact on the bottom line and that the simple payback for addressing these problems is under two years. Productivity losses due to poor comfort can easily dwarf the costs associated with improving the operation of equipment systems.[i] And, polls show that indoor air quality is one of the most

important factors considered by building occupants and potential tenants.[ii]

In today's competitive markets it is essential to focus on the needs and desires of occupants. By adding indoor air quality monitoring and control it is possible to enhance the total environment of a facility.

- Data Logging—Air Quality Conditions Can Be Recorded and Logged. With a number of BAS this data can be directly imported into standard Windows™-based spreadsheet packages for analysis and reporting. Today this can be done without the need for any special software development efforts. This ''first step'' can give the building owner an understanding of the actual air quality conditions in a facility. Problem areas and operational trends can be identified. One of the most important benefits can be to identify the source of air quality problems. For example:

  - How good is the outside air? Is it better than the air inside the facility? Could poorly located intakes actually be introducing poor quality air into the facility?

  - Are components of the facility (carpets, finishes, etc.) creating air quality problems? Do certain areas of the facility, which contain certain types of furnishings or equipment, have different air quality conditions?

  - How do air quality conditions track occupancy of the facility? Does air quality get worse due to occupancy our does it get worse during unoccupied times when the HVAC systems are not operating? Should specific areas of the facility be tested for chemical contaminants by an industrial hygienist?

- Demand-based Control of Outside Air Intake. With online monitoring it is possible to intelligently adjust outside air intake rates in relation to actual air quality needs. The benefits of demand-based control of outside air can be two-fold: (1) it insures that air quality needs are met and (2) helps identify and eliminate situations where excess outside air is being supplied. The result can be improved air quality and reduced energy usage.[iii]

- A Proactive Approach Demonstrates Concern For Tenants. Adding air quality monitoring to facilities management activities can help assure existing and potential tenants about the quality of a facility and the owner's commitment to total facility management and tenant satisfaction.

These tenant-environment related issues are bringing a new set of values to many facility owners and managers, and are becoming an important part of their decision making process. At the same time they are expanding the understanding of the role of BAS and HVAC systems.

TRAINING OF FACILITY MANAGEMENT PERSONNEL

While virtually all experienced facilities engineers have some exposure or training in conventional controls, a far fewer number are experienced computer users. This is simply a result of the fact that computer technology is still new compared to conventional pneumatic and electric controls which have been around for over 60 years, and ''computer literacy'' is not universal among facility operators.

A lack of familiarity with computers can result in a fear factor, or simply distract an operator's attention from the operation of the overall facility, as they try to learn to deal with the computer and the details of a specific manufacturer's system. A fear of the unknown can, in turn, prevent an informed decision from being made when evaluating control system options, or in some cases create a predisposed bias against automation systems.

Consulting engineers are not immune either. With tremendous responsibility to look out for the interests of the building owners who hired them, they are often reluctant to embrace newer technologies. Building automation systems can fall into this category.

In both cases education is the solution. Facility owners should be concerned with the ongoing education of operators. The costs of training programs are easily offset by the enhanced performance of more knowledgeable operators.

Ongoing training to prevent the '' Library of Alexandria Syndrome[iv]''

Automation systems do not provide maximum benefit if they do not become a part of the daily routine of building management. The industry is rife with examples of systems that were once operational and then ignored, decommissioned, or ''overridden'' manually. If a project makes it through the installation and commissioning phase, and the operators receive adequate initial training, the next major obstacle to long term success of the system is the lack of continued training. Ongoing training is necessary for a number of reasons:

(1) *Turnover of operations personnel.* Is the same effort expended training new operators as was invested in the original operators? New operators may actually be in greater need of training because they are new to both the facility and the automation system. A success-

ful BAS project should include a plan for the training of new operations personnel.

(2) *The addition of new features and functions to the system as manufacturers offer new revisions and products.* Building automation technology is a work in progress. Today's systems offer important features that were not available even months ago. The good news is that more and more manufacturers are providing the ability to cost effectively upgrade their systems as new features become available. But, this is only a benefit if the owner is made aware of these new features, and can take advantage of them. Training is essential to make this happen.

(3) *Changes to the utilization and physical characteristics of the facility.* New tenants, refitting of tenant spaces, changes in utility rate structures (i.e., changes to demand rates or power factor rates)—all of these factors can create a situation where operational sequences and procedures previously in place must be changed. The management of the facility must keep in mind the fact that such changes may affect the automation system when planning them. The facilities team must be involved in the process in order to evaluate, and plan for, the necessary changes.

(4) *Expansion of the goals of the system.* Major benefits of automation systems can be gained after the initial installation, as building operators learn more about the operation of their facility, the capabilities of the automation system, the opportunities to utilize features to address operational needs, and become more comfortable with the system.

(5) *System optimization.* It is important to realize that there is no system that is perfectly adapted to a facility at the time of its initial design and installation. The successful automation system will provide the trained operator with countless opportunities to improve the facility's operation through modifications to the initial control sequences. These opportunities need to be exploited. Analysis of information collected via the data logging capabilities of BAS can, and should, be used to identify opportunities for enhancements in the operation of the facility.

INVOLVEMENT OF OPERATIONS STAFF IN THE DECISION MAKING PROCESS

One of the simplest, but most effective methods of optimizing the overall performance of a BAS is to insure that the facilities staff is directly involved in the decision making process. They should have the opportunity to contribute to the specification process and the definition of the scope of work. They should have the opportunity to interview potential vendors during the evaluation phase. Management should support their role in such a way that the vendor knows that the facilities staff is the final customer that must be satisfied. Unfortunately, this is often difficult, if not impossible, for many new construction projects where staffs have not even been selected at the time the system is designed.

In cases where the facilities staff is not supported in this way, and made an integral part of the decision making process, the vendor may feel they only need to satisfy the consulting engineer or a higher level contractor. If the facilities staff ends up being dissatisfied with the BAS, anger at the vendor can end up being directed at the system itself and the overall concept of a BAS. A spiral of poor attitude can result as the facilities staff uses the shortcomings of the system as ammunition to defend their resistance to making changes in the way that the facility is operated. The result can be a system that ''just never seems to work right'' and is considered an impediment to the process of running the building. The result for the owner is that he never receives maximum benefit from the investment. In response to the question ''what is the most important factor in installing a successful BAS?'' the answer is clearly ''involved, supportive operators.'' Involving them in the entire procurement and analysis process, and providing them with adequate training is one of the best ways to achieve this goal.

THE IMPACT OF ACCOUNTING PRACTICES

Another key factor in the acceptance of BAS can be found in the accounting practices used by firms that build, own and manage real estate assets. Practices that do not take into account maintenance costs, the affect of the BAS on energy usage, and other life cycle costs that are part of the total financial picture of such an investment, will make it more difficult to justify the purchase of an automation system.

The installation of a BAS represents a large capital expenditure. As such it will be analyzed like other similar expenditures. Does the facility analyze these types of capital expenditures based on: Simple Payback, Life Cycle Costing, Return On Investment (ROI), etc.? Can outside financing plans be considered? Are energy costs in the same budget so that energy savings can be used to offset the cost of the system? Are utility incentives available and will they be used to offset the cost of the system? For example, there have been cases where a utility company rebate gets applied to the utility budget, not the capital expense budget where it would directly help the payback analysis of the BAS.

The issue of accounting practices is especially evident in new construction/built-for-sale buildings where most projects are evaluated on a ''lowest first cost'' basis, as opposed to a life cycle cost basis, where the investment in a BAS (and other energy saving equipment) would show a significant benefit. In some cases this situation can be overcome because a good argument exists to support the fact that a facility with a properly operating BAS will yield a higher price when sold. In other cases the lowest first cost option is selected based on that criteria alone.

Financial accounting practices also have an important affect when evaluating energy conservation related retrofit projects, where a number of financial analysis methods can be used to evaluate the value or ''payback'' of a project (Present Worth, Annual Cost, and Rate Of Return). The ''Simple Payback'' analysis is often used due to the fact that it is easy to calculate and managers wish to recover their investment as rapidly as possible, but should be used in conjunction with other decision-making tools. When used by itself as the principal criterion it may result in choosing less profitable investments which yield high initial returns for short periods as compared with more profitable investments which provide profits over longer periods of time. (Thumann, Albert, P.E., C.E.M., ''Fundamentals of Energy Engineering.'' The Fairmont Press, Inc. Atlanta, Georgia 1984).

THE TENDENCY TO LOSE SIGHT OF THE ACTUAL NEEDS OF THE FACILITY DURING THE BIDDING PROCESS

First cost is always a primary concern, and the competitive bidding process is typically used to insure the most competitive pricing. In numerous cases, however, the bidding process allows the original intent of the system to be lost. This is not to say that the bidding process should not be used to get the most competitive price possible for the owner. In many cases, however, systems which do not meet the published specification are bid at a much lower price than ones that meet the specification. This obviously attracts the owner's (or general contractor's) attention and sometimes results in the award being given to the less expensive non-complying system. But does it meet the original need that justified the project? Does it need to meet the specification to meet the owner's true needs?

The case for alternative design proposals

Alternative design proposals can be a great advantage to the owner. If the owner is willing to accept alternative proposals and system designs, however, this fact should be taken advantage of through a value engineering process where contractors are officially encouraged to offer alternative system designs in addition to a design that is in compliance with the specification. Otherwise, contractors who follow the explicit requirements of the specification in good faith can actually be denied the opportunity to compete ''on a level playing field'' and provide the owner with valuable options which were not included in the original specification due to fear of excessive costs. The result can be that the owner will not be presented with all alternatives and may choose an inferior system. The point is that all bidders should be made aware of the opportunity to submit alternative proposals if they will be considered by the owner. Currently, this is an area where consistency is often lacking.

On the other side of this same issue are cases where no alternatives to the specification are allowed. Government projects are a notable example. In many of these projects, the bidding process has become so rigid that vendors are not allowed to take any exceptions to the written specification, and will place themselves in jeopardy just for offering written clarifications. Bidding practices encourage vendors to bid the project as if they can meet every item in the exact form written in the specification, when in reality they can't. The problem with this situation is that it encourages vendors to '' just bid the job and worry about the actual spec afterwards''. Vendors that would like to take an ''upfront'' approach and present the differences (which in many cases could benefit the owner), can often be eliminated from the process.

By using this approach an organization denies itself critical information that has a direct bearing on the success of a BAS project and the true cost they will pay. When asked about this situation on an unofficial basis, government officials have said that ''if the contractor's price is low and they didn't take written exception to the specification then we have to award them the project, even if we feel the system doesn't actually meet the intent of the spec. We will try to enforce the spec as the project gets underway and, depending on how hard we push, it will often end up requiring arbitration.'' These is not a good situation and can be a major impediment to achieving successful BAS installations.

Performance oriented specifications level

In all cases it is in the owner's best interests to insure that the specification is performance-oriented. By this we mean that the language of the specification focuses on the actual operational results that the system is to achieve as opposed to manufacturer specific items such as: exact I/O configuration per panel, exact length of alarm message text, detailed menu structures of operator software, analog to digital conversions in excess of the accuracy and resolution range of the sensing elements, and other exclusionary details designed solely to eliminate qualified vendors from bidding. BAS

manufacturers have excelled at focusing sales and marketing efforts on these proprietary approaches to specification writing, creating items such as these that sound very good in a sales presentation, but do not directly serve the needs of the owner and work to reduce their range of choice.

Perhaps the most important element of a performance-oriented specification is a thorough, detailed sequence of operation for all major types of HVAC equipment. It is surprising to see how many specifications still lack this critical item. Without this information vendors will be left to submit a wide variety of system configurations and equipment features, making the job of evaluating the different proposals more difficult. Further, it opens up the opportunity for systems to be proposed which will not meet the owner's real needs. Far too great a number of BAS specifications do not include a detailed sequence of operation.

COMMISSIONING TO INSURE PROPER OPERATION AND OPERATOR SATISFACTION

Virtually every industry has come to learn the essential role that quality control plays in assuring a reliable end product that meets the expectations of the user. Building automation systems are no different. In the case of a BAS, one of the fundamental quality control procedures is known as commissioning. In the commissioning process, each installed component and each intended function of the automation system as a whole is verified. Specific examples include:

- Point-to-point checkout of all input devices (i.e., temperature sensors) to insure accurate readings and accurate labeling.
- Verification of input device locations as per the specification and appropriate location considerations.
- Exercise all actuators to insure full travel and correct labeling.
- Verification of all grounds and cable shields.
- Verification of all alarm routines via simulation of alarm conditions to insure that they execute as expected.
- Review of control sequences to insure that they meet the specification and/or scope of work definition. Verification that all control sequences are adequately annotated (commented) with descriptions.
- Review and test of all hardwired and software interlocks.
- Verification of proper system interaction with life safety equipment and systems.

Unfortunately commissioning is not a standard practice on all BAS systems. Much progress needs to be made to educate owners, contractors and vendors of the benefits of commissioning for all of the parties involved in a BAS project.

Commissioning raises another opportunity where the specification process can work to improve the final performance of the system. Specifications should include language requiring a formal commissioning process that produces documentation on all items tested. Here again the goal is to level the playing field and insure the best system for the lowest prices.

FACTORS FOR MANUFACTURERS TO ADDRESS

Manufacturers too, have an important role to play in improving the acceptance of BAS and helping to insure their successful implementation. Efforts need to be focused in the following areas.

Committing to the support of existing systems as new technology becomes available

Computer technology advances rapidly, with no end in sight. Because BAS represent a significant investment of the building owner, and the fact that the investment goes far beyond just the value of the automation hardware (engineering and installation costs typically account for over 60% of a typical BAS project), it is not realistic to expect that systems will be replaced just because newer controller hardware is available in the market. BAS vendors need to make a commitment to support, and provide connectivity, with their older systems as they release new systems.

Addressing the need for connectivity between different manufacturer's systems

One of the issues on the minds of facility owners and managers is the need to make different manufacturer's system communicate with each other or ''interoperate''. This is important because of the fact that today's buildings contain a variety of microprocessor-based devices such as factory packaged controls on air handlers, chillers and boilers, variable fequency drives, computer room air conditioning units, etc.

One of the most promising efforts to address this need is the development and implementation of a standard protocol for BAS and similar microprocessor-based devices. BACnet™ is a standard protocol developed for building automa-

tion system components, in conjunction with building automation vendors and ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers). This protocol provides mechanisms through which different manufacturer's computerized building automation components may exchange information. (''BACnet—A Data Communication Protocol for Building Automation and Control Networks.'' Document SPC-135P-031. ASHRAE, Atlanta, Georgia, March 1994).

One of the primary goals of the BACnet™ protocol is to allow building owners, operators and their consultants to integrate equipment from different vendors into a coherent building automation system in a competitive environment. (Kim E. Shinn, P.E., ''A Specifier's Guide to BACnet''. ASHRAE Journal, Vol. 36, No. 4. April 1994. ASHRAE).

One of the issues that must be understood when considering interoperability, however, is the fact that today's buildings contain a variety of microprocessor-based devices, many of which are not directly related to HVAC equipment, or traditional building automation and control networks. This is a key point; the opportunities for integration go beyond HVAC equipment alone.

Because of this fact, a standard protocol for HVAC products may not necessarily provide all of the interoperability solutions required by users. For example, will all variable speed drive manufacturers conform to a communication standard for building automation systems? What about manufacturers of laboratory monitoring equipment? What if they have standards of their own which they must conform to for their primary market? What if a facility contains industrial control equipment for automation of manufacturing processes? These systems typically have their own standards to adhere to. This adds a ''new twist'' to the problem and will cause the need for multi-vendor interfaces to continue to grow as new products are released to the market.

Because the range of products which need to be interfaced to has become so diverse, a standard protocol for building automation and control networks will not eliminate the need for specialized open systems solutions. This should not be taken to mean that a standard protocol for HVAC and building automation products is not needed and will not be good for the industry. It will be an important advance. It simply means that it will not negate the need for other multi-vendor integration solutions. It is important for owners and engineers considering integrated solutions to realize this. The existence of a standard(s) should make systems integration easier in the future by reducing the number of protocols used in BAS, and will most likely result in even more integration activity.

Improving ease of use

Tremendous opportunities exist to simplify the operation of BAS systems through the development of software tools. This is an area that is really only beginning to be exploited. The most widely known tool in this area has been the implementation of color graphic displays of equipment systems functioning as the user's primary method of interacting with the BAS and the equipment systems controlled by it. While these new ''human-machine interface'' tools are rightly considered to have ushered in a new era in ease-of-use, much of the development effort invested in these products over the last decade has revolved around making these systems functional and robust under the Microsoft Windows software platform. Two specific areas needing further development are: (1) creation of more integrated software tools that unify overall facility design information (schematics, blueprints) with control system design information (control system as-built drawings) in a dynamic environment, and (2) tools that make it easier to define, review and troubleshoot control sequences. Another area offering the promise of easier and more effective operator interaction is that of expert system features that help diagnose actual problems when abnormal conditions are detected.

CONCLUSION

Today, the issues that affect the acceptance of Building Automation Systems are related not only to automation technology but with overall project management, and the proper attention to human factors. The financial goals, and measurements used by building managers, issues related to the involvement of personnel that will live with the system, consideration of the pitfalls of a bid and spec process, attention to the role of quality control, adequate training, and a thorough performance oriented specification are determining factors. While manufacturers have an important role to play in continuing to simplify systems and improve user interaction.

ENDNOTES

i. *Worker Productivity: Hidden HVAC Cost.* Shlomo Rosenfeld, P.E., Heating Piping Air Conditioning, September 1989. Penton Publishing, Inc. ''Assume an initial cost of an HVAC system for an office building is in the range of $10 per square foot. The average salary in an office building is in the range of $300 per square foot per year, assuming a $30,000 yearly salary and 100 square feet per person occupancy. It can be seen that the initial cost of the HVAC system is very small in comparison to the cost of the occupant's average salary; therefore, the occupant's productivity as a function of comfort and satisfaction within the office envi-

ronment must be weighed in this context. How should this affect the selection of HVAC system options? For an HVAC system option that saves 10% of the initial cost ($1 per square foot savings) to be cost effective, it should have an adverse impact of less than one-third of 1 percent (1/3 percent of $300 per square foot per year, or $1 per square foot per year) of employees' salary during one year. If we measure it in time, one third of 1 percent of a normal business day of 8 hours is about 1.5 minutes per day. In an office building of 100,000 square foot, a $1 per square foot initial cost cut will result in a $100,000 initial cost saving. On the other hand, a loss in productivity of 1.5 minutes per day for 1000 employees (100 square foot per person) who receive an average salary of $30,000 per year will result in a loss of about $100,000 per year. Thus, the 10 percent initial cost cut has been wiped out by the loss in productivity in one year. In this case, such cost cutting measures for the HVAC system should not be implemented.''

ii. The top complaints reported in a survey of 2,100 members by the International Facility Management Association were that offices are too hot, too cold, lack enough storage and filing space and have poor cleaning service or indoor air quality.

iii. The costs associated with conditioning outside air (heating, cooling, humidification, dehumidification) are significant. Conditioning of excess outside air can be expensive. California for example, in their Title 24 Energy Code, allows the amount of outside air let into the building to be regulated by a BAS via air quality sensors that senses Volatile Organic Compounds. If the air quality is bad the system brings in more outside air. When the air quality is good the system can bring in less than the 15 CFM per person minimum normally used.

For example, consider an 80,000 square foot office building with 60,000 CFM air handling capacity, occupied by 400 office workers. Several years ago the building was designed by the old standard of 0.1 CFM of outside air per square foot of floor area (8000 CFM in this example). By today's standards, the outdoor air requirement for this area is 15 CFM per person. As an alternative, ventilation can be controlled based on actual demand as monitored by IAQ instrumentation. For this exercise, we will assume we can reduce the total outside air demand to 5000 CFM, which is 12.5 CFM per person. It is important to note that even in newer designs, outside air dampers have leakage, often in excess of 10%. If the dampers leak, and this leakage is not factored into the existing outside air control strategies, even systems designed to introduce 15 CFM per person will introduce excess outside air, which will then need to be conditioned. By using an automation system to monitor IAQ and implement demand-based intake of outside air, significant cost savings can be acheived. Consider for example, that a savings of over $2000 per year in energy costs can be acheived if outside air intake to the air handling system is reduced by an average of 3000 CFM, for the time the HVAC equipment is in operation.

iv. The city of Alexandria in Northern Egypt became, from the 3rd century BC, the outstanding center of Greek culture and the largest center for Jewish scholarship in the ancient world. It later became a major focal point for the development of Christian thought. A great museum, or shrine to the Muses, which included a library and school, was founded by Ptolemy I. The library eventually contained more than a half million volumes. The library lasted for several centuries but was destroyed during the reign of the Roman emperor Aurelian late in the 3rd century AD. A smaller library was destroyed by the Christians in 391 because it harbored so many non-christian works. Source: ''Comptons Living Encyclopedia.'' 1996.

The destruction of the library and loss of its written manuscripts is considered one of the contributing factors to the dawn of the Dark Ages.

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