CABA Intelligent & Integrated Buildings Council (IIBC)

CABA White Paper

Improving Organizational Productivity with Building Automation Systems

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ABOUT CABA

The Continental Automated Buildings Association (CABA) is an international not-for-profit industry association, founded in 1988, and dedicated to the advancement of intelligent home and intelligent building technologies. The organization is supported by an international membership of over 300 organizations involved in the design, manufacture, installation and retailing of products relating to "Internet of Things, M2M, home automation and intelligent buildings". Public organizations, including utilities and government are also members. CABA's mandate includes providing its members with networking and market research opportunities. CABA also encourages the development of industry standards and protocols, and leads cross-industry initiatives. CABA's collaborative research scope evolved and expanded into the CABA Research Program, which is directed by the CABA Board of Directors. The CABA Research Program's scope includes white papers and multi-client market research in both the Intelligent Buildings and Connected Home sectors. (http://www.CABA.org/iibc)

CABA Intelligent & Integrated Buildings Council

ABOUT CABA'S INTELLIGENT & INTEGRATED BUILDINGS COUNCIL (IIBC)
The CABA Intelligent & Integrated Buildings Council works to strengthen the large building automation industry through innovative technology-driven research projects. The Council was established in 2001 by CABA to specifically review opportunities, take strategic action and monitor initiatives that relate to integrated systems and automation in the large building sector. The Council's projects promote the next generation of intelligent building technologies and incorporates a holistic approach that optimizes building performance and savings. (http://www.CABA.org/iibc)

DISCLAIMER

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Executive Overview

"Improving Organizational Productivity with Building Automation Systems" is a white paper resulting from the interest of the CABA member organizations in this topic and the efforts of the CABA Intelligent & Integrated Building Council (IIBC) White Papers Sub-Committee. The working group that oversaw the creation of this paper consisted of CABA members, and industry and academic representatives from: Andrews University, Oxford Properties, TD Bank Group, University of Western Ontario, and the U.S. General Services Administration.

The worldwide emphasis on energy management and sustainability has stimulated the development of new building automation and IT technology, and the adoption and integration of these systems in smart buildings. The rate of adoption is dramatically increasing, resulting in increasing numbers of organizations housed in smart buildings with advanced building control technology. Beyond resource sustainability, there is growing interest in the potential for buildings to affect the health and well-being of occupants, and the productivity of organizations. This white paper explores how the use of advanced building control technology can improve organizational productivity. It concludes with a call to action to developers, building owners, and tenant organizations to form a real estate movement that realizes the full potential of buildings to save energy and to be a factor in improving as contributors to corporate performance and environmental sustainability.

1.0 Introduction

1.1 Structure and Scope

This white paper analyzes the contributions of building automation to the organizational productivity of building owners and tenant organizations, showing that diverse effects build the business case for investments in such systems.

In order to enable organizations to identify the "sweet spot" where an investment in a sophisticated building automation system leads to improvements in organizational productivity through both reduced costs and increased output values, this white paper sets out a framework for understanding these inter-relationships. New technologies for building automation offer new opportunities to influence organizational productivity, and the report will identify knowledge gaps where further research is needed to demonstrate their benefits. The white paper considers benefits to owner-occupied buildings as well as to tenant-occupied buildings, where the benefits are split and, in some cases, indirect.

The paper opens with definitions to set out the scope and then provides some examples of where these effects have been quantified, so that the reader may interpret the potential implications in their own context. Finally, the paper closes with a proposal for a Building Organizational Productivity Scorecard as a method to summarize and to track the effects over time.

1.2 Building Automation Systems

It might surprise some to learn that automatic controls have existed in one form or another for two millennia (Bennett 1996). Having gone through phases of increasing complexity including pneumatic and electrical controls, today's automatic controls are digital systems based on direct digital control (DDC) (Building Automation Systems, 2008). A building automation system (BAS) efficiently links, controls and monitors a variety of different building functions. At its most basic, automation is the centralized but stand-alone control of one building system, such as the heating, ventilation and air conditioning (HVAC) system or the lighting system. At its most sophisticated, building automation is part of an integrated building and energy information system (EIS) and energy monitoring system (EMS). The sophisticated BAS is capable of monitoring, analysing, decision-making, controlling and reporting on the building environment, security and lifesaving systems, and the IT systems. The BAS can respond to building occupancy needs, changes in the operational environment (e.g., outdoor temperature), and smart grid prices. Sophisticated systems may operate multiple geographically-distant locations remotely. They are flexible to system extensions, allowing new functionality to be added as required, can be re-programmed to accommodate different space layouts and user requirements (Union Investment Real Estate, n.d.), and, importantly, are easy to use.

"If you expect your people to realize their full potential, why not expect the same of one of your most visible assets – your building?"
(California Energy Commission, 2002)

BAS are designed to make building operation easier and more efficient for building owners and facility managers, while delivering the interior conditions needed for tenant organizations and individuals. Thus, enhanced building automation includes "strategies to increase the capability of energy or building management systems to control current, and plan for future, building energy costs while maintaining the comfort and productivity of all building occupants" (California Energy Commission, 2002).

Building automation is essential for complex buildings (Cole, 2003). The needs of each building and organization are different and the optimal level of automation for a building should be assessed "to determine what rewards are possible and what makes good business sense by implementing new, enhanced automation strategies" (California Energy Commission, 2002). Customization is required, as this process involves identifying the appropriate number and location of monitoring and control points, optimization of programming, integration of existing or new systems, commissioning, and ongoing maintenance.

Sophisticated BAS installations, therefore, represent a significant investment. Energy and maintenance savings can offset this investment, but evidence that the conditions created and maintained by a BAS can improve the financial performance of organizations (organizational productivity) would add considerably to the attractiveness of such systems.

1.3 Organizational Productivity

"Productivity" has long been a popular word applied loosely to several related concepts concerning both the efficiency and effectiveness of individuals, groups, organizations, economic sectors, and nations (Pritchard, 1992). In this document, we consider organizational productivity as the efficiency with which an organization operates. It is the balance between input costs and output values (Figure 1). Organizational productivity improves when costs are reduced (e.g., energy and maintenance costs drop), or when outputs increase in value (e.g., sales volume increases; newly introduced products increase sales; revenue rises with product quality improvements).

There is no single uniformly accepted way to measure organizational productivity (Haynes, 2007). Quantification and monetization of organizational productivity, even for a single organization, is a long-standing problem. As Figure 1 shows, both the input and output sides of the equation are influenced by contextual factors, here labelled "economic conditions and external factors". Neither the organization itself nor a BAS supplier has any control over these (and a researcher studying the subject has even less). Thus, a focus on the total input costs or the total output value is unlikely to clearly identify the effects of targeted changes to buildings or their automation systems.

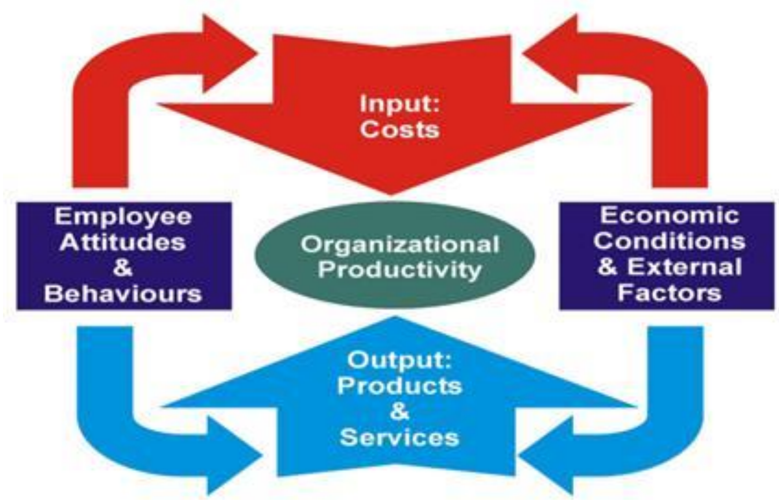

Figure 1. Organizational productivity depends on the balance between inputs and outputs.

To demonstrate the potential value of strategic investment in building design (of any kind), consider that people costs (salaries & benefits) represent a large majority of all annual enterprise costs. Brill et al. (2001) estimated staff costs at 82% of total expenditure, compared to IT costs of 10%, building and furnishings 5%, and maintenance and operation costs at only 3% of organizational costs. Another estimate came to the conclusion that over the lifetime of a building the personnel costs can be 10-40 times that of the maintenance of the building and operational costs (Sullivan et al., 2013). Relatively small increases in staff efficiency will benefit organizational productivity far more than reductions in real estate costs. These efficiency benefits come in the form of reduced input costs (e.g., less use of paid leave, lower turnover) and higher-value outputs (e.g., faster work, more satisfied customers who purchase more), Conversely, a saving in real estate costs that negatively affects staff risks being "penny wise and pound foolish".

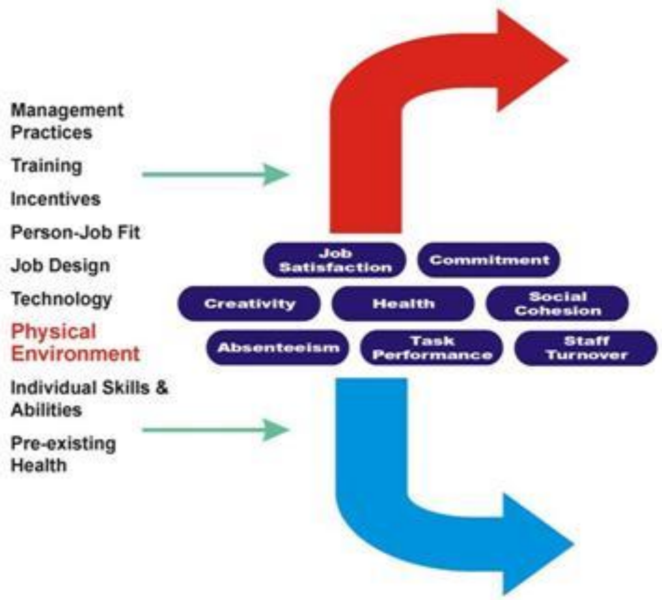

Figure 2. Research and evaluation can identify the effects of specific influences on specific employee attitudes and behaviours.

Quantifying organizational productivity in general is difficult, but widely-used measurements of its components exist (Becker & Pearce, 2003; Sullivan et al., 2013; Viswesvaran & Ories, 2000). As Sullivan et al. said, "organizational productivity can be defined in terms of behaviors that may be related to productivity and which may provide indicators of improved organization outcomes". Figure 2 shows some of these components. The measurements include: archival reports of absenteeism or turnover rates and injury reports; business unit financial performance; survey data from employees such as job satisfaction, work group cohesion; and customer surveys. In addition, some organizations have objective measurements of work performance, such as call center response times. Researchers and evaluators can use research and program evaluation tools to study the effects of various influences on these measures. The choice of measurements in any particular investigation or evaluation will depend on data availability and on the priorities of the project sponsor.

2.0 Organizational Productivity and Building Automation

2.1 Chain of Effects

Many authors have argued that effective workplaces and buildings are those that support the needs of those who occupy them (e.g., Brill et al., 1984; Clements-Croome, 2000; Veitch, 2012). Well-established scientific research can now demonstrate the link between the building environment and the health, well-being and comfort of occupants (World Green Building Council, 2014). Linking the operation of the BAS to the provision of better environmental conditions is a newer addition to the chain.

Figure 3 is a simplified diagram linking BAS to improved organizational productivity. There are two sequences. The top sequence is the more easily demonstrated effect of BAS on building energy use and maintenance costs. The paper discusses this below, although (as discussed above) these cost reductions are small in comparison to the potential effects through employees and building occupants. The lower sequence illustrates the effects of BAS on environmental conditions, which in turn influences the individuals. If one targets only the top row of the model, one misses important influences on organizational productivity.

The World Green Building Council framework (2014) identified seven outcomes that experts consider the easiest to measure and most critical to evaluating the impact of better indoor environments on organizational productivity: 1) absenteeism, 2) staff turnover/retention, 3) revenue breakdown, 4) medical costs, 5) medical complaints, 6) physical complaints, 7) self-perceptions as determined by surveys. These seven (7) outcomes are supported by the academic literature and are applicable to quantifying the impact of BAS on organizational productivity.

For individual organizations the costs and benefits of improving the built environment will differ based on local contexts. Carefully designed large-scale investigations can, however, establish average effects of BAS on particular types of organizations across many buildings. These general relationships can inform decision-makers about the likely effects on their buildings or organizations, which they may then use in their own cost-benefit calculations to determine whether or not a given investment ought to be made (World Green Building Council, 2014). The sections below describe both the potential for reduced input costs and increased output values that might be associated with a well-designed, well-installed, well-commissioned and well-operated BAS.

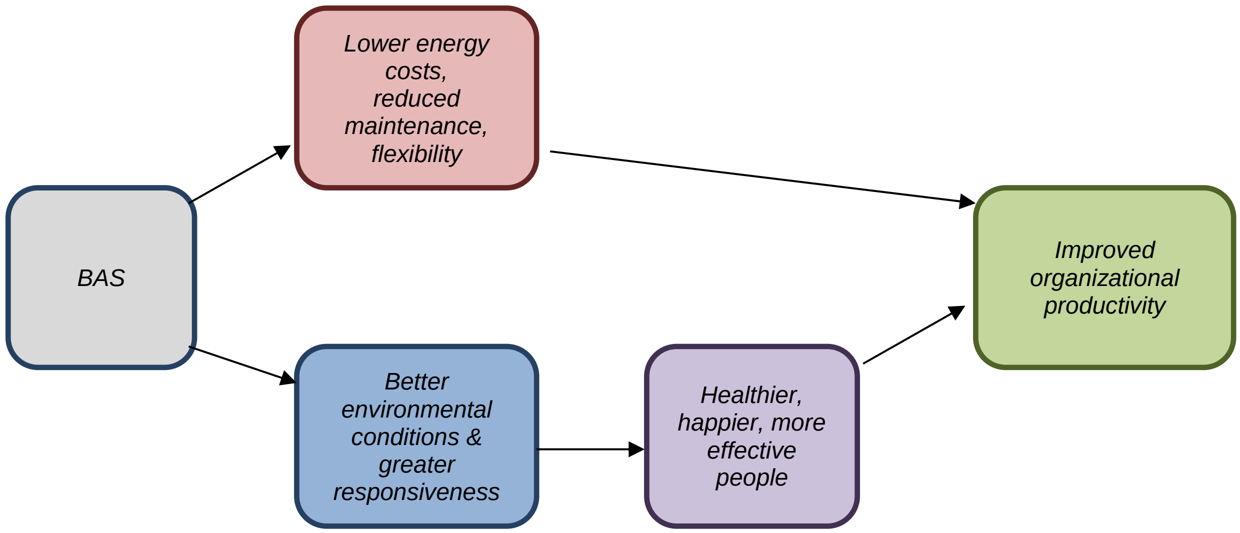

Figure 3. Building automation systems influence owner and tenant organizational productivity by creating suitable environmental conditions in an energy-efficient manner.

2.2 Effects through Environmental Conditions

2.2.1 BAS and Environmental Conditions

Most office spaces in the industrialized world have indoor environmental conditions that meet a minimum standard that enables occupants to work without causing extreme physical discomfort. Commercial offices generally meet environmental standards for lighting set by the Illuminating Engineering Society of North America (IESNA), such as RP-01-13 (IESNA, 2013), or relevant European Committee for Standardization (CEN), International Organization for Standardization (ISO), or International Commission for Illumination (CIE) standards. For thermal comfort, North America follows the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 55 (ASHRAE, 2010), and for ventilation, ASHRAE Standard 62 (ASHRAE, 2013).

Enhancements in lighting, ventilation and acoustics from minimal levels are often driven by guidance materials from the green building movement such as Leadership in Energy and Environmental Design (LEED), BOMA Go-Green (Building Owners and Managers Association), Green Globes, BREEAM (BRE Environmental Assessment Method), or the WELL Building Standard, depending on the country and interests of the building owner. These voluntary standards are designed to reduce energy and resource use while improving interior conditions – goals shared by the developers of BAS.

As with excellence in design, smart building automation operation "conjures away onerous constraints and makes them seemingly irrelevant to the user – although they are still there" (Leaman, 2003). Incorporating sensors into the BAS provides immediate current state knowledge of, for example, the occupancy and indoor environment. For facilities management real time data can be used to identify corrective measures before problems arise, or for conflict resolution for occupant complaints. For energy-management, sensors can be used to control ventilation and lighting levels according to real-time or anticipated demand, based on occupancy, exterior conditions, and other factors. Where individual control over local conditions is a feature, individuals may tailor lighting or ventilation according to their preferences and immediate needs. For energy-saving and personalization, sensors that recognize an individual's identification (e.g., building pass) can trigger the BAS to supply the worker's preferred indoor environment conditions. Where the BAS increases the likelihood that the environment is suitable to the occupants, it has the potential to improve organizational productivity both through value enhancements and cost reductions.

2.2.2 Value Enhancements

We know of no comprehensive evaluations of BAS systems on organizational productivity outcomes; thus, this model is founded upon empirically-demonstrated linkages from building conditions through to tangible business outcomes.

Previous NRC research showed that occupants' degree of comfort and satisfaction with the lighting, ventilation, privacy and acoustic conditions of their workspace is predictive of their satisfaction with the environment overall. Environmental satisfaction, in turn, predicts job satisfaction (Veitch et al., 2007).

The happy-productive worker hypothesis states that "the presence of positive emotional states and positive appraisal [enables] the worker's relationship within the workplace to accentuate worker performance and quality of life" (Harter et al., 2002). Harter et al. analysed Gallup data from nearly 200,000 individuals in 7,939 business units in 36 companies, finding that greater business-unit-level job satisfaction predicted higher customer satisfaction, better business-unit financial performance (both value enhancements), and lower turnover (a cost reduction). The NRC research links environmental conditions to job satisfaction; Harter et al. (2002) showed the critical importance of job satisfaction.

BAS will add value when they improve building performance by consistently delivering suitable interior conditions. These are extensively reviewed in Appendix A; here we give a few examples: NRC's data showed that the physical conditions predicted the likelihood of experiencing dissatisfaction. Satisfaction with lighting was placed at risk when desktop illuminance was outside the range 300-500 lux and when illuminance uniformity was outside the range 0.5-0.7 (Newsham et al., 2008). Air temperatures more than 0.5 °C from neutral increased the risk of dissatisfaction with ventilation and temperature by a factor of 3 (Newsham et al. 2008); NRC's data showed that CO_2 concentrations lower than 650 ppm reduced the risk of dissatisfaction by a factor of 3 (Newsham et al. 2008). Note that in ASHRAE Standard 62.1 following the prescriptive ventilation rates should result in CO_2 levels less than ambient levels plus 700 ppm (ASHRAE, 2013). Similarly, a meta-analysis of 24 studies found that poor office air quality consistently lowered performance in office buildings by up to 10% (Wargocki et al., 2006). In a laboratory test-high CO_2 levels produced a significant detrimental impact on decision-making of 11-23%, worse at 1000 ppm compared to 600 ppm (Satish et al., 2012).

A fifteen-year sequence of progressively more naturalistic investigations has demonstrated the value of individual control over workplace lighting, which is a feature of some BAS installations. Individual control enables occupants to obtain their preferred light level, which can differ widely from one person/occupant to another (Newsham & Veitch, 2001). In laboratory settings this control has been associated with improved mood and greater environmental satisfaction (Newsham & Veitch, 2001; Veitch et al., 2008). In a large field study, Veitch et al. (2010) further demonstrated that individual control (and direct-indirect light distributions) leads to greater job satisfaction and organizational commitment and reduced intent to turnover. Job satisfaction was already high in the host organization, but those with the lighting redesign had mean job satisfaction 11% higher on a 7-point scale than those without.

A few investigations have included measured task performance. Individual control over temperature (in a 4°C range) led to an increase of about 3% in logical thinking performance and 7% in typing performance (Wyon, 1996).

Some field investigations call out benefits on self-reported productivity, although others (e.g., NRC work cited above) consider this an aspect of environmental satisfaction. Some researchers have suggested that increases in individual self-reported productivity of up to 15% may be gained from environmental improvements (Oseland, 1999; Sullivan et al., 2013). The Probe (Post-Occupancy Review Of Building Engineering) studies (Leaman & Bordass, 2001) showed uncomfortable staff reported productivity impacts of 8.8% below 'normal' because of the indoor environment; whereas comfortable staff reported increases in productivity of 4.0 % above 'normal'. The Probe studies, conducted in the UK, are key here because of the importance of responsiveness to self-reported productivity: buildings where conditions rapidly responded to occupant needs, and with management who responded quickly to problems, were those with the highest self-reported productivity. BAS are designed to facilitate exactly this, if the systems they are attached to allow it.

Most buildings constructed to voluntary environmental sustainability standards such as LEED ("green buildings") will include some form of BAS, although not all of these will be fully integrated and sophisticated. Notably, a large NRC field investigation of 24 buildings, composed of 12 matched pairs of green and conventional buildings, found that the green buildings showed superior performance on many dimensions of occupant experience that point to enhanced output value, including environmental satisfaction, mood, and night-time sleep quality (Newsham et al., 2013).

2.2.3 Cost Reducers

As indicated above, many investigations have shown effects on both sides of the equation. The wrong environmental conditions can keep people away from work and can reduce their effectiveness when present.

"Displacement ventilation, with circulation of 100% fresh air, was the optimal choice for maximising indoor air quality and thermal comfort, while minimising energy costs. Estimated value for tenants: AUS$248/m^2/year" (Corney (2007) for 'Refresh').

When employees are not at work (absenteeism), the costs include opportunity costs associated with work not completed as well as the costs of sick leave and the provision of medical benefits. Presenteeism is the act of employees coming to work despite having a sickness that justifies an absence and more broadly it includes those present on site but not being very motivated to do useful work; and as a consequence, they are performing their work under sub-optimal conditions. Indoor environmental quality affects both. Poor office environments, including increased temperatures and reduced outdoor ventilation are linked to the prevalence of sick building syndrome symptoms (Mendell, 1993; Seppänen et al., 1999; Milton et al., 2000; Wyon & Wargocki, 2006a & 2006b). Fisk (2000) estimated potential annual savings in productivity gains of $6 to $14 billion from reduced respiratory disease, $1 to $4 billion from reduced allergies and asthma, and $10 to $30 billion from reduced sick building syndrome symptoms in the USA if indoor air conditions were improved. Whether these particular estimates apply in other countries with different health-care models, or under different assumptions, may be questioned; however, when one considers that these effects are probably additive across disorders, one can see that the magnitude of the potential benefits is very large even under the most conservative assumptions.

Moreover, health-related outcomes are not the only costs to consider. Turnover is a substantial cost to organizations, although a highly variable one from one sector and job category to another. Harter et al. (2002) showed that job satisfaction predicted actual turnover in both high-turnover and low-turnover companies. Veitch et al. (2010) found a small, but statistically significant, effect in which people with individually-controllable lighting reported a lower likelihood to leave the organization. Organizations that can attract and retain younger employees - for whom sustainability is a key value, along with brand image and healthy working conditions - will be ahead in the market (US Green Building Council (USGBC) Research Committee, A National Green Building Research Agenda, 2007).

2.3 Effects through System Design

The properties of BAS lend themselves to cost reductions; indeed, the return-on-investment case for BAS installation is often made primarily on the basis of these reductions because they are more easily monetized than the component measurements described above. However, there is additional complexity to the calculation because some of these cost reductions accrue to the tenant and others to the building owner, and in most situations these are different organizations.

2.3.1 Energy and Maintenance

The most immediate and measurable benefit of enhanced automation strategies is the reduction of energy costs through increased control over facilities and equipment. "Energy efficiency and cost-cutting are the key objectives of standardised installation bus systems like KNX, LON and BACnet. A 2008 study commissioned by KNX Deutschland clearly illustrated the energy-saving potential of room and building automation systems" (Union Investment Real Estate, n.d.) (Figure 4). Whether the tenant or building owner is the beneficiary of these reduced costs depends on how the charges are carried through and on whether the building is owner-occupied or not.

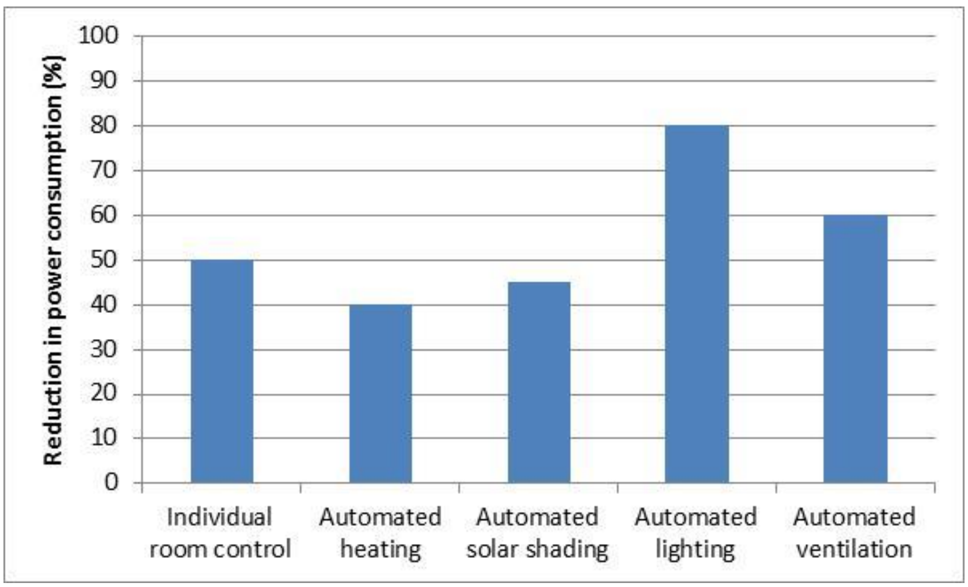

Figure 4. A study by the German Electrical and Electronic Manufacturers' Association (ZVEI) produced these estimates of the potential energy and cost reductions available through the adoption of sophisticated building technologies (Union Investment Real Estate, n.d.).

Re-commissioning and developments in automatic continuous commissioning/fault detection help combat degradation of energy savings over time by detecting "where energy is being wasted, determine the cause of the problem, notify the person in charge, generate work order for "fixes", or adjusting accordingly (St. John, 2009). This is both a reduction in energy use and in maintenance costs because of automatic fault detection. As seen above, this benefit also influences the value-enhancement chain of effects because the increased responsiveness improves occupant satisfaction.

Some of the energy savings from a BAS occur by automating scheduling and occupancy controls to avoid the circumstance of user-operated systems being left in their on state when not needed. By re-setting systems after the occupant has left the workspace the BAS resumes 'neutral' conditions, ready for non-occupancy or for the preferred conditions of the next occupant. However, the effective balance of automated and user environmental controls requires consideration, recognizing that excessive automation may become an annoyance to users (e.g., Vine et al., 1998).

As with any technology, successful BAS implementation requires thoughtful design, installation, and commissioning as well as suitably trained and empowered operators. In the absence of these conditions, the intended energy or maintenance savings will not be achieved.

2.3.2 Further Benefits for Tenants

In addition to the employee and customer benefits described above, BAS may also facilitate a better fit between the building and the tenant needs. Depending on the sophistication of the system and the design of the installation, BAS can permit the tenant to make decisions based on their preferences for workspace layout. Work areas can be designed to support the activities of employees (e.g., open plan spaces for tasks requiring high levels of communication), and changed as the organization changes. Further, BAS can enable the provision of comfortable conditions for hot-desking or hoteling office arrangements, remote access and improved scheduling of meeting space to accommodate the offices of the future.

BAS improves facilities management responsiveness, including fault detection, and leads to more rapid repairs (Leaman & Bordass, 2001). As a consequence the employees of tenant organizations experience minimal time with sub-optimal environmental conditions. The speed and efficiency of the facilities team in rectifying occupant complaints has been shown to be a reflection of the organizations 'caring' for its employees (Leaman & Bordass, 2001). The negative consequences of poor indoor conditions are listed above.

Where tenants are billed directly for their energy consumption, BAS enables the tenant to track current and historical energy use. Older models of utility bills simply pro-rate the building energy bill for the organization by its proportion of occupied space. Providing tenants with knowledge of energy-use opens up possibilities to implement energy-saving programs. The success of energy-saving strategies (e.g.

occupant engagement strategies) can be evaluated by the tenant organization and can encourage reduced energy consumption.

2.3.3 Further Benefits for Building Owners

Building owners, independent of experiencing the above benefits for their own occupied space, can derive further organizational productivity benefits in the form of both value enhancements and cost reductions.

On the value enhancement side, there is some evidence from green buildings that rents and resale values are higher in such buildings. One would expect that when environmental conditions deliver organizational productivity improvements to tenants, those tenants will not only stay longer but will also be willing to pay more for the space: higher rents reflect greater value to tenants. Both higher occupancy rates and higher rents add value for the building owner (California Energy Commission, 2002) and can boost brand image.

> *"Ongoing product & systems innovation is crucial for both increasing energy-efficiency and improving the experience for occupants. This appears to be happening apace but could be further driven by clients" (World Green Building Council, 2014)*

Considering cost reductions, in part dependent on the HVAC and lighting systems, building owners can benefit from the ability to easily configure the indoor environment to the layout or specification of a new tenant. Moreover, more sophisticated BAS can reduce the need for separate parallel installations (e.g., shared infrastructure between building systems), reducing both installation costs and operating costs because all personnel are qualified on a single system. Emergency repairs will take place more quickly because of automated maintenance schedules and fault detection, meaning reduced down time and more satisfied tenants.

3.0 Demonstrating the Effects

3.1 The BAS-Organizational Productivity Scorecard

Scorecard approaches to reporting dynamic changes in performance are used in both the building management industry (e.g., CABA's Building Intelligence Quotient [BIQ]) and in the human resources (HR) industry. Both Heerwagen (2000) and Bradley (2002) have proposed Kaplan and Norton's 'balanced scorecard' approach in an attempt to offer a more holistic or 'balanced' approach to real estate and business performance. Business measures are derived for the balanced scorecard that are specific to real estate and workplace. The balanced scorecard monitors the progress toward accomplishing the strategic objectives set out by the executive team in the organization's strategy map. Measurements are not just for reporting current status, they are for re-invigorating and moving the organization towards meeting its goals.

We propose a balanced scorecard approach to demonstrating the effects of a BAS on organizational productivity. The scorecard is a tool for showing impact. The proposed NRC scorecard, Table 1, builds on the literature above and on Appendix A in a manner similar to other publicly available workplace scales (e.g., Kaplan & Norton, 1992; World Green Building Council, 2014). The key performance indicators in any specific case are to be derived from the organization's strategic plan and priorities. Part of the benefit of the balanced scorecard comes from the scorecard design process itself (Epstein & Manzoni, 1997).

Such management control strategies require three (3) things to be effective - a choice of data to measure, the setting of an expected value for the data, and the ability to make a corrective intervention. For the NRC scorecard, much of the data required is probably already collected routinely by organizations, but by disparate groups, and not necessarily with building space as the unit of aggregation/analysis. The environmental measurements are derived from objective environmental measurements that the BAS system may already provide, or that it could provide if suitably configured. Satisfaction with the environment, job, health and well-being could be determined from occupant surveys administered by HR, from tenant satisfaction surveys administered by the building owner/manager, or from purpose-designed post-occupancy evaluations. Financial and organizational productivity data can be provided by human resources and business management departments. The barriers are low and the potential pay-off is high for this approach to demonstrating the organizational impact of BAS.

The overall score gives a snapshot of performance compared to target values set by the organization. By showing the linkages between environment and organizational productivity, corrective changes to the building can be anticipated in response to current performance and future predicted demand. Potential corrective interventions can be proposed, acted on, and the consequences to management and staff can be monitored over time.

The scorecard has been designed to be easy to read and is conceptually simple, based on the familiar nutritional label found on food packaging. These numbers can be displayed in a public space so all employees can themselves easily see and interpret the impact of each factor, make comparisons and draw conclusions. With reference to this paper, if tracked over time, such a scorecard can clearly demonstrate, across multiple metrics, the changes associated with a new BAS or operational procedure.

The example in Table 1 is not an exhaustive list of metrics that such a scorecard could include; it is intended to be illustrative. The data collected to compile the scorecard can be examined over time, but comparisons can also be made between buildings within an organization, between business units, between parts of buildings and between locations (e.g., Wing A has a higher number of physical complaints than Wing B).

The NRC scorecard is different in its focus to BIQ, LEED, BREEAM, Green Globes and the WELL Building Standard. It taps into something new - 'the bright green building' – a convergence of the major green rating scales and building intelligence (Frost & Sullivan, 2008). The scorecard enables transparency and the demonstration of the use of both technology and process to improve occupant safety, health, comfort, well-being and productivity. In this scorecard the impact on the occupant and organizational productivity is its basis, rather than being a component among other competing factors as in other rating schemes. The NRC scorecard differs from some rating scales as it is dynamic. Based on ongoing performance rather than design criteria, post-occupancy performance can be tracked over time and correlated to events, thereby giving the ability to try, test and evaluate new approaches. Further, the NRC scorecard is highly relevant to each organization as the key performance indicators and benchmarks are selected by the organization according to their goals rather than being stipulated by a third-party or standard, giving the opportunity to modify goals and criteria in line with organizational priorities.

Table 1. Sample BAS Organizational Productivity Label, showing example values

Building Organizational Productivity Label Per Building			
Monthly Score	This Month	% of Our Target Value	Industry Norm
Environmental Satisfaction	**6**	**70%**	
Satisfaction with Lighting	5		
Satisfaction with Ventilation and IAQ	7		
Job Satisfaction	**3.5**	**50%**	
Linked to Organizational Issues	3		
Linked to Environmental Satisfaction	4		
Health Ratings	**7**	**55%**	
Health symptoms	6		
Well-being	7.5		
Mood	6.5		
Staff Commitment	**4**	**50%**	
Organizational Commitment	7		
Intent to Turnover	1		
Absenteeism (absence days per 100 employees)	**10**	**10%**	
Business Unit Performance	**5**	**55%**	
Customer Satisfaction	5		
Financial Outcomes	5		
Environmental Conditions	**8**	**70%**	
Average particulate count (µg m^{-3})	6		
Average ventilation rate (air changes per hour)	6		
Light level range (lux)	200-400		
Average articulation index	.5		
Energy Use (kWhr/m^2)	**258**	**30%**	
Lighting	65		
Heating, Cooling and Ventilation	105		
Water	15		
IT	13		
Plug loads	50		
Others	10		
Responsiveness	**2.5**	**35%**	
Number of complaints (monthly)	3		
Average response time (days)	2		

Separate scorecards can be developed to reflect the different arrangements and roles of tenant organizations and landlords. The scorecard in Table 1 is an example of a scorecard for an owner-occupied building. For other arrangements, such as a building with multiple tenants, separate scorecards could be developed for each tenant. In this situation some facilities data may not be available to tenants so the scorecard criteria would be based on information gathered by the tenant organization solely.

3.2 Recommendations

Moving beyond the recognition that buildings that support employees result in better organizational outcomes, the following recommendations give guidance on how businesses should leverage BAS to positively impact people, both in the long-term using research to build the evidence base and immediately using existing data and resources.

3.2.1 Research–Validating the Scorecard

Although others have also called for the use of multiple indicators for organizational productivity effects of work environments or building conditions (e.g., Becker & Pearce, 2003; Charles et al., 2004; Haynes, 2007, Kampschroer et al., 2007), we know of no systematic applications of this concept to the evaluation of BAS installations. This leaves many opportunities to answer a host of technical, social, economic and design questions that go beyond the current remit of building professions. Answering these questions requires applied multi-disciplinary research, which in turn requires financial support and engagement at the institutional and individual level.

A strong evidence base showing a significant level of impact will be crucial to moving investment away from minimising cost to maximising employee health and productivity. Impact should be demonstrated through practical applications for building professionals, such as the scorecard and perhaps through monetization of financial returns.

Firstly, the additional link between building automation systems and environmental conditions and owner and tenant organizational productivity needs validation. This could include:

- For benchmarking, there is a need to collect organizational, building level and employee data in many buildings to build a database for which comparisons over time can be made. Such a database needs to include detailed BAS characteristics and operational data.
- Does the general model above (derived from general environment-behaviour research) apply to building conditions created by a BAS? Such studies require careful design to support causal

attributions to the BAS itself.

- In some instances, criteria are required against which to evaluate the metrics. For example, having no absences is unrealistic and suggests presenteeism might be occurring; what is a reasonable target?
- What are the effects of varying degrees of BAS sophistication (e.g., as expressed in BIQ)? Are some buildings, some HVAC system designs, some locations, or some organizations better suited to a complex system than others? Is there a degree of complexity that fails to pay back?
- Where BAS has not delivered the expected benefits, what changes could be made to its design, commissioning, or operation that can remedy the problem?
- Can BAS performance be enhanced with further detailed attention to operators' needs, particularly as regards to usability and training?

Secondly, there remain open questions about the best design for BAS and its installation:

- How robust is the interaction strategy between users and building automation systems? Does the smart building require the user to participate actively in the operation of the building?
- Have the ergonomic issues associated with active/passive user involvement been considered and incorporated into the BAS (i.e., will people behave as anticipated in the BAS model or will the ergonomic issues reduce the level of active participation and therefore the BAS model will need to adapt)?
- How visible is the failure of the BAS and what are the consequences on occupant trust of the system?

These questions could be addressed through data collected from a large number of buildings, controlled intervention studies, and longitudinal studies.

3.2.2 Application General Recommendations

The scorecard approach can also be applied to existing buildings with minimal expense and with existing personnel. These general recommendations are directed to organizations both at the building owner and tenant level that are interested in starting immediately to track performance and to gauge the likely benefits of BAS implementation.

1. Identify what key performance indicator (scorecard criteria) datasets could already be accessed from organizational records. This would require no third-party involvement or additional cost, but would provide an idea of how much time investment would be required to initiate the scorecard. For example, HR may already conduct employee surveys, records of complaints may be gathered by facilities, absenteeism data may be collected, energy sub-metering may be in place, the training received by the BAS operators may be tracked, but the data is not collated. Are there unknown datasets that could provide useful information? These basic questions would go a long-way towards the set-up of a scorecard.

2. Ask searching internal organizational questions. For example, what criteria are important enough to the organization to put on a scorecard? What is the target level of occupant satisfaction, and by what deadline? What is the organization willing to invest to measure and meet the criteria?

3. Engage tenant organizations and/or building owners (as appropriate). Some information relevant to a tenant will be collected by a landlord and vice versa. Limiting the tenant-landlord gap so that information can be exchanged freely will benefit the organizational productivity of all parties. Similarly, information about the capacity of the building automation system may be gathered through this route. The scorecard can facilitate the development of this interaction.

4. Engage building occupants. Many studies have shown that if the occupants are engaged, change is more effective and quicker. What do new recruits or existing staff value and how will the organization attract or retain them?

5. Get intimate with the full capability of the existing BAS. There may be simple operations that save time, energy or money that could be implemented immediately.

6. Volunteer the building or organization to participate in a research project by a trusted

organization. Being a study building in a research project can provide a benchmark to compare facilities, BAS operation and productivity today and provide targets for future performance.

4.0 Summary

Technology has made possible the creation of integrated digital systems to monitor and control building systems that can deliver comfortable and functional indoor environments (California Energy Commission, 2002).

The efficient skilled operation of buildings has had to swiftly adapt in line with technology development so building operation today is markedly different to what it was only a few years ago. As building complexity increases, and especially with the potential to integrate renewable energy generation into buildings, the need for BAS will increase. Nonetheless, the much greater value of the occupants and the work they do makes clear the importance of demonstrating that BAS delivers more than energy and maintenance savings.

Logically, BAS installations will increase organizational productivity for tenants and building owners alike. These benefits could be assessed on an ongoing basis and displayed to all using a scorecard approach. Such an approach will provide the evidence needed to support the business case for BAS installation, because the benefits will be clearly above and beyond the immediate energy and maintenance savings.

5.0 Conclusion: A Call to Action

Others have proposed scorecard approaches for organizations and buildings, but as far as we are aware there have been no systematic evaluations of BAS using such tools. A comprehensive, scientifically valid investigation using a scorecard approach would go a long way to demonstrate the value of more advanced, integrated systems for building operation, expanding the business case for BAS beyond simple energy bill payback periods and increasing their attractiveness to the market. The time is now for developers, building owners, and tenant organizations to form a real estate movement that realizes the full potential of buildings to save energy and to contribute to corporate performance and environmental sustainability.

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Appendix A: Detailed Model

The model presented in the main body of the text is necessarily simplified. Individuals do not work in a vacuum, but in contexts that are both local and global. These contexts have important influences on their behaviour and attitudes and can modify the effects of physical conditions on these behaviours and attitudes. The social factors, and the wider issues of human relations, as well as task design and a multitude of performance motivators, play a significant role in determining worker productivity (Haynes, 2007). An assessment of the impact of BAS on individual performance has therefore to include an understanding of the direct link between the environmental conditions inside a building, as well as individual performance and the indirect factors that mediate and moderate that relationship.

Figure A1 shows a possible model through which environmental conditions, including those created by a BAS, might influence organizational productivity indicators (both value enhancers and cost reducers). The model uses positive affect theory (Isen & Baron, 1991), in which improving working conditions improves employees' well-being and work behaviours. The comprehensive model was constructed by amalgamating research over fourteen years by Harter et al. (2002); Veitch et al. (2007); Newsham et al. (2009); Veitch et al. (2010); Veitch et al. (2013), and referencing dozens of empirical studies from building science, environmental, industrial and organizational psychology, and business research.

Conditions that create positive affect also improve motivation and work engagement (Veitch et al. 2013). Increased work engagement can be a high average of continuous time spent on work tasks, fewer breaks and reduced movement away from the workstation. Work engagement is an indirect influence on value enhancement, because it sets up the conditions for employees to give their best to the job. Positive work engagement produces improved complex cognitive appraisals (good for knowledge-based jobs) and improved motivation. The connection from mood to creativity and motivation also has its basis in the positive affect theory. Positive affect influences creative thinking (Frederickson, 1998; Isen and Baron, 1991; Ziv, 1976) thus, conditions that create positive affect may lead to greater innovation and shorter product development cycles.

Many studies have demonstrated the inverse relationship between mood and health problems; as mood improves the incidence of health problems decreases (Veitch et al., 2010). Like work engagement, health outcomes are also indirect influences on value enhancement as they set up the conditions for employees to give their best to the job. The occupational health literature shows that the indoor environment can affect health directly (Bluyssen et al., 2011). Improved physical conditions are linked to a reduction in incidence of symptoms of poor health or injury. Fewer symptoms of poor health or injury are associated with fewer health problems and lower rates of sick days and time off work (Newsham et al., 2009). Less disruption from work leads to increased individual output and therefore improved organizational productivity.

Overall environmental satisfaction is positively related to job satisfaction (Carlopio, 1996; Veitch et al., 2007). Satisfaction with the environment links the occupant's acceptance of their environment to many indirect organizational value enhancements via job satisfaction. Some authors believe that job satisfaction is the most useful predictor of important employee behaviours (Roznowski & Hulin, 1992). For example, Iaffaldano & Muchinsky (1985) and Judge et al. (2001) revealed positive relationships between job satisfaction and individual performance. Charles et al. (2004) demonstrated the link between environmental satisfaction and job satisfaction in relation to ventilation and indoor air quality, and Zweers et al. (1992) showed that lower levels of indoor climate complaints were associated with higher job satisfaction. Higher returns on assets and earnings per share are also related to job satisfaction (Schneider et al., 2003).

Carlopio (1996) and Donald and Siu (2001) observed a further connection from workplace (environmental) satisfaction to job satisfaction to organizational commitment. Organizational commitment is negatively associated with intent to turnover (i.e., increased organizational commitment is linked to reduced intent to turnover, and vice versa) (Tett & Meyer, 1993; Meyer et al., 2002). The connection from job satisfaction to turnover intent and organizational rates of turnover is well-established (Harter et al., 2002). Low employee turnover saves costs of: reduced output (no one is doing the job); staff covering the role are overworked, produce reduced quality work and show reduced satisfaction and work engagement; lost knowledge; on-the-job and paid staff training; interview travel costs; candidate selection preparation; recruiters fees.

Intent to turnover and turnover are directly linked to business unit performance (Harter et al., 2002). Harter et al. (2002) also found that organizations with higher job satisfaction show improved customer satisfaction and business unit performance, as well as profitability from increased sales/revenue.

Although not included in the model, contextual performance activities that contribute to the social and psychological core of the organization are beginning to be viewed as equally important to task performance and worthy of further consideration (Dimotakis et al., 2011). Workplace image is important to customer satisfaction. A well-regarded organization draws better staff and this reflects in customer satisfaction. Finally, employee engagement: "Positive emotions are facilitated by actions within organizations that support clear outcome expectancies, give basic material support, and encourage individual contribution and fulfillment, a sense of belonging, and a chance to progress and learn continuously. All of these elements together can be called employee engagement." (Harter et al., 2002). Employee engagement is positively related to job satisfaction and organizational commitment. When engaged, employees are productive; when disconnected, individual productivity decreases (e.g., more breaks are taken, tasks take longer) and employees are more likely to consider a change in employer.

In tandem to health costs, costs occurring from low occupant well-being can be minimized. The theory of person-environment fit (French et al., 1982) expresses that "worker performance and quality of life are hindered by strain (too much challenge) or boredom (too little challenge). When demands exceed or fall below the resources, individuals experience undesirable states (e.g., strain or boredom) which hinder the quality and quantity of their performance as well as their well-being (Harter et al., 2002). Finally, in addition, employees engaged in adapting to indoor conditions cannot spend that same time working efficiently. As this brief overview shows, the study of organizational productivity is complex. Demonstrating the influence of BAS on this concept will require careful research designs in order to deliver convincing evidence.

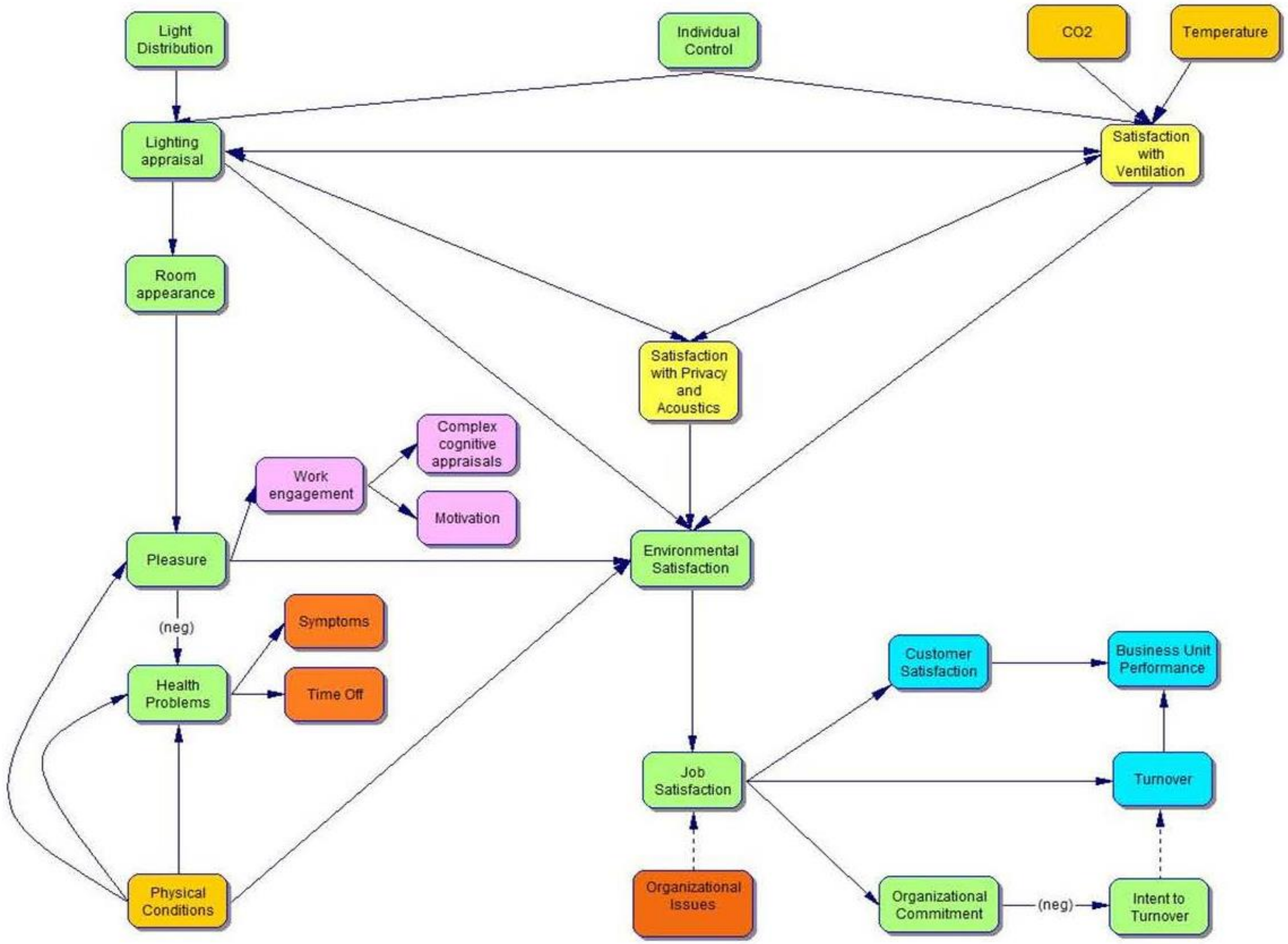

Figure A1. One possible detailed conceptual model showing how the physical environment created by a BAS system could affect job satisfaction and organizational productivity (from Harter et al., 2002 [blue]; Veitch et al., 2007 [yellow]; Newsham et al., 2008 [mustard]; Newsham et al., 2009 [orange]; Veitch et al., 2010 [green]; Veitch et al., 2013 [pink].