

Green Buildings and Productivity

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Abstract Healthier space need not be new space. In fact, some new buildings are extremely unhealthy as chemicals leach out into the air from glues, carpets, concrete, and paint. There is no reason this must be the case. The cost to provide healthier environments is modest compared to the benefits. Healthier buildings reduce sick time and increase productivity, making it easier to recruit and retain employees. The results provided here are based on a survey of over 500 tenants who have moved into either LEED or ENERGY STAR-labeled buildings managed by CB Richard Ellis (CBRE). It is part of a much larger study that includes details on operating expenses, leasing, and management available from the authors or www.josre.org.

Do Green Buildings Improve Productivity?

While we now have some evidence on rental premiums and occupancy differences for green buildings (e.g., Spivey and Florance, 2008; Eichholtz, Kok, and Quigley, 2009; and Fuerst and McAllister, 2009), defined as including both ENERGY STAR-labeled and/or LEED-certified at any level, we know little about the real impact on productivity for tenants. There has been one widely cited study by Kats (2003), which had a sample of 33 green building projects that suggested present value benefits of \$37 to \$55 U.S. dollars per square foot as a result of productivity gains from less sick time and greater worker productivity. These resulted primarily from better ventilation, lighting, and general environment.

Here we greatly expand our scope of analysis and re-visit the productivity issue. Unfortunately, one impediment to answering this question is the problem of measuring productivity. Studies in the past that dealt with typing speed or output are not quite satisfactory for those who wish to know about overall productivity in better environments. Here we review some of the literature on measuring productivity in office environments, then we examine some of the attempts to monitor productivity and last we examine our own efforts to determine if better environments result in greater productivity. This is part of a larger joint study by the authors with details available by request.

Subjective Productivity Measurement

An excellent review is provided by Kemmilla and Lonnqvist (2003), who state that “Productivity is an important success factor for all organizations. Improvements in productivity have been recognized to have a major impact on many

economic and social phenomena, e.g., economic growth and higher standard of living. Companies must continuously improve productivity in order to stay profitable...There are several different methods for productivity measurement. Most of the methods are based on quantitative data on operations. In many cases, it is quite difficult and sometimes even impossible to collect the data needed for productivity measurement. An example of this situation is the work of professionals and experts. Their work is knowledge-intensive and the inputs and outputs are not easily quantifiable. Therefore, the traditional productivity measures are not applicable...An old but scarcely used approach to productivity measurement is subjective productivity measurement. Subjective productivity measures are not based on quantitative operational information. Instead, they are based on personnel's subjective assessments. The data is collected using survey questionnaires." Essentially, Kemmila and Lonnqvist point out that measuring productivity directly is a great challenge. This is because direct measurement for professionals in an office environment requires the monitoring of: (1) the ability to focus and think, synthesize, and add value to the firm; (2) the ability to measure the contribution of individuals that likely work in a team environment; and (3) the ability to monitor the quality of work as well as efficiency and output.

While productivity itself could be measured using financial and economic measures for the entire system, firm, or division using statistics like revenues, billable hours, net income, or market share gained, there are leads and lags from the input of capital and labor to the output effects based on measureable indicators. Even if these indicators can be measured in real time there is the question of external and internal influences that must be controlled. Did the competition change material costs in some way? We do not live in a status quo world so controlling for external changes is a challenge. Last, assuming you could control for all external changes, you need to be able to divvy up the output by internal inputs as well as vendors and others that contribute to the firm's revenue generation or production of services.

Direct measures may be useful such as customers served by a cash register operator or calls taken by a customer service representative and certainly management does use such measures. But often these are hard to apply to professional service environments where many participants contribute to a process and service. Most commonly we use indirect measures such as absenteeism, hours worked, tardiness, safety rule violations, number of grievances filed, or employee turnover.

The reason these are indirect measures is that managers often assume that hours worked equates to productivity. Yet, there are many examples where workers are not efficient and hours worked do not equate to productivity. This is one of the problems with managers allowing more telecommuting. Telecommuting requires managers to use other measurements of productivity beyond hours worked such as projects completed or in the case of lawyers, billable hours.

In a fairly recent study in Australia a law firm tracked the before and after sick days after a move to a five Green Star-rated building, a high rating in Australia, and found sick days reduced by 39% overall to 0.28 days per month. That change

alone cut the average monthly cost of sick leave significantly. Other productivity gains were said to have “gone through the roof.” But this is one case study, and we need to know if we can generalize from such indicators (Dunckley, 2007).

Drucker (1999) also suggests that knowledge-intensive work is not easily quantifiable. He points out the common delays in outputs or results from inputs or the variations in quality and the lack of a measurement culture among management.¹ There is also the problem of controlling environments such as interruptions to work by colleagues or the general public or social interactions with clients that may support long-term or team success but take away from current short-term productivity. We are left with indirect and subjective productivity measures in most cases, based on subjective assessments. Subjective productivity data is usually collected using survey questionnaires gathered from employees, supervisors, clients, customers, or suppliers. Survey data is subject to all sorts of biases so any survey data including the qualitative data provided here should be repeated and based upon as large and representative a sample as possible.

Objective and Subjective Productivity Measurement

Halpern, Shikiar, Rentz, and Khan (2001) performed a study to quantify the differences in productivity between current, former, and never-smokers in the workplace. The targeted sample was 300 employees at a reservation office of a major U.S. airline. The study consisted of three types of productivity measurement, including assessment of absenteeism, objective assessment, and subjective assessment of productivity.

The reservation center collected data on number of attendance interruptions, absenteeism days, and lost hours caused by both absenteeism and work injury as an assessment of absenteeism.

The reservation center collected other objective productivity measures based on an employee’s performance:

1. Revenue calls handled: The number of calls leading to a sale handled per month by an employee.
2. Ticket delivery system segments: The number of flight segments arranged by reservation personnel for delivery.
3. Call work time: The average time a reservation clerk is unavailable between calls.
4. Hours lost: The average time a reservation clerk is unavailable between calls without a sanctioned excuse.
5. Potential flown segments: The total number of flight segments booked in the past scheduled to fly during the time period reviewed.

In addition, five measures of productivity were assessed as performance ratios:

1. Dollar amount per revenue call handled.
2. Dollar amount per productive sign-in time.

3. Potential flown segments per revenue call handled.
4. Potential flown segments per productive sign-in time.
5. Ticket delivery system segments per productive sign-in time.

The Health and Work Questionnaire (HWQ) assesses productivity subjectively and consists of 24 questions. Six subscales were identified and include productivity, impatience and irritability, concentration and focus, work satisfaction, satisfaction with supervisor, and personal life satisfaction.

The results showed current smokers had significantly greater absenteeism than did never smokers, with former smokers having intermediate values; among former smokers, absenteeism showed a significant decline with years following cessation. Former smokers showed an increase in seven of 10 objective productivity measures as compared to current smokers, with a mean increase of 4.5%. Workplace productivity increased and absenteeism decreased among former smokers as compared to current smokers. If smoking affects productivity then so may air quality in general, something encouraged by better ventilation in green buildings.

Evaluating Productivity Measurement

In this paper, Haynes (2007a) evaluates different methods of assessing productivity. The author presents historical context to office design and reviews appropriate literature. The review aims to establish the limitations in defining office productivity and the range of approaches to its measurement. Aronoff and Kaplan (1995) suggest using absence measures, activity logs, and attitude and opinion surveys, along with direct measures. Hadi (1999) believes productivity measures should be split into three sections: quantifiable and tangible measures, indirect measures, and organizational measures such as teach-work and creativity using data collection methods such as questionnaires, observational techniques, structured interviews, focus groups, and job/task analysis. Oseland (1999) believes productivity measures should be split up into performance measures, self-assessed productivity, staff costs, and profit. The Office of Real Property (1999) suggests several measurements of productivity including turnover, absenteeism, self-assessment of workplace effects on one's own productivity, time-tracking devices such as long books, overtime and project hours, observed downtime for modifications, complaints and interruptions, anecdotal evidence on workplace suitability, and finally churn costs, which include employee downtime, space move costs, and time to execute a move and get a person back up and running.

The review of the literature reveals that there is no universally accepted measure of office productivity but recent researchers have adopted the self-assessment approach. Haynes' follow-up paper (2007b) establishes links between real estate and facilities performance metrics and the organizational performance metrics. The aim of Haynes' follow-up paper was to provide a validated theoretical framework for the measurement of office productivity.

Haynes (2007b) suggests that office productivity can be linked to the physical office environment through office layout and office comfort. It can also be linked

to the behavioral environment, which likely has a greater impact on office productivity. Haynes established a model to represent the concept of office productivity with the dimensions of both the physical and behavioral environment. His model used seven distinct components to represent office productivity:

1. Distraction (interruptions, crowding, noise, privacy, overall atmosphere).
2. Environmental services (ventilation, heating, natural lighting, artificial lighting).
3. Office layout (personal storage, general storage, work area, desk, overall office layout, position of colleagues, circulation space).
4. Interaction (social interaction, work interaction, physical security, creative physical environment).
5. Designated areas (informal meeting areas, formal meeting areas, quiet areas).
6. Comfort (décor, cleanliness, overall comfort).
7. Informal interaction points (position of equipment, refreshment areas).

Evidence from the study proves that interaction and distraction have the greatest negative and positive influence on self-assessed productivity. The goal is then to find the optimum balance between encouraging positive interactions while reducing negative distractions and to allow group collaborative working to coexist with individual private working. This can only be achieved if the office designers can identify and quantify the impact of the behavioral environment on office occupiers' productivity.

Recent Workers' Productivity Gains from Technology or Economic Pressures

According to the results from the 2008 White Collar Productivity Index (WPI), the only study of its kind providing long-term data on how people actually spend their time at work, there was a reduction in the time people are spending on low productivity tasks during 2007 as compared to both 2006 and 2005. According to Bary Sherman, CEO of PEP Productivity Solutions, "The WPI study indicate[s] that America's white collar workers are becoming smarter and more effective in their day-to-day routines. They appear to have a better grasp on how to use technology as a productivity tool and are getting more of the right work done in less time. Until this year we have seen a steady increase in non-productive time usage every year since we started measuring office productivity in 1994. It will be exciting to see how this trend plays out over the next years."

The WPI study (PEP, 2008) generated serious interest from academia and organizations when it was first made public in 2005, presenting annual statistics collected since 1994 from over 3,200 employees (administration, staff, middle management, and senior executives) in major U.S. companies representing a variety of sectors, including the manufacturing, automotive, finance, biotech, education, insurance, accounting, and technology industries. The core subjects

measured by the 2008 WPI study are handling email, handling paper mail, attending meetings, working overtime, delegating responsibility, dealing with interruptions, looking for lost data, managing work backlogs, and planning work. What may be happening is that as the economy weakens we are forced to work smarter and more efficiently. In other words, highly profitable firms or economies allow more goofing off.

The entire WPI, expressed in hours per week, per person, is as follows:”

Issue	2006	2007	% Change
Handling Email	9.4 hours	7.3 hours	-22%
Handling Paper Mail	1.2 hours	1.0 hours	-17%
Attending Ineffective Meetings	3.0 hours	2.2 hours	-27%
Working Overtime	5.8 hours	4.4 hours	-24%
Delegating Work	4.3 hours	3.0 hours	-30%
Being Interrupted	4.6 hours	3.8 hours	-17%
Looking for Information	1.6 hours	1.3 hours	-19%
Working on Backlog	3.0 hours	2.2 hours	-27%
Planning Work	2.0 hours	2.1 hours	+0.5%

Telecommuting and Productivity

Telecommuting is becoming more prevalent in today’s workplace. It has evolved for various reasons for employees and employers. Employers may opt to allow their employee to work from home when rush-hour traffic is a true hindrance in arriving to work at a set time, hence reducing commuting time and potentially increasing productive work hours. Working mothers who cannot afford to maintain a full-time job and a full-time household now have access to achieving the goals of home and work through telecommuting options. In addition, the working student or professional that seeks to further his education is more valuable to the company working from home where he can still maintain his workload and focus on scholastic achievement simultaneously. Many workers, who for various reasons, prefer or need to work from home, when permitted assist firms in the retention of successful talent. Thus the prevalent need for telecommuting forces recognition of its pertinent impact on worker productivity.

Jensen (2008) examined employee and manager awareness of home-office distractions and productivity. He found that “a positive relationship exists between the level of managers’ self-reported awareness about telecommuters’ home-office environment distracters and managers’ self-reported levels of telecommuters’ productivity.” The managers’ mean reported that the immediate manager had a low level of awareness of home-office distractions for the telecommuting employee. His study showed that even when managers were aware of these

distractions, they did not rigorously attempt to solve the problem. Thus management acknowledged the changing workforce and is learning to manage the telecommuter. The telecommuter is becoming a growing percentage of the workforce, so if management does not determine how to effectively manage them now and implement new policies, there will be an insurmountable dilemma in the future.

Health and Productivity

Health care maintenance has a close relation to an employee's productivity level. In times of economic turmoil, Taggart (2009) states that employers reduce company health care premiums to alleviate uncontrollable financial losses in other areas. When in actuality states Taggart, "the cost per month per employee for wellness programs can range from as low as \$2 (more traditional health promotion only) to \$10 depending on the complexity of the program." Companies neglect the importance of the health of their workforce when it is in competition with financial incentives of reducing company health care costs. Perhaps the question to ask is "How much will NOT investing in wellness cost my business?"

The company obtains its cost reduction through passing-on higher deductibles and out-of-pocket expenses to the employee. Often the employer rationalizes that this shift of liability grants the employee autonomy over their own health, but in periods of economic hardships many employees also have a decrease in expendable cash flow and health care costs can be one of the first expenses to be eliminated.

Employees realize the benefits of a healthy mental and physical state of being, and prefer its rewards versus the companionship of stress and physical ailments. Therefore, through the implementation of employer-sponsored wellness programs "employees can and will change their lifestyles if approached in the right way and consistently reinforced through the process," (Taggart, 2009).

Taggart (2009) believes that company wellness programs must be aligned with the preferences of the employees. If programs are viewed as beneficial to employees' health, there can be a two-fold advantage for the company. First, worker productivity will improve in the future for the organization. Second, company morale will increase due to the company's interest and success in the betterment of employee health. Successful wellness programs focused on the employee include time management training, conflict resolution classes, and team-building exercises. Yet some alternatives are coordinated to assist with external employee matters, such as child care, legal assistance, and elder care. All approaches should be available through numerous access points, whether via online learning, telephone, one-on-one, or group activities, so that all employees can utilize these resources despite their personality type.

Today's work culture is team oriented, hence if one employee is absent or not working at full productivity, then the team is hurt exponentially. If employer-implemented wellness programs can reduce absenteeism, increase presenteeism

(when employees come to work in spite of illness), decrease employee turnover, and increase employee retention then the financial benefits to the company will eventually outweigh the present costs of health care premiums. “The challenge for employers is to help employees begin to connect productivity with being in better health, greater life satisfaction, and being physically active,” (Taggart, 2009).

Temperature and Productivity

Many office studies were performed in call centers where the time required talking with customers, the processing time between calls with customers, and other relevant information were automatically recorded in computer files. In these studies, the speed of work, e.g., average time per call or “average handling time,” was used as a measure of work performance. Laboratory studies typically assessed work performance by having subjects perform one or more tasks that simulated aspects of actual work and by subsequent evaluation of the speed and/or accuracy of task performance. Seppanen, Fisk, and Lei (2009) calculated the quantitative effect on performance of temperature. “We calculated from all studies the percentage of performance change per degree increase in temperature, positive values indicating increases in performance with increasing temperature, and negative values indicating decreases in performance with increasing temperature. We also applied a weighting factor based on the authors’ judgment of the relative relevance of the performance outcome to real work. For these judgments, we assumed that measurements of the performance changes of real work in office workers was more representative of overall real-world work performance, and should be weighted higher than performance changes in computerized tasks, such as proofreading or typing, that simulate a portion of work. We also assumed that performance changes in simulated work tasks were more relevant (deserved more weight) than performance changes in school tests, manual tests, and vigilance tests. Using command “regress” in Stata 8.2 for Windows (a program that selects the best-fitting linear model of dependent variable on explanatory variables), we fit a quadratic model to the data for normalized percentage change in performance vs. temperature unweighted, weighted by sample size, and weighted by combined final weight separately.” The results show that performance increases with temperature up to 21–22°C (69–72°F), and decreases with temperature above 23–24°C (73–75°F). The highest productivity is at a temperature of around 22°C (71.6°F). For example, at the temperature of 30°C (86°F), the performance is only 91.1% of the maximum (i.e., the reduction in performance is 8.9%). The conclusion is that temperature matters and influences productivity.

Indoor Air Quality and Productivity

A series of experiments to determine limiting criteria for human exposure to the very low levels of indoor humidity that occur in aircraft cabins at altitude (<10% RH) and in winter in cold countries (<20% RH) was performed in two climate

chambers at The International Center for Indoor Environment and Energy (ICIEE). Three different office tasks were simulated, including text-typing from a hard-copy onto a computer screen, proofreading a printed text into which spelling, grammatical, and logical errors had been inserted, and an addition of a column of five two-digit random numbers, without zeros, printed conventionally. In these tasks, the rate of working and percentage errors were examined separately. In the first air quality experiment, a performance assessment battery that has been widely used for military purposes was used instead of the proofreading task, but as it proved insensitive to environmental conditions it was not used in subsequent experiments. Open-ended tests of memory, recall, and creative thinking were applied in most of the experiments. “Field intervention experiments in two call-centers demonstrate that the decrement in performance can be larger in practice than it is in realistic laboratory simulation experiments,” (Wyon, 2004).

“It has now been shown beyond reasonable doubt that poor indoor air quality in buildings can decrease productivity in addition to causing visitors to express dissatisfaction. There is an approximate 20% to 70% linear relationship between the percentage dissatisfied with indoor air quality and the measured decrement in performance. The size of the effect on most aspects of office work performance appears to be as high as 6%–9%, the higher value being obtained in field validation studies. It is usually more energy-efficient to eliminate sources of pollution than to increase outdoor air supply rates. The experiments summarized by Wyon (2004) documented and quantified relationships that can be used in making cost-benefit analyses of either solution for a given building. The high cost of labor per unit floor area ensures that payback times will usually be as low as two years.”

Indoor Pollution and Productivity

Bako-Biro, Wargocki, Weschler, and Fanger (2004) describe a study where 30 subjects were exposed for 4.8 hours in a low-polluting office to each of two conditions: the presence or absence of three-month-old personal computers (PCs). During exposure, subjects performed simulated office work consisting of text typing, proofreading, and arithmetical calculations (addition and multiplication of numbers). These are typical office tasks requiring concentration and in previous studies were shown to be sensitive to changes in air quality. The subjects assessed perceived air quality, indoor climate, and SBS (Sick Building Syndrome) symptoms upon entering the office and on several occasions during exposure. The subjective responses and performance data were analyzed using either the Wilcoxon matched-pairs test or the paired *t*-test, depending on whether or not the data were normally distributed. A binomial test was used whenever the other two tests failed to show significance. A chi-square test was used to analyze the data in 2×2 contingency tables. Reported *P*-values for a one-tailed test were in the expected direction, showing that the presence of PCs has negative effects on air quality, increases SBS symptoms, and reduces productivity.

Moving and Productivity

What is the impact on worker productivity of an organization physically moving their office into a new space from a pre-existing space? This question is important as we could have a placebo effect and thus biased results when asking about worker productivity after moving into a green building. A Montreal corporation chose to relocate its office to provide employees with an open atmosphere for increased communication, collaboration, teamwork, and an overall increase the quality of the company's services. The new office was designed to increase productivity through the creation of accessible space for employees to share and generate new ideas.

Vischer (2005) showed "that the two buildings differ slightly in their effects on work, with workstation comfort being more supportive in the new building. Air quality is rated positively in both buildings, but more so in the new building. Thermal comfort and lighting quality are neutral in both buildings but draw no energy away from the performance of work. Privacy (or lack of it) is drawing energy away from task performance in both buildings, and in the new building, poor acoustic conditions are also having a negative effect."

Overall, the Vischer (2005) survey results indicate that the newer workspaces are more supportive of workers but that new buildings often had chemicals that polluted the air from concrete, paint, or carpets. So new buildings do not necessarily increase worker productivity and often decrease it when the presence of pollutants is temporarily increased.

Building Intelligence and Productivity

Clemets-Croome (2000) argue that occupants of an office with "advanced building intelligence" experience decreased rates of illness and absenteeism and that advanced building intelligence should ultimately increase worker productivity. He begins by examining brain rhythm patterns to understand the nature of concentration, which is at the fundamental level of productivity since the mind and body need to be in good condition for ideal work and concentration. Brain rhythm patterns can be observed by measuring the beta and theta rhythms, which are related to different states of concentration and are therefore linked to productivity.

Clements-Croome (2000) reviews many academic papers regarding productivity and the workplace. Some of the productivity measures mentioned include absence from work or workstation, sickness records, incidents of accidents, health costs including sick leave, accidents and injuries, interruptions to work, controlled independent judgments of work quality, self-assessments of productivity, speed and accuracy of work, output from pre-existing workgroups, cost for the product or service, exchanging output in response to graded award, volunteer overtime, cycle time from initiation to completion of process, multiple measures at all organizational levels, visual measures of performance, health and well-being at

work, development of measures and patterns of change over time, mental performance through word puzzles, number of errors made per subject per hour, employees leaving work early, extra long breaks/lunches, and self-reports of productivity.

Measuring productivity using absentee rates, sick leave, and health and well-being at work are deemed unreliable because they may be attributable to entirely different factors. It costs more to employ people than to maintain and operate a building; hence spending money on improving the work environment may be the most cost-effective way of improving productivity. Overall Clements-Croome (2000) concludes that determining a quantitative relationship between environment and productivity proves to be highly challenging and controversial.

Innovative Workplaces and Productivity

“Two concurrent trends have helped our professional focus shift from ‘place’ to ‘workplace.’ One is the recognition of knowledge work as being qualitatively—and fundamentally—different from the task-oriented work of the industrial age (a category that, despite the nomenclature, would include ‘office work’). The other trend is the recognition of knowledge workers as ‘human capital’ that can be enhanced by environmental improvements and amenities,” (Kaczmarczyk and Murtough, 2002).

Kaczmarczyk and Murtough (2002) established three models to measure total workplace as opposed to facility performance. Those models are the “GSA Cost Per Person” model (U.S. General Services Administration), the “Employee Satisfaction with the Workplace” model, and the “Productivity Payback” model.

The “GSA Cost Per Person” model measures the default values for the base case based on an actual pilot study in the GSA Central Office building in Washington, D.C. The model is a spreadsheet that allows users to input their own data or to accept default values in the absence of known cost data. Reviewers of the draft model consist of professional colleagues from the facility management and real estate disciplines, who could not provide feedback on the information technology and telecommunications cost data in the model. Often these data were not available in their organizations. Consequently, a good deal of the professional interest in the Cost Per Person Model lies in the value of the base case data it supplies. The model is a useful tool for systematically comparing the cost implications of working in the main office facility versus alternative work environments such as that of a telecommuter. Some basic components are: real estate, telecommunications, information technology, workstation furniture, and alternative work environments.

The “Employee Satisfaction with the Workplace” model developed the conceptual “Workplace Performance Model.” The workplace can be divided into three components: people, places, and tools. A high-performing workplace is defined by three measures: employee satisfaction, productivity, and employee retention. A workplace analysis based on the survey design was developed on the above

assumptions: the presence of particular factors in the people, places, and tools; the components of the workplace; and then gauged the respondents' satisfaction with each component.

The "Productivity Payback" (PPM) model used the concept of productivity in a broader analytical framework. The PPM is based on the perspective that investments in the workplace are primarily investments in the people who work there. The model uses compensation cost as a proxy for productivity. Investments are categorized according to the people, places, and tool's scheme discussed earlier. PPM addresses two questions: (1) How much must productivity of the employees increase to offset the workplace investment (return on investment)? and (2) How confident are we that the required productivity increase can be achieved?

A matrix in the PPM collects the results of workplace upgrades and interventions. Users can refer to the matrix to input the productivity increase required by the proposed investment in a real world context. The value of the PPM is its effect on the people, facilities, information technology, productivity, and investment in a relative context that facilitates better decision making.

"Many organizations, including the national governments of the U.S. and Canada, have realized that the workplace has a critical impact on the performance of the people who work there...The measurement challenge has already moved past the justification stage. This is not an attempt to 'prove' that innovative workplaces are a good idea. They are already part of the facilities management picture, and will become increasingly more prevalent and important. What is needed are tools and models that will help to measure their impact on human capital development so that the best investment decisions can be made—investment focused on primarily people and not buildings," (Kaczmarczyk and Murtough, 2002).

Office Environment Color and Productivity

Kwallek (2007) provided a report from a large-scale study that examined the effects of three office color interiors (white, predominately red, and predominately blue-green) on worker productivity. Matched on relevant variables, participants were assigned to one of three offices and performed simulated office tasks for four consecutive days. Productivity was measured through workers' task performance and task accuracy, taking into account individual differences in environmental sensitivity (i.e., stimulus screening)... Trait arousability can be defined 'by strength of arousal response to sudden increase in complexity, variation, novelty, and/or unexpectedness of stimuli,' stimulus screening is conceptualized as individual innate ability to routinely block or filter out irrelevant stimuli within one's surrounding. Screeners are individuals who are more capable of screening irrelevant stimuli and thus are more adept at simplifying information from sensory input... The findings suggested that the influences of interior colors on worker productivity were dependent upon individuals' stimulus screening ability and time of exposure to interior colors. Implications of office workers'

long-term productivity are discussed in relation to issues concerning the visual complexity of interior environments.”

This study was performed to measure a correlation of office wall color with productivity. Productivity was measured through workers’ task performance and task accuracy. Participants spent four days in a simulated office setting performing office tasks. Three tasks were chosen to test task performance and task accuracy: proofreading text, proofreading ZIP Codes, and a typing test. Subjects were judged by the number of errors made.

Kwallek (2007) found that, “There is a prevailing perception that some colors are more productive than other colors. Specifically, warm colors, such as red, are assumed to have more arousing effects on human responses than cool colors, such as green and blue. On the basis of his work with brain-impaired participants, Goldstein proposed that red, a warm color, has an ‘expansive’ property. The color red increases human receptiveness to external stimuli and induces a state of excitation, which would affect an individual’s emotional and motor responses. In contrast, he suggested that green, a cool color, has a ‘contractive’ property, which provokes human withdrawal from the external stimulation and reduces one’s receptiveness to external influences. In addition, he suggested that green has a soothing effect on emotion and performance.

Kwallek (2007) found that: “In terms of text proofreading accuracy, no overall significant interaction effect of stimulus screening ability and color interior was found, $F(4,81) = 1.23$, ns. There was no significant difference found in any of the offices. In brief, except for ZIP Code proofreading task, no overall pattern of difference (color-stimulus screening-day interaction) was detected in task accuracy. This can be due to the fact that, on average, the number of errors made by the participants was small and it prevented us from identifying significant group difference in task accuracy. The color stimulus screening interaction was only reported in the white office interior in terms of task accuracy. In general, low and moderate screeners committed more errors in both typing and ZIP Code proofreading tasks toward the end of the work week, compared with high screeners. However, contrary to the hypothesis, this pattern was not found in either the predominantly red or blue-green office interior.” Color was found to have a very modest impact on productivity and could be eliminated if workers were able to self-focus on the task at hand.

Workplace Illumination and Productivity

Hoffman (2008) writes about the relationship between workplace illumination and employee productivity and well-being. Eleven volunteers performed experimental office work in two different lighting environments. The simulated office work consisted of general and special ability tests, which were all part of the Vienna Test System. Urine samples and a questionnaire were the measurement tools used in this study. Power analyses and statistical evaluations of the data were

performed. Hoffman concludes that variable light exerts a potential advantage in indoor office accommodations with respect to subjective mood. Light matters.

Employee Engagement and Productivity

The question of productivity is difficult to study absent some controls for management and behavior. Some managers may believe that it is not important for an employee to like their job, but Irvine (2009) has reported otherwise. Employees must be engaged strategically by their firm. It is not enough to think that the mere appreciation of being employed gives the employee satisfaction, but the employer must proactively design a system to engage each employee or face turnover. Taggart (2009) has found that 40% of employees turnover within five years of employment. Yet when workers are connected with the company mentally and emotionally, they “are twice as likely to be top performers and miss 20% fewer days of work,” (Irvine, 2009). Among engaged employees, employers reap the benefits of increases of operating income in upwards to 19% “vs. companies with the lowest percentage of engaged employees saw a 33% decline,” (Irvine, 2009). Employers need to follow the example of these companies and dedicate their employees to the company, not to a paycheck. Employee retention is at the heart of how well a company engages and motivates their human capital. Management likely matters more than most environmental factors.

Sick Building Syndrome

According to the U.S. Environmental Protection Agency, Sick Building Syndrome (SBS) is caused by four major categories, as listed below:²

Inadequate Ventilation

In the early- and mid-1900s, building ventilation standards called for approximately 15 cubic feet per minute (cfm) of outside air for each building occupant, primarily to dilute and remove body odors. As a result of the 1973 oil embargo, however, national energy conservation measures called for a reduction in the amount of outdoor air provided for ventilation to 5 cfm per occupant. In many cases, these reduced outdoor air ventilation rates were found to be inadequate to maintain the health and comfort of building occupants. Inadequate ventilation, which may also occur if Heating, Ventilating, and Air-Conditioning (HVAC) systems do not effectively distribute air to people in the building, is thought to be an important factor in SBS. In an effort to achieve acceptable indoor air quality while minimizing energy consumption, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) revised its ventilation standard to provide a minimum of 15 cfm of outdoor air per person (20 cfm/person in office spaces). Up to 60 cfm/person may be required in some spaces (such as smoking lounges) depending on the activities that normally occur in that space (see ASHRAE Standard 62-1989).

Chemical Contaminants from Indoor Sources

Most indoor air pollution comes from sources inside the building. For example, adhesives, carpeting, upholstery, manufactured wood products, copy machines, pesticides, and cleaning agents may emit volatile organic compounds (VOCs), including formaldehyde. Environmental tobacco smoke contributes high levels of VOCs, other toxic compounds, and respirable particulate matter. Research shows that some VOCs can cause chronic and acute health effects at high concentrations, and some are known carcinogens. Low-to-moderate levels of multiple VOCs may also produce acute reactions. Combustion products such as carbon monoxide, nitrogen dioxide, as well as respirable particles, can come from unvented kerosene and gas space heaters, woodstoves, fireplaces, and gas stoves.

Chemical Contaminants from Outdoor Sources

The outdoor air that enters a building can be a source of indoor air pollution. For example, pollutants from motor vehicle exhausts, plumbing vents, and building exhausts (e.g., bathrooms and kitchens) can enter the building through poorly located air intake vents, windows, and other openings. In addition, combustion products can enter a building from a nearby garage.

Biological Contaminants

Bacteria, molds, pollen, and viruses are types of biological contaminants. These contaminants may breed in stagnant water that has accumulated in ducts, humidifiers, and drain pans, or where water has collected on ceiling tiles, carpeting, or insulation. Sometimes insects or bird droppings can be a source of biological contaminants. Physical symptoms related to biological contamination include cough, chest tightness, fever, chills, muscle aches, and allergic responses such as mucous membrane irritation and upper respiratory congestion. One indoor bacterium, *Legionella*, has caused both Legionnaire's Disease and Pontiac Fever.

These elements may act in combination, and may supplement other complaints such as inadequate temperature, humidity, or lighting.

Some New Research

Research discussed above suggests that new buildings may often result in sickness-inducing environments as pollutants are generated from carpets, paint, and concrete and constructed without regard to chemical compound release. Thus, it is not uncommon for newly occupied buildings to not meet modern ASHRAE standards or LEED standards and result in an increase in SBS where occupants report higher levels of illness. ENERGY STAR-labeled buildings do not necessarily have healthier environments, although we presume that the ENERGY STAR label is correlated with healthier buildings.

Our hypothesis: Green buildings (ENERGY STAR-labeled or LEED-certified) provide more productive environments for workers than non-green buildings.

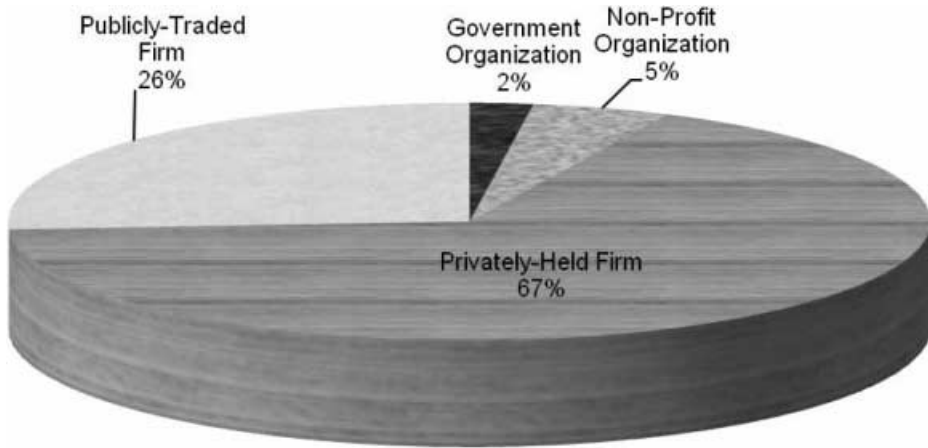
Methodology: We use two measurements of productivity: sick days and the self-reported productivity percentage change after moving into a new building. We admit that this is preliminary, but the data set is far larger than any other previously collected from ENERGY STAR or LEED certified buildings.

Data and Results

In May of 2009 a team from CBRE and the University of San Diego surveyed 154 buildings containing over 2,000 tenants that were deemed green by virtue of either the ENERGY STAR label or LEED certification (at any level). Some 534 tenant responses were collected from buildings spread across the country, as shown in Exhibit 1. Forty-four percent of the buildings were located in the central business district (CBD) while 56% were midtown or suburban; 94% of the buildings were multi-tenant. Most buildings were Class A or A-. Exhibit 2 shows the legal status of the tenant types, predominantly the private sector. Exhibit 3 shows the breakdown of tenants by industry type with the largest being Other at 33%, suggesting we need to pin this down in further research. Of standard categories, financial services and legal were the largest groups. Exhibit 4 shows the years in business, and we can see that most firms have been in business a long time—more than 20 years. Exhibit 5 shows the gross annual pay of employees; the mode group is in the \$50,000 to \$75,000 range while the average was about \$106,644. As shown in Exhibit 6 (see the left bar for the sample group), this figure is far above industry averages, suggesting that green-occupying tenants

Exhibit 1 | Location of Buildings Surveyed



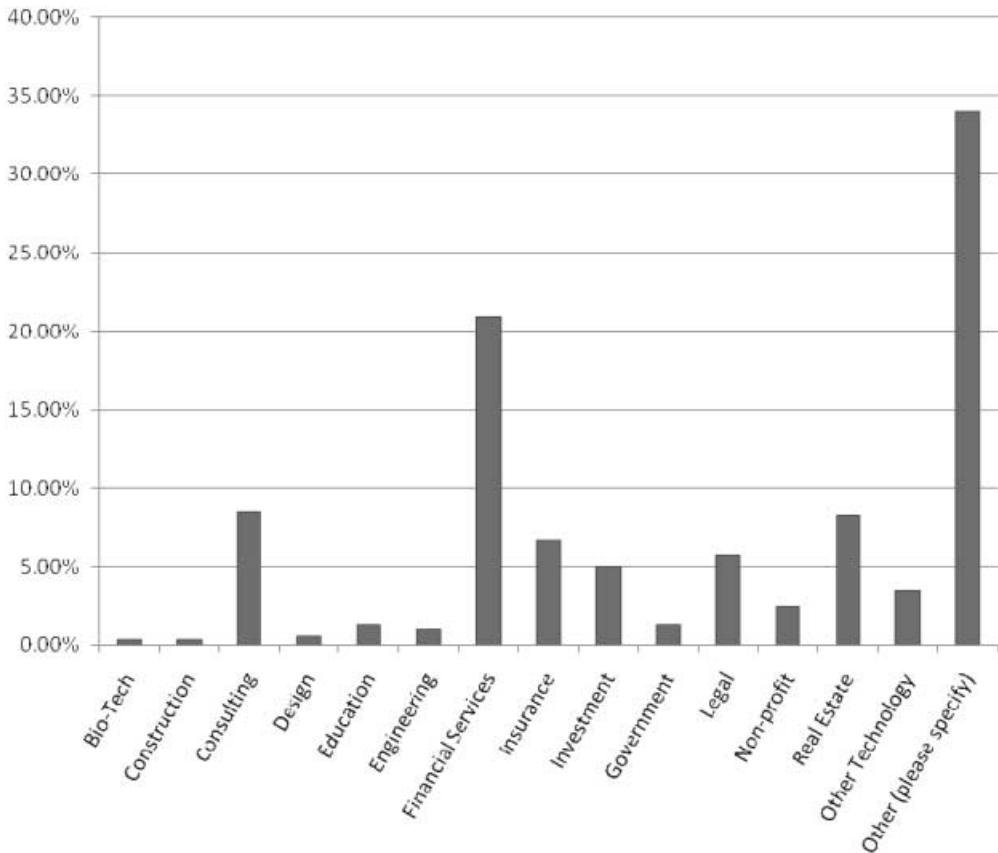
Exhibit 2 | Tenant Types by Ownership Status

Source: CBRE and USD Survey Data 2009.

tend to be from more productive industries. In Exhibit 7, we see some other benefits of occupying green buildings—higher employee morale, lower turnover, and greater ease of recruitment.

With respect to those all important questions on productivity and sick days, we show in Exhibit 8 that 12% strongly agree that employees are more productive, 42.5% agree that employees are more productive, and 45% suggest no change. In Exhibit 9, we see that 45% agree that workers are taking fewer sick days since moving, 45% find it is the same as before, while 10% of those find more sick days. The 10% that reported more sick days were residents of ENERGY STAR-labeled, not LEED-certified buildings. But both LEED buildings and ENERGY STAR buildings have air quality requirements, so we see this result as difficult to explain. It appears that they suffer what often happens to new buildings when ventilation systems are not kept clean or VOCs are not eliminated from new construction materials and finishes. We need to do further work on this 10% to verify why they ran into more sick time, but we should emphasize that these are not LEED-certified buildings. Of those who did find less sick time than before, the mode was two days less sick time, followed by five days less sick time, as shown in Exhibit 10.

Note that not all tenants found productivity increases; the literature suggests that behavioral influences such as management mean as much or more than environmental factors. Note also that these buildings are for the most part ENERGY STAR-labeled buildings and not necessarily LEED-certified buildings. If we take only those tenants who claimed an increase in productivity, we observe economic impacts based on salaries that approach the cost of rent using a very conservative square foot per worker assumption. Total revenue enhancement may be more or less. If we used 200 square feet per worker the results would be closer to or exceed typical rents from this one single impact. The LEED results were

Exhibit 3 | Industry Profile

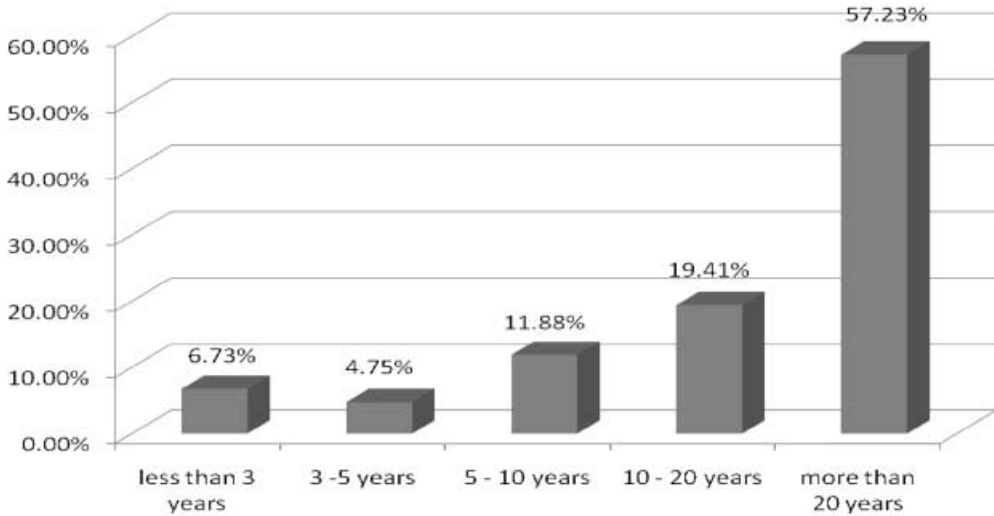
Source: CBRE and USD Survey Data 2009.

slightly better at 5.24% increased productivity but we use the entire sample here. We expect that future data on LEED-certified buildings, which score high on environmental dimensions, will see similar if not better results.

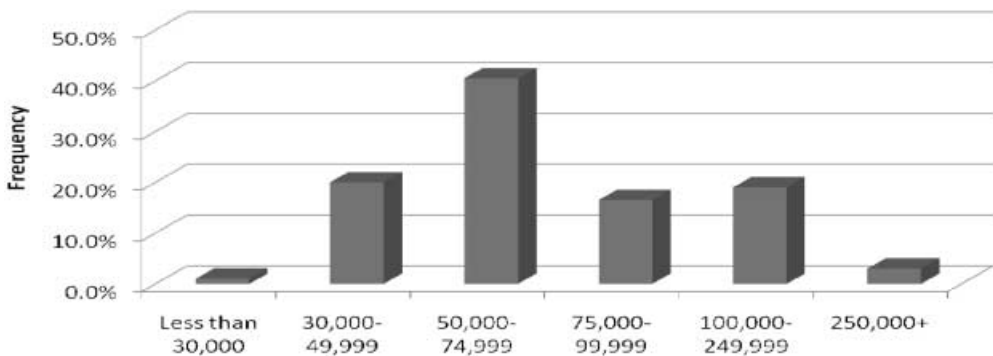
Productivity Impact for Those Tenants Who Claimed Greater Productivity

Average Productivity Increase	4.88%
Average Salary (Note: There are other ways to measure this)	\$106,644
Average Impact Per Worker in Value Add	\$5,204
Net Impact at 250 Sq Ft Per Worker Using Salary as Index (Note: Impact could be more on marginal revenues than this)	\$20.82

Repeating the same analysis using the average sick day declines and excluding the 10% that claimed an increase in sick days, we find potentially another nearly

Exhibit 4 | Number of Years in Business

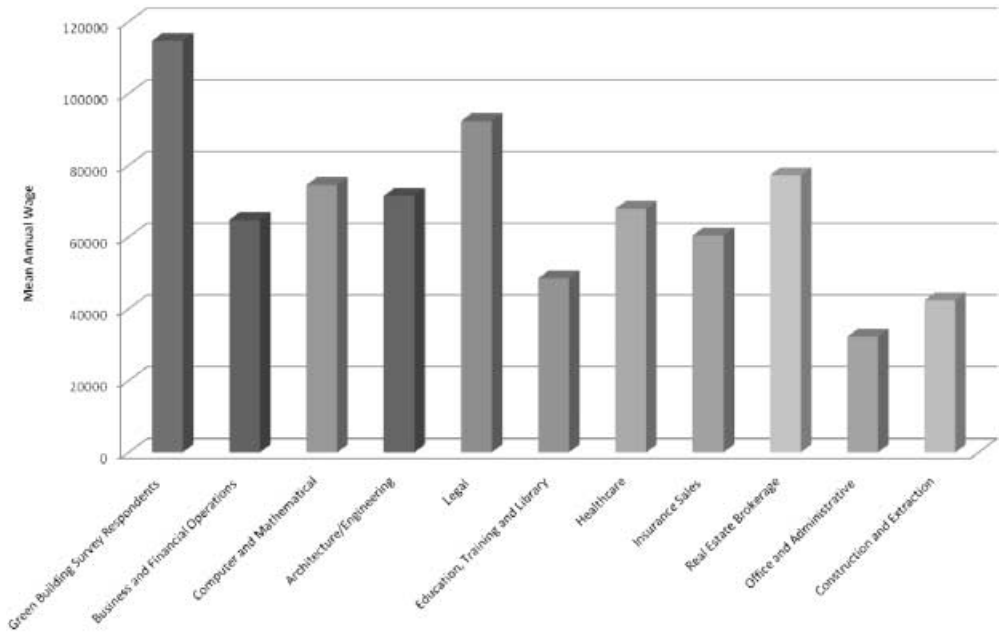
Source: CBRE and USD Survey Data 2009.

Exhibit 5 | Average Annual Gross Pay of Employees

Source: CBRE and USD Survey Data 2009.

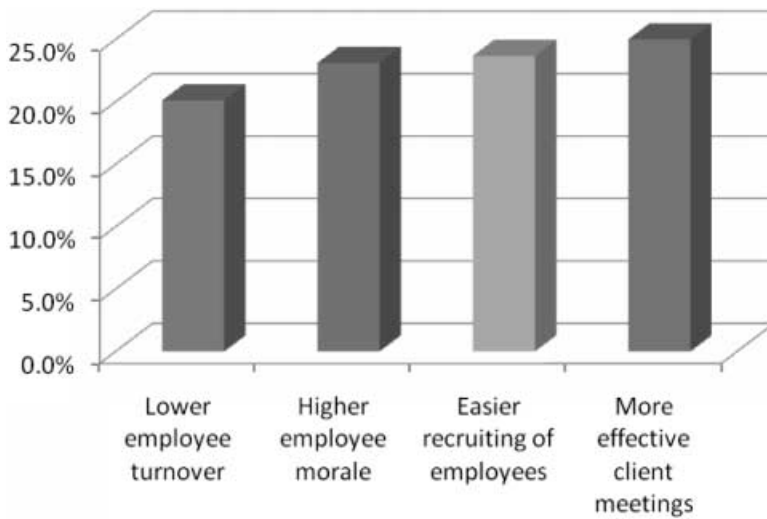
\$5 PSF in economic impact. Again, it would be better to have real productivity impacts based on longer-term revenues, but these are nearly impossible to estimate. We also recognize that simply being located in an ENERGY STAR building does not ensure less sick time. We do know that highly rated LEED-certified buildings (Gold, Platinum) should exhibit fewer sick days with better light, ventilation, and less contaminated, cleaner air.

Exhibit 6 | Mean Wage of Employees in Green Buildings Compared to Industry Averages



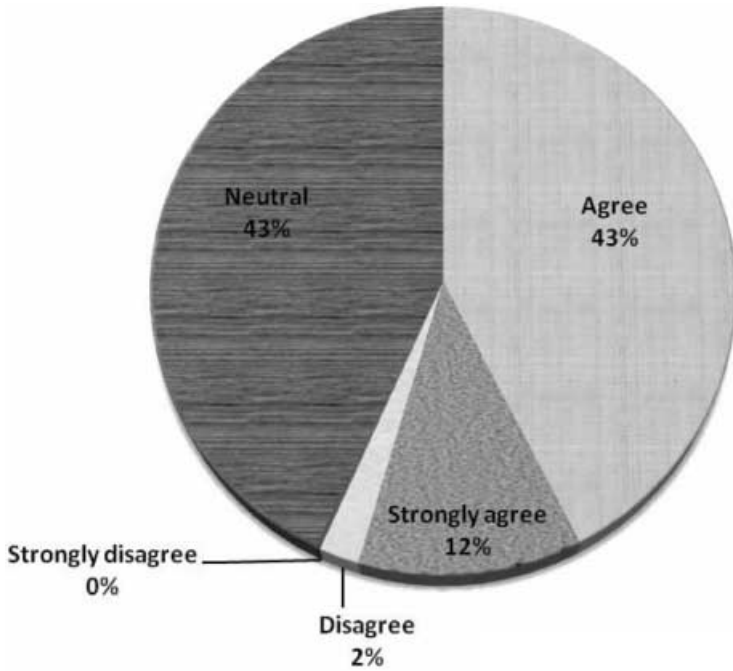
Source: CBRE and USD Survey Data 2009; U.S. Bureau of Labor and Statistics 2008 Occupational Employment Statistics, 2009.

Exhibit 7 | Tenant Perceived Benefits from Occupying Green Space



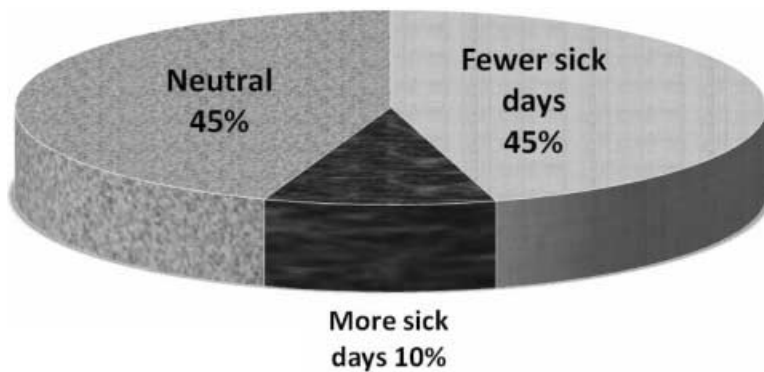
Source: CBRE and USD Survey Data 2009.

Exhibit 8 | Employees are More Productive



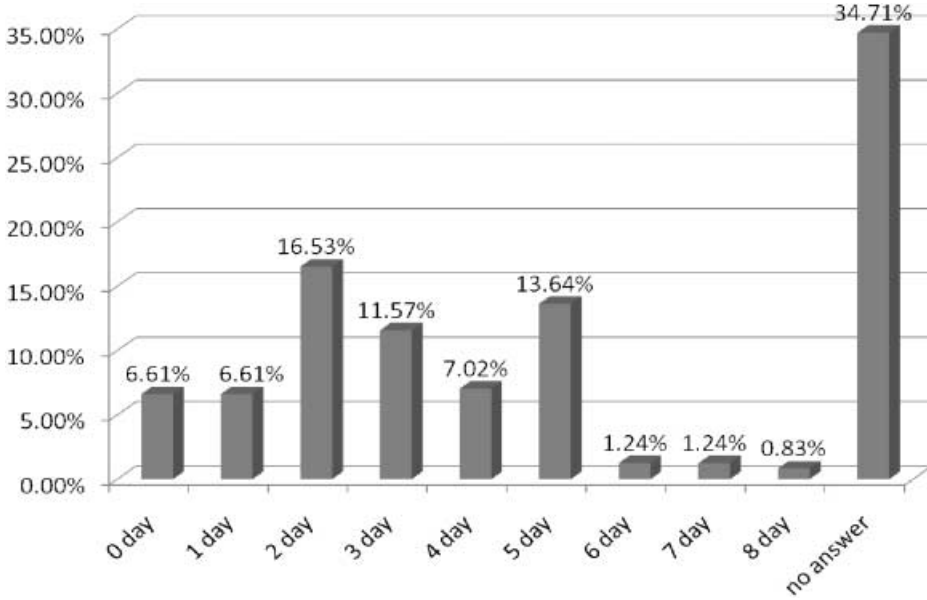
Source: CBRE and USD Survey Data 2009.

Exhibit 9 | Number of Sick Days Taken Compared to Previous Location



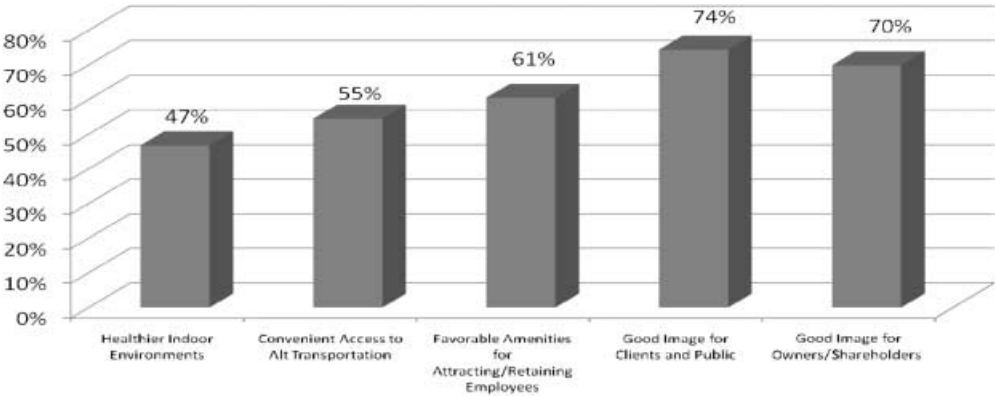
Source: CBRE and USD Survey Data 2009.

Exhibit 10 | How Many Fewer Sick Days are Employees Taking?



Source: CBRE and USD Survey Data 2009.

Exhibit 11 | Other Benefits



Source: CBRE and USD Survey Data 2009.

 Productivity Impact of Fewer Sick Days Using Average Survey Results

Average Fewer Sick Days	2.88
Working Days Per Year	250
Average Salary	\$106,644
Average Impact Per Worker in Value Add	\$1,228.54
Net Impact at 250 Sq Ft Per Worker	\$4.91

Conclusion

In the extreme, tenants tend to look for two kinds of space: as cheap as possible or high-quality space. Those who fall in the middle are often in space they have either occupied a long time or they have placed greater weight on location and other features. Healthier space need not be new space. In fact, some new buildings are extremely unhealthy as chemicals leach into the air from glues, carpets, concrete, and paint. There is no reason this must be the case. The cost to provide healthier environments is modest compared to the benefits.

Healthier buildings reduce sick time and increase productivity. The steps required to provide a healthier building are not that much of a design and engineering challenge. Generally, natural light, good ventilation, and the absence of organic compounds leads to happier, healthier workers. Appropriate temperature ranges or localized controls are also a big plus to workers and past research does support the notion of greater productivity from any or all of these improvements. Sick Building Syndrome should be a thing of the past, but it is not. ENERGY STAR-labeled buildings need not also be healthier, although generally they appear to be. More recently, we are finding a surge in LEED-certified buildings, which tend to require better and safer environments. We now have some evidence that there is an economic pay-off to tenants who pay attention to space quality. If you consider the benefits in terms of recruitment, retention of employees, lower sick time, and greater productivity, tenants should be willing to pay more rent for such space or require steep discounts for less healthy space. We have seen some evidence of rent differentials, even if tenants do not admit to being willing to pay more, and now we see economic support for a differential which will likely persist until all buildings improve environmental workspace quality.

What is increased productivity and reduced sick time worth in net present value terms? The early study by Kats (2003) suggested NPV benefits in the range of \$37 to \$55 per square foot. For an owner-occupied building, we can easily imagine NPVs equal to much more than these figures. For example, discounting \$25 per year per square foot for 10 years at 10%, based on the sum of the two benefits shown above and rounded and assuming a 10-year differential for such benefits and a fairly conservative discount rate, we get a present value of \$153.61 per square foot. It costs much less than this to build a better environment for workers, so the NPV certainly could reach \$100 per square foot or more when an owner-occupant captures those benefits. But when the productivity and lower sick time

benefits accrue to a tenant who does not receive the higher residual building value created by a better building within an informed market, the NPV to tenants is less clear. Tenants should be willing to pay higher rent for better buildings and even though most tenants won't admit to this (84% or more say "No"), we have found evidence in past studies that suggests they do pay premiums and based on the results here, these premiums of only 5% to 10% are a bargain.

Endnotes

- ¹ Perhaps the challenge of developing new ways to measure productivity within knowledge-based work environments is too great for management researchers to solve.
- ² See <http://www.epa.gov/iaq/pubs/sbs.html#Causes of Sick Building Syndrome>.

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