

CREATING A FRAMEWORK TO EXAMINE BENEFITS OF GREEN BUILDING CONSTRUCTION

Kim LaScola Needy, Ph.D., P.E., University of Pittsburgh
Robert Ries, Ph.D., R.A., University of Pittsburgh
Nuri Mehmet Gokhan, M.S., University of Pittsburgh
Melissa Bilec, M.S., University of Pittsburgh
Brett Rettura, University of Pittsburgh

Abstract

This paper will provide a methodology for the cost justification of standard vs. green building construction. Although very little comprehensive analysis has been performed, it is often reported that green construction can result in significant cost savings via improved employee productivity, health and safety; as well as savings from energy, maintenance, and other operational costs. This paper will outline an approach to examine improvements in worker productivity, health and safety, maintenance costs, and energy savings used in an ongoing research project. This project utilizes the PNC Firstside Center, located in Pittsburgh, Pennsylvania, as its case study. The performance of the green building will be compared to standard building cases.

Introduction

During the design and construction of many new building projects, engineering managers are often asked to consider green building construction as an alternative to standard construction. Often the final decision is made based solely on schedules and budgets – the long-term effects are often overlooked. The outcomes of these quick decisions often lead to short-term benefits. It is suggested that it is the engineering manager's duty to carefully compare the added first time costs of construction against the recurring, long-term associated benefits and costs savings and to conduct a more thorough analysis. Several studies suggest green design and construction can result in significant cost savings by gains in employee productivity, reduction in health and safety costs, and savings from energy, maintenance and operational costs. It is proposed that benefits will far exceed any added initial cost of green design and construction.

This research investigates the relationship between the above variables and green building features. The company involved in the project, PNC Bank, is interested in understanding the linkage between green building features and worker health and productivity. In fact, PNC is looking to pursue green design in future facilities. The research proposed in this paper will collect both quantitative and qualitative data in order to analyze the hypothesized relationship. The project, which started in May 2004, is in its preliminary stage, and data collection is expected to be underway during the summer of 2004. Preliminary results will be available for the ASEM Conference in the fall of 2004.

The case study building is PNC Bank's Firstside Center, located in Pittsburgh, Pennsylvania. Firstside Center is a 5 story, 647,000 square foot building. The building was designed by L.D. Astorino Companies, and built by Dick Corporation, with a final construction cost of \$108 million. Firstside Center was completed in September 2000, three months ahead of schedule (Moser, 2003). The purpose of this building was to consolidate both the technology and processing operations into one facility and promote horizontal work flow processes (Astorino, 2003). PNC Firstside Center, with an occupancy of 1800, houses PNC University; O'Brien Family Center, which provides emergency childcare for employees; human resources; routine operations, such as check processing and electronic processing; corporate loan services; and PNC's data communications and telecommunications (Moser, 2003). The United States Green Building Council's (USGBC) 2.0 Leadership in Energy and Environmental Design (LEED) rating system has certified the PNC Firstside Center with a Silver rating.

Benefits of Green Building Construction

Productivity and Health. One of several benefits that green buildings may offer is an increase in individual and team employee productivity. Productivity is defined as the output of any process, per unit of input; so it is directly related to the performance of the process elements, including the workers. A large number of articles and case studies show that there is a strong positive correlation between the work performance of employees and the building in which the process takes place. For example, Romm and Browning (1998) reported eight case studies that show up to 16% in productivity gains between the employees in existing facilities and the employees in remodeled or new facilities designed according to green building principles. Heerwagen (2000) found significant productivity gains and reported that the workers' 'overall [positive] feeling about the environment' increased by 60%. Kats (2003) states various study results that show significant productivity increases both in commercial and educational areas. Wyon (1996) estimated that providing temperature control of ± 3 °C to workers would increase work performance by 3% - 7%. Exhibit 1 shows the estimated potential productivity gains from improvements in indoor environments in the United States (Fisk, 2002c).

Exhibit 1. Potential Savings from Productivity Gains and Health Benefits.

Source of Productivity Gain	Potential Annual Health Benefits	Potential Annual Savings or Gains
Reduced respiratory illness	16 to 37 million avoided cases of common cold or influenza	\$6 - \$14 billion
Reduced allergies and asthma	8% to 25% decrease in symptoms within 53 million allergy sufferers and 16 million asthmatics	\$1 - \$4 billion
Reduced sick building syndrome symptoms	20% to 50% reduction in health symptoms experienced frequently at work by ~15 million workers	\$10 - \$30 billion
Improved performance from thermal and lighting changes	Not applicable	\$20 - \$160 billion

Employee salaries constitute the major ratio of overall office buildings' expenditures. According to Kats (2003), employee cost is 89% of the total building costs and it is roughly 10 times the property related costs. Exhibit 2 (Kats, 2003) gives the distribution of building costs. Therefore, a 1% increase in employee productivity would equal about a 10% decrease in property costs.

Exhibit 2. Costs in California State Employee-Occupied Office Buildings.

Cost Drivers	Percentage in the Total Building Costs
Employee	89 %
Rent	6 %
Operations & Maintenance	4 %
Electricity	1 %

Health-related problems constitute the major portion of reasons that lead to lower productivity. Health problems affect the productivity of employees directly in the work area or indirectly by causing absenteeism. Direct effects of health problems on productivity can be identified as employee discomfort. For example, allergies, sneezing, drowsiness, feeling tired and similar symptoms might be related to health problems caused by low indoor environmental quality (IEQ). All these symptoms cause discomfort and may reduce productivity. As described above, Fisk (2002c) reported potential productivity loss due to these kinds of health problems. Absenteeism is an indirect effect of health problems on worker productivity. Absenteeism due to health problems is called "sick leave" in the literature meaning that employees do not show up for or leave work because of a particular health problem. Studies show that sick leave is one of the primary sources of low productivity.

Since, on average, people spend 80% to 90% of their time in buildings, indoor environmental quality is an important building feature. Air quality, ventilation, temperature control, natural lighting, office material / furniture quality are some of the green building aspects

that directly affect IEQ. IEQ "refers to the interactions among many factors in indoor environments, including the quality of the air (e.g., air flow, the presence of chemical or microbiological agents), physical conditions such as temperature and humidity, ergonomic factors, and stressors from social/psychological or work organizational factors" (NIOSH, 2004). Fisk (2002c) summarizes two studies about IEQ and related health and productivity gains which report potential productivity gains (in 1996 \$US) from \$6 - \$14 billion by reducing acute respiratory illness, from \$1 - \$4 billion by reducing allergies and asthma, and from \$10 - \$30 billion by reducing sick building syndrome (SBS) symptoms. Direct productivity gains from better lighting and temperature control, without affecting worker health, are also reported to be \$20 - \$160 billion, considering only U.S. office workers. Wide research has been conducted on the relationship between health problems and IEQ levels. For example, Wargoeki et al. (2000) report that as the ventilation rate increases, perceived air quality and productivity improve when the intensity of SBS symptoms decrease. Menzies and Bourbeau (1997) list some building related illnesses such as allergies, irritations, and infectious diseases and provide their sources related to the buildings with the support of several case studies. Milton et al. (2000) found consistent associations of increased sick leave with lower levels of outdoor air supply and IEQ complaints. They also reported a loss of productivity of \$22.8 billion per year on a national scale. Fisk (2000, 2002a, 2002b) and Fang et al. (1998) provide further information about IEQ, worker health and productivity.

Maintenance and Energy. Maintenance and energy savings are some other potential benefits of green buildings. For example, an office building in Cambria County projected potential savings of \$843,759 over the study period. Another example is Herman Miller, the furniture manufacturer, which projected \$6 million in savings over a seven-year lease. Herman Miller has also estimated reductions of 33% building costs, 41% operating costs, and 66% churn costs (GBA, 2003).

The Firstside study will provide another comparison in the green construction realm.

PNC Firstside Design and Construction Overview Site Selection and Environmental Considerations.

The PNC Firstside project began with site selection. The selection of the PNC site established the environmental tone for the project. PNC elected a brownfield site, over 17 other possible locations. The 4.9-acre site, a former railroad station, is located in Pittsburgh's central business district, and was selected for the following reasons: (1) the size and shape of the site promoted a more efficient horizontal work flow environment, (2) proximity of public transportation, both a light rail station and bus routes, (3) proximity of public parking, (4) access from major highways, (5) location of adjacent bike trail, and (6) views of the Monongahela River and Mount Washington. If PNC chose a site in the suburbs, then approximately 20 acres for parking and storm water control would be needed; furthermore, the commute imposed additional environmental considerations (10,000 Friends, 2004). A 2003 Brookings Institution study states "Pennsylvania's population grew by just 2.5 percent between 1982 and 1997, but its urbanized footprint grew by 47 percent over that time. That meant that the third-slowest-growing state in the country developed the sixth-largest amount of land." (2003, 10).

Design Process. After site selection, it was decided to create a sustainable framework to guide the design and construction process. The Pittsburgh-based Green Building Alliance (GBA) was a catalyst for promoting sustainability in the project. The GBA encouraged LEED certification, and presented the benefits of a green building, including improvement of the bottom line, to the owner and the design and construction teams.

The USGBC's Leadership in Energy and Environmental Design (LEED) rating system provided a framework for the design team. What is LEED? LEED is a consensus based certification program created by the USGBC to define 'green building', promote integrated buildings, recognize environmental leadership, stimulate green competition, raise consumer awareness, and transform the building market (USGBC, 2004a). LEED is an evolving rating system with increasing acceptance by the architecture, engineering, and construction industry. It is a point based system with four different levels of certification: Certified, Silver, Gold, and Platinum. There are five broad areas in which LEED attempts to reduce or eliminate the negative impacts of buildings on the environment: (1) sustainable site planning, (2) safeguarding water and water efficiency, (3) energy efficiency and renewable energy, (4) conservation of materials and resources, and (5) indoor environmental quality (USGBC, 2004b). The LEED rating system also recognizes design innovation.

With a commitment from PNC management, the design and construction project team decided to pursue a LEED rating. In addition, the team used economic analysis to compare different design decisions and had a two-year payback requirement (Moser, 2003). In September 2000, PNC Firstside Center was awarded a Silver rating in the 2.0 version of LEED.

Green Features. As indicated previously, PNC's first step towards environmental stewardship was the decision to select a more sustainable site. This selection, along with alternative transportation, provided a basis for several LEED points. In addition, the Firstside Center installed an innovative stormwater management program and reduced the building's heat island effect by utilizing light colored/high-albedo materials on portions of the site's non-roof impervious surfaces. In terms of water efficiency, the sub-surface irrigation system reduces water use by 50%, and water conserving fixtures were installed. (USGBC, 2004c)

Other key features related to the building interior are the hybrid HVAC system, the raised plenum floor, and the use of shaded glazed areas for daylighting. The hybrid HVAC system combined ventilation from under the raised floor with reconditioning from an overhead system. The building's use of raised accessible flooring with releasable adhesive carpet tiles and workstations can improve air quality, reduce the cost of churn, and minimize the use of future material resources. The atrium and the light wells provide natural light into the building's core while exterior sun shading and interior window coverings to reduce glare and heat gain.

Commissioning and Performance. In order to ensure the building was functioning according to the design, the Firstside Center was commissioned. Commissioning, ensuring all the components of the building are functioning properly, is a prerequisite for LEED's Energy and Atmosphere, which this building achieved along with an additional point for additional commissioning. It has been cited that green features can lead to significant cost savings of energy, operational, and maintenance costs (Romm and Browning, 1998). Now that PNC Firstside Center has operated for about four years, it is the goal of this research team to attempt to evaluate the performance of the building, both quantitatively and qualitatively.

Research Approach and Methodology

An 18-month research project is underway to conduct a comprehensive and rigorous analysis to measure the benefits of the green building construction of PNC Firstside Center. A team of researchers from the University of Pittsburgh departments of Industrial Engineering and Civil and Environmental Engineering will collect and analyze data in five major areas of improvement: (1) gains in worker productivity, (2) reductions in health and safety costs, (3) improvements in indoor environmental quality, (4) reduction in

maintenance costs, and (5) energy savings. The data will be both quantitative and qualitative in nature. The purpose of the data collection is to determine a relationship between IEQ, productivity, and health and safety. In addition, the life cycle cost of employees and building operational costs such as maintenance and energy will also be estimated.

Firstside Center and its employees will be benchmarked against other PNC facilities. These other sites will serve as the controls for the study. The other buildings were built to typical commercial building standards and do not have the green building features of PNC Firstside. The employees in the other PNC facilities perform similar functions. Another data point will be the PNC Firstside employees in their previous buildings, i.e., before the move to Firstside. These buildings also did not have distinguishing green building features.

Productivity Measurement. The productivity analyses are carried out both in check process and office work areas. We will attempt to analyze both blue and white collar workers. Employee satisfaction surveys, data collection, and direct observation are used as measurement methods for productivity. In the office work area the nature of the jobs may necessitate the use of qualitative measures. This area is occupied by the employees who are managers, administrators, professionals, engineers, and technical specialists. Most of the work is done at the individual desks by using computers. The productivity of office workers is analyzed through employee satisfaction surveys, focus groups and interviews. The check processing area, which is not office-type work, is another productivity measurement area. One reason to analyze this area separately is that the actual work area is located in the basement of the facility, so it differs physically from other areas of the facility. For example, in the check processing area, workers do not have access to daylight. However, several green building concepts are also employed in this area, such as temperature, air speed and volume control, so the effects of the green building on the employees in the check processing area may be evaluated. Several existing measures of productivity are used by PNC for the check processing area. These measures are quantitative in nature such as the number of checks processed per unit time.

Health Measurement. Data, including reported health problems and sick leave information as well as costs associated with these values are gathered from an existing PNC database. Absenteeism data will be gathered and analyzed to compare the same employees pre- and post-move as well as compared to employees in the control buildings. Absenteeism due to illness is analyzed separately to investigate the effects of the green building features on employee health and productivity. Absenteeism not related to health is analyzed to compare other green building aspects such as the ease of transportation, comfort of the work

environment, and the provision of additional services (child care, cafeteria, etc.). Health insurance costs are another cost driving part of the employee costs. The effects of the green building on health insurance costs are investigated in this study. As green buildings are expected to have positive effects on employee health, effects on health insurance costs are also expected. The insurance cost data is collected and compared to pre-movement costs and the control facilities' health insurance costs.

Indoor Environmental Quality (IEQ) Measurement. The Firstside Center attempted to improve indoor conditions by increasing the effectiveness of the ventilation system, installing low-emitting materials, and providing 90% of the space with daylighting and views. In terms of sustainable design, the Firstside Center was lauded for its energy efficiency, raised flooring system, and the innovative HVAC system. Furthermore, LEED recognized these features in the rating system. We will attempt to quantify the results by collecting data related to maintenance costs, energy savings, and IEQ. The IEQ information will be reconciled with productivity and health.

Air quality within the office and check processing areas is measured in order to analyze its effects on employee health and to provide a basis for comparison with the other control facilities. The data collection for determining the indoor environmental quality will be done by physical measurements of spaces in terms of air temperature, air speed, air humidity, glare, light levels, and carbon dioxide levels. In parallel with the data collection related to productivity, the blue and white collar areas will be physically tested. Furthermore, general observations and conversations with employees may lead to specific areas requiring more detailed investigation. The duration and method of physical testing will be determined after access and equipment are identified.

Building Performance Measurement. Qualitative data for the building performance will be collected through surveys, interviews, and focus groups. The main focus for building performance will relate to indoor environmental quality. Since psychological factors can “override the strictly physical or physiological ingredients that determine how an individual experiences the surrounding environment (Heerwagen, 2004, 59),” the qualitative data will assist in potentially reconciling the physical results compiled in the quantitative building section. Another area that will be explored is the relationship between the employees' understanding of a green building, its proposed benefits, and the employees' response to the proposed benefits. It will be important to differentiate between green features and other building amenities.

Energy and Maintenance. PNC Firstside received four LEED points for “Optimizing Energy Performance.” It is the intent of this research to

quantify the savings, if any, by means of collecting energy use data for the building operation to date. These results will be compared on a per square foot basis with both the previous buildings and the control buildings. It has been estimated that the building will be 33% more energy efficient than the largest building previously occupied by the employees in Pittsburgh (Moser, 2003).

In terms of maintenance, we will attempt to understand the maintenance procedures and attempt to quantify the savings associated with a reduction in churn costs, everyday maintenance costs, and long-term maintenance costs. One of the key elements is expected to be the ease of network reconfigurations. The data will be collected by first interviewing the key facility maintenance personnel and compiling costs associated with maintenance items.

Total life cycle cost of both maintenance and energy will be estimated. This result will be compared with the control buildings and other published studies.

Conclusions

This paper creates a framework to examine benefits of green building construction. Worker productivity and health are analyzed for both blue and white collar employees, who often benefit from different green features of the building. IEQ, maintenance costs and energy costs are compared to pre-move costs. All the results are also benchmarked with a standard building in which similar job functions are performed. Cost analysis of resulting data and life cycle costing of the green building are also investigated. The project, on which this paper is based, is in progress. As further progress is made, additional results will be shared at the presentation, including implications for the engineering manager.

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About the Authors

Kim LaScola Needy is an associate professor of Industrial Engineering at the University of Pittsburgh. She received her B.S. and M.S. degrees in Industrial Engineering from the University of Pittsburgh, and her

Ph.D. in Industrial Engineering from Wichita State University. Prior to her academic appointment, Dr. Needy accumulated nine years of industrial experience while working at PPG Industries and The Boeing Company. Her research interests include activity based costing, engineering economic analysis, engineering management, and integrated resource management. Dr. Needy is a member of ASEE, ASEM, APICS, IEEE, IIE, and SWE. She is a licensed P.E. in Kansas.

Robert Ries is an assistant professor of Civil and Environmental Engineering at the University of Pittsburgh. He received a B. Arch. Degree from Pratt Institute and M.S. and Ph.D. from Carnegie Mellon University. Dr. Ries's primary research work is focused on improving the environmental performance of buildings, with a concentration on environmental impact assessment methods, indoor environmental quality, lighting, thermal comfort, and benefit-cost analysis of high-performance building systems.

Nuri Mehmet Gokhan is a doctoral student in Industrial Engineering at the University of Pittsburgh. He received his B.S. and M.S. degrees in Industrial Engineering from Istanbul Technical University and Sabanci University, respectively. His doctoral research interests are cost analysis of green construction and supply chain management. He is a member of IIE.

Melissa Bilec is a doctoral student in Civil Engineering at the University of Pittsburgh. She received her B.S. and M.S. degrees in Civil Engineering from the University of Pittsburgh. Prior to the doctoral program, Ms. Bilec worked for five years as a project engineer at the Urban Redevelopment Authority of Pittsburgh, where she managed the design and construction of building and infrastructure projects. Her doctoral research focuses on green construction and life cycle assessment.

Brett Rettura is an undergraduate student in Computer Engineering at the University of Pittsburgh. Brett is a ResCon Technology Representative of the University of Pittsburgh. He is also currently an acting chair and member of the IEEE. Brett is active in undergraduate research with the Mascaro Sustainability Initiative in Sustainable Engineering.

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