

DESIGN, PRODUCTIVITY AND WELL BEING: What are the Links?

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There is growing recognition that to be truly effective, a facility will need to succeed across three interrelated domains: environmental sustainability, organizational effectiveness, and human well being. There is also a growing consensus among the sustainable design community that “green” buildings may be a vehicle by which benefits in all three domains can be achieved.

This article will draw upon the conceptual framework and results from a study funded by the U.S. Department of Energy (Building, Technology, State and Community Programs) to identify and assess the “ancillary benefits” of green buildings. Ancillary benefits are defined as unexpected, or hidden, positive outcomes that accrue as a result of the green building, but which are not directly related to its energy efficiency and green features. The project analyzed both individual and organizational level outcomes.

Central to a building’s success is its impact on people, individually or collectively. In order to identify and assess the how a green building could positively affect people, we drew on research and theory in psychology, biology, and behavioral ecology. The first step in this process was to identify key dimensions of success at the individual level of impact. We then worked backwards to identify what is known or hypothesized about the specific features and attributes of green buildings that influence the selected dimensions. At the organizational level, we followed the same process: identifying the major dimensions of organizational effectiveness and then working backwards to identify how building features and attributes might influence these dimensions. The following sections present more details on this process.

Buildings, Human Performance, and Well Being: A Conceptual Framework

At the individual level, a highly effective facility is one that has positive impacts on work performance, psychosocial well being, and health. This section discusses how a building can potentially affect each of these outcome areas. It is useful to begin with a discussion of well being because it is less well understood than performance and health.

Biologist Stephen Boyden (1971), in an article on the biological foundations of well being, distinguishes between “survival needs” and “well-being” needs. Survival needs deal with aspects of the environment that directly affect human health, such as clear air and water, lack of pathogens or toxins, and opportunity for rest and sleep. Well-being needs, on the other hand, are more indirect in their locus of impact.

These needs affect overall health through their relationship to fulfillment, quality of life, and psychological health. Where failure to satisfy survival needs may lead to serious illness or death, failure to satisfy the well-being needs produces the “gray life” of psychosocial maladjustment and stress related illnesses. Among Boyden’s well-being needs are several that are directly relevant to building design. These include:

- ? Opportunity to engage in spontaneous social encounters
- ? Freedom to move between one social phase and another (from solitary work to group interaction)
- ? Opportunity to engage in a full range of species typical behaviors (creativity, self expression, cooperation, exploration)
- ? Opportunity for regular exercise
- ? Noise levels not much above or below that in nature
- ? Meaningful change and sensory variability
- ? An interesting visual environment

The biological approach espoused by Boyden also forms the basis for a number of other theoretical perspectives relevant to design and well being (Orians and Heerwagen, 1992; Heerwagen and Orians, 1993; Kaplan and Kaplan, 1989; Ulrich, 1993; Kellert and Wilson, 1993; White and Heerwagen, 1998). Although each of these researchers approaches the topic from a different perspective, the common thread uniting their theories is captured in the concept of “biophilia” -- the evolutionary tie between people and nature. Taken as a whole, this diverse body of research suggests that building environments that contain the essential features of preferred natural settings will be more supportive of human well-being and performance than environments lacking these features. The research on nature is especially relevant to green buildings because many of the leading proponents link their ideas and designs to the vital ties between people and the natural world. Because this literature has not been well integrated into building design, a summary of key ideas is presented below.

Buildings as Habitats for People

Central to our approach is the recognition that buildings are habitats for people. Thus their features and the behaviors they enable or constrain can be framed within the context of habitat selection. For most organisms, being in “the right place” is an important determinant of survival and well being. There is no reason why this should be different for humans.

Drawing on habitat selection theory, Orians (1980) argues that human environmental preferences should correspond to the features of the ancestral savanna environment that enabled *Homo sapiens* to flourish. The savanna landscape form has clustered trees and semi-open spaces, refuge from excessive solar gain and rain (from spreading tree canopies), and high levels of visual access, especially views to the horizon, which supported visual surveillance and planning of distant moves. Even though we now live primarily in urban settings dominated by buildings, there is increasing cross-cultural evidence that that savanna like environments are preferred

over other habitat types. Furthermore, natural environments are consistently preferred over built settings, and built environments with trees, vegetation, and water are more liked than those lacking natural elements (Ulrich, 1993; Kaplan and Kaplan, 1989). Our evolutionary history in natural environments appears to have also made us especially attentive to the patterned complexity of natural forms (Humphrey, 1980). These features also characterize many buildings of consistent historical appeal (Hildebrand, 1991)

Given our affinity for nature, it is hardly surprising that many large building complexes create indoor parks with large trees and plants, water features, daylight, multiple view corridors, an interior “big sky,” and comfortable retreats. Builders and developers would be disinclined to invest in such costly aesthetic touches if they didn’t believe such “amenities” had positive payoffs.

Natural comfort

A biological perspective also contributes important insights into comfort maintenance. Two issues are key to understanding the importance of our natural history. First, people differ from one another in their ambient preferences (inter-individual differences). These differences result from a combination of influences, including cultural experiences, life styles, genetic differences, gender. Second, a given person varies over time depending upon their state of health, activities, clothing levels, and so forth (these are intra-individual differences.) For most of human history, people have actively adjusted the environment as well as their behaviors to achieve comfort. Yet buildings continue to be designed with a “one size fits all” approach. Very few buildings or workstations enable occupants to control lighting, temperature, ventilation rates, or noise conditions. Although the technology is largely available to do this, the advanced comfort systems have not sold well in the market place, even though researchers are beginning to document human performance benefits associated with these technologies (Kroner et al, 1992).

Ephemeral Qualities of Space

In addition to these spatial features of the environment, our ancestors also needed to be attentive to ephemeral stimuli associated time and weather. These stimuli include changes in daylight (e.g., color, shadows, brightness contrasts, sun angle) and thermal/haptic sensations associated with direct sun, wind, and humidity. Even today we use ambient conditions as an intuitive guide to behavior. For instance, the smell of the air, the color of the clouds, and wind speed are good predictors of how immanent a storm is. Although perception of sensory variability evolved for survival purposes, it continues to be a critical part of people’s responses to buildings. Increasing evidence shows that people prefer moderate levels of patterned complexity and sensory variability in the environment (Humphrey, 1980; Platt, 1961). An environment devoid of sensory stimulation and variability can lead to boredom and passivity (Cooper, 1968; Schooler, 1984). The sensory variability in the natural environments also enables people to actively select conditions that fit their current needs and desires – e.g., the warmth of the sun when they are cold, or

the comfort of a tree canopy if they are too warm. Building interiors seldom offer such personally adaptive possibilities.

Stress Reduction, Health and Well-being

Studies by Roger Ulrich (1993, 1984) have consistently found stress reducing and health promoting outcomes associated with passive viewing of nature stimuli through windows, videos, and photographs. R. Kaplan (1992) reports similar results in a field study of office workers. Kaplan found that workers who had window views of nature felt less frustrated and more patient, and reported more overall life satisfaction and better health than workers who did not have visual access to the outdoors or whose view consisted of built elements only. The positive effects of nature may also extend to the immune system, thereby directly affecting human physical health (Parsons, 1991).

In contrast to the enhancing effects of nature, buildings can also have negative impacts on health. Of particular importance are ambient conditions, including noise, temperatures, air quality, and lighting. Uncontrollable noise or excessive temperature conditions have been linked to stress symptoms and irritability (Heerwagen et al, 1995), while lighting that produces glare or visual discomfort is more likely to be associated with headaches and eye problems (NRC, 1983).

The problem that has received the most attention is indoor air quality. Building attributes that directly influence health include air borne toxins and noxious chemicals associated with materials and finishings, cleaning products, and equipment; noxious and hazardous substances associated with work processes; and air borne pathogens associated with HVAC systems.

Enhanced indoor air quality from reduced use of toxic and noxious materials is a core feature of green buildings. Improved IAQ is also central to the arguments about ancillary benefits. According to a model developed by Fisk and Rosenfeld (1997), improved air quality could result in significant reductions in illness and absenteeism associated with respiratory disease, asthma and allergies, and sick building syndrome symptoms. They estimate productivity gains of \$17 billion to \$164 billion annually associated with improved air quality. They also estimate improved worker performance from enhancements of the thermal environment and lighting to be in the range of \$12 billion to \$125 billion annually.

Summary of Implications for Health and Well-being

To fully understand the relationship between buildings and people, we need to integrate traditional building science emphasis on ambient conditions with an understanding of the evolutionary pressures that underlie environmental preferences and experiences. We also need to recognize that our ties to nature are deep and enduring; when we sever these ties we create conditions that are contrary to basic human needs. The key insights from the research presented in this section include:

- ? Buildings that integrate, in an analogous manner, the features and attributes of preferred natural settings and nature stimuli are more likely to be supportive of

human health and well-being than buildings which lack these features. Naturalistic building features include daylight, views to the outdoors, presence of green vegetation indoors or in views, and some degree of sensory variability in ambient conditions across time and space (as long as the variability is not so extreme that it creates discomfort or interferes with work).

- ? Certain spatial and ambient features of savanna habitats are also important for human emotional functioning. These include a balance between visual access and visual enclosure, visual perspectives that are primarily horizontal rather than vertical, presence of tree-like forms (especially an overhead “canopy”), and multiple retreats.
- ? Building factors most likely to influence health and safety are: the presence or absence of toxins and pathogens in building materials and systems; the degree to which toxic or noxious substances are used in work processes; and quality of lighting, especially lighting for computer work.
- ? Well-being, on the other hand, has to do with quality of work life, motivation, psychological state and social support. The research presented here suggests that impacts on well-being may come from a different set of features – such as presence of daylight and windows, opportunities for active and passive contact with nature, sensory change and variability, and opportunities for relaxed enjoyment of the environment.
- ? Active comfort maintenance has evolutionary origins, and research evidence shows that the ability of people to adjust the ambient environment to their own preferred levels may influence work performance.
- ? Many green buildings intuitively incorporate at least some of these preferred naturalistic features, with the assumption that they are good for people and for the environment.

Buildings and Worker Performance

A useful way to conceptualize the relationship between buildings and performance is to draw upon a highly used framework in organizational psychology:

$$\text{Performance} = \text{Ability} \times \text{Motivation} \times \text{Opportunity}$$

Performance is viewed as a function of these three factors acting together: ability, motivation, and opportunity. *Ability* deals with whether or not a person *can* do a task, while *motivation* is a measure of whether or not a person *wants to* do it. *Opportunity* relates to accessibility -- a person can't do a task if he/she is not given a chance or if he/she is denied access to needed resources or amenities. Thus, any study of a building's impact on performance must take all of these factors into account.

How can a building affect these three dimensions of performance?

- ? A building can positively affect “*ability*” by providing comfortable ambient conditions, by enabling individual control and adjustment of conditions, and by reducing health and safety risks. Negative impacts on ability to do work are

associated with conditions that are uncomfortable, distracting, hazardous, or noxious.

- ? A building can positively affect “*motivation*” by providing conditions that promote positive affective functioning, psychological engagement, and personal control. According to George (1989), moods create the “affective context” for thought processes and behaviors and are directly tied to motivation.
- ? A building can affect “*opportunity*” by providing equitable access to conditions that reduce health and safety risks, equitable access to amenities, and compensatory design options where inequities exist and are difficult to eliminate entirely.

A building can have both positive and negative effects on performance (Aronoff and Kaplan, 1995). Negative effects are associated with discomforts, distractions or health risks that interfere with peoples’ ability to do their work. A great deal of attention has been devoted to understanding these problems and to reducing them in building design and operation. However, the mere absence of problems does not mean that a facility has what it takes to enhance performance. Performance enhancement is more likely to come from a different suite of building features. Especially relevant are features and attributes of the building that influence motivation, social functioning, emotional experience, and work attitudes.

Unfortunately, research in environmental psychology has tended to focus on the negative impacts of buildings -- noise, heat, glare, crowding, poor indoor air quality -- with the unstated assumption that high performance and well-being will be achieved if problems are eliminated. It may be true that problems diminish when stressors are eliminated, but to assume that removal of noxious stimuli or conditions is sufficient overlooks the design work that may be required to generate truly positive experiences at work. Indeed, as the literature cited below indicate, performance and well being appear to depend not only on the *absence* of significant problems, but also on the *presence* of particular kinds of features and attributes in buildings.

Building features and attributes affect performance in both direct and indirect ways. For instance, a direct effect would be glare on the computer screen that interferes with the ability to see written words or numbers. An indirect effect, on the other hand, operates through an intermediate mechanism such as mood or motivation. A frequently cited example is the positive impact of daylighting on mood. The assumption is that daylight makes us feel good and therefore should make us more motivated to work. Although there is no empirical data to support this belief, it is not an unreasonable hypothesis given the research on emotional functioning and performance.

Links between Nature, Emotional Functioning and Performance

In one form or another, nature is a dominant feature of green buildings. Whether nature's presence comes from daylight, fresh air, indoor plants, or landscape views, there is growing evidence of positive impacts on building occupants. Most of the studies have focused on emotional states and stress reduction (see Ulrich 1993 for a review). However, there is growing evidence of a strong linkage to cognitive functioning.

For instance, a recent experiment by Lohr (Lohr et al, 1996) found that subjects working in a windowless room with plants worked more efficiently, had lower blood pressure readings, and felt more attentive than subjects working in the same room without plants. In another study varying window views, Tennessen and Cimprich (1995) found that people whose view was predominantly natural (as opposed to built) scored better on tests of directed attention. Hartig and colleagues (1991) report similar results in a field experiment. People who went for a walk in a predominantly natural setting performed better on several attentional tasks than those who walked in a predominantly built setting or who quietly read a magazine indoors. These results, coupled with work on stress reduction by Ulrich (1993) strongly indicate that green buildings that incorporate natural vegetation are likely to have positive benefits on both well being and performance. At the present time, the exact psychological and physiological mechanisms that lead to such effects are not known. However, Ulrich suggests that a critical dimension is the relationship between contact with nature and positively toned moods.

Positive moods turn out to be critical for a wide range of outcomes of interest to this study, including job satisfaction, work involvement, motivation, organizational attachment and lowered absenteeism (Mitchell, 1989). Clark and Watson (1988) found that positive moods are associated with the physical setting at work and with daily events (especially social interactions among workers), while negative moods are associated with daily hassles (such as discomfort and distractions).

Studies by Alice Isen (1990; Isen et al, 1987; Moore and Isen, 1990) show that positive moods also have numerous beneficial impacts on cognitive and social functioning. Isen's studies have found that positive moods are associated with:

- ? Enhanced discriminative learning and more efficient decisional processes on complex tasks.
- ? Greater use of inductive rather than analytic heuristics in problem solving.
- ? Higher joint benefits in negotiations and more innovative approaches.

Complex cognitive strategies are less likely when people are depressed, unhappy, or stressed. This is because negative moods or stress tend to restrict attention and lead to stereotypic responses. Daily irritants, including discomforts, tend to generate high negative affect and thus are likely to interfere with higher level cognitive functioning (Clark and Watson, 1988).

Isen (1990) speculates that positive moods increase the tendency to “break set” and to see relatedness between divergent events or appearances. This is because feeling good promotes diffuse rather than focused attention and this leads people to see things differently (e.g. people notice more details) or to search more broadly for solutions and alternative interpretations. Joseph LeDoux (1996), one of the nation’s leading brain researchers, cites neurological evidence to support this hypothesis. He has found that positive feelings lead to heightened activity of the right parietal brain region – the section of the brain that is associated with a more global, expansive cognitive style. Thus, positive feelings directly affect brain processes related to performance on tasks requiring creativity and novel problem solving.

Building Features and Cognitive Functioning.

Although Isen and LeDoux do not discuss the specific aspects of the environment that influence positive feelings and cognitive processes, we know from the research on nature that non-threatening, aesthetically pleasing natural settings elicit positively toned moods and physiological restoration. It is not unreasonable to expect that similar results would be true of buildings that incorporate naturalistic features, either literally (through contact with nature) or through design features that mimic the key aesthetic and sensory characteristics of preferred natural environments (Orians and Heerwagen, 1992; Hildebrand, 1991).

Another potential mechanism linking building attributes to performance is cortical arousal. Arousal is important to attention, memory, perception, and problem solving. Without some degree of arousal, we simply don’t notice what is happening or we miss important details. However, with too much arousal, the brain can’t work efficiently. This suggests that the design of work settings needs to take into consideration the arousal potential of environments. In general, the relationship between arousal and performance shows an inverted U-shape. That is, too little arousal as well as too much arousal is associated with low levels of performance; optimal performance occurs at intermediate levels of arousal. Although this general relationship appears to be quite strong, the optimal level and type of arousal is related to the task and to individual differences (such as personality and age).

High levels of arousal are associated with information overload and environmental stressors (such as heat or noise stress), especially when they cannot be controlled or avoided. Low arousal is associated with information “underload,” and with monotonous and repetitive sensory stimulation.

Research at NASA suggests that arousal maintenance may be an important characteristic of effective work performance. For tasks requiring high levels of cognitive effort, the ability to access sources of “cognitive tranquillity” may be an effective way to keep arousal at a desired level, if it begins to exceed levels conducive to the task (Coss, Clearwater, et al, 1989). Environmental features that support cognitive tranquillity include perceptual distance and expansiveness. This can be real (as in a distant view of the landscape through a window), or it can be

virtual (as provided by the design of vertical surfaces in the workspace surround). Coss and Clearwater found that distant views and view corridors with interesting focal points are even especially powerful in promoting cognitive rest. Focal interest can be created as part of a green design strategy, particularly through lighting design and windows.

Personal control

Personal control has assumed such a powerful place in environmental psychology that few question what it means or what people really want to control. Some argue that perceived control is more important than actually control; that is, if people think they have control over environmental conditions (as with a sham thermostat), they will be satisfied. On the other hand, some researchers believe that if people are given too much control and are asked to adjust everything, that the environment will appear to be "out of control" (S. Kaplan, pers. comm.) Yet others see control as empowering (Langer, 1983).

Given the high personal variation in ambient preferences as well as variability within a given person over time, it is likely that control over temperature, noise, air movement, and lighting are an important component of an effective work environment. The research on the advanced comfort workstation produced by Johnson Controls supports this notion (Kroner et al, 1992). The research tracked workers in an insurance company as they moved to a new building with advanced controls workstations. The study found that productivity increases of 2.8 % could be attributed to the new workstation. Interestingly, the total productivity increases associated with the move to the new building were substantially higher (16%). Although the research report does not try to link the overall productivity increase to the building features, it is evident from the pictures and from the report descriptions that the new building had a number of amenities that were lacking in the old building. Especially relevant is the presence of an attractive landscape with a pond, extensive windows and daylight, and a more open and spacious interior. Another key difference is the location of the workstations: in the new building, 96% of the workers with the personalized control workstations were located on the perimeter with window views. In contrast, only 30% of the workers in the old building had access to windows. The remainder were in interior core spaces.

Summary of Implications for Performance

The conceptual framework we present provides an integrated process for identifying and assessing the performance, health and well-being impacts of green building. It also provides a framework for linking these outcomes to features, qualities, and attributes of the environment. To summarize the research highlighted in this section:

- ? Personal control over ambient conditions is likely to promote performance and well being because it enables workers to adjust the environment to the task at hand and to achieve their personal preferences.
- ? Positive moods at work are a key factor in both performance and well being. Positively toned moods are linked to reduced absenteeism, increased organizational commitment, enhanced creativity and problem solving, and more

positive social interactions, including increased ability to negotiate in contentious situations.

- ? Positively moods are likely to be associated with a number of building features common to green design, especially the presence of daylight, windows, sensory variability and contact with nature.
- ? Ability to adapt environmental conditions to individual preferences is likely to be associated with reduced negative moods and discomforts, and also to increased ability to focus attention on work tasks.
- ? Building discomforts and problems, especially those viewed as “hassles”, are likely to generate negative moods that are detrimental to work performance, especially on cognitively complex tasks. Hassles include thermal discomfort, glare, noise, and loss of privacy.

Potential Links between Highly Effective Facilities and Organizational Success

In the past decade, senior executives around the country have begun to rethink how they measure the performance of their businesses. In a frequently cited article in *The Harvard Business Review* (Jan-Feb. 1991), Robert Eccles describes the change as revolutionary and far reaching: “At the heart of this revolution lies a radical decision to shift from treating financial figures as the foundation for performance measurement to treating them as one among a broader set of measures.”

Although management specialists approach the concept of “success” from many different perspectives, there appears to be considerable agreement regarding the domains across which success is measured (Sink, 1985). These include:

- ? Product quality
- ? Customer satisfaction
- ? Capacity for innovation
- ? Quality of work life (including employee work attitudes and job satisfaction)
- ? Employee retention
- ? Perceived value of goods and services
- ? Operational efficiency
- ? Social responsibility

The list can be divided into strategies that primarily “reduce costs” or that primarily “add value.” Surprisingly, only one of these dimensions (resource efficiency) is clearly oriented toward the cost side. All of the other dimensions are concerned with adding value to goods and services, work life, customer relationships. Ironically, however, when it comes to facility decisions, costs are almost always the predominant consideration. In part this is because there is so little evidence, or even theoretical work, linking features and attributes of the building environment to these key dimensions of organizational success.

However, there is growing attention to design of facilities that add value to organizational performance while minimizing costs, and doing so in ways that are environmentally sustainable (Duffy et al, 1993). The potential linkages between green buildings and overall organizational success are still in the formative stages; nonetheless, case studies as well as theoretical considerations suggests that the links are multiple and far reaching. These potential links are discussed below.

Turnover and Organizational Commitment

As the economy continues to grow and unemployment decreases, many U.S. companies are discovering that finding and retaining high quality employees is not as easy as it used to be. In response to the downsizing and job insecurity of the 1980's, many workers are focusing on their own careers at the expense of their companies. Job turnover is at an all time high in many professions as employees switch positions whenever a better prospect appears. As a result, many organizations are looking for ways to attract high quality employees and to keep them better connected to the company. Turnover is costly to any company (Phillips, 1990), but especially in knowledge fields where the "product" is human brainpower that goes with the worker when he/she leaves. In this new climate, building design that contributes positively to human well being and performance may be perceived by decision-makers as one of many strategies to attract and retain workers. There is growing evidence that buildings are used strategically as a sales and marketing tool (Petzinger, 1997) and as an employee "benefit" to attract and retain high quality workers (Becker and Lynn, 1986). In addition, the building itself as a symbol of the corporation's environmental and social performance may be a powerful attraction for potential employees (see studies reviewed in Turban and Greening, 1997).

Absenteeism

Companies also care about absenteeism and health care costs. A growing number of organizations have on-site fitness facilities and stress reduction programs as part of their benefits package in the belief that these amenities will contribute to higher level performance, better overall sense of well-being, and reduced illness. Companies have also invested in ergonomic furnishings to reduce costs associated with muscular skeletal problems (especially carpal tunnel syndrome) and visual problems generated by the introduction of computers into environments that were mainly designed with typewriters and paper in mind.

Although the physical setting at work has received relatively little attention in the literature on absenteeism, there is growing evidence of its importance. For instance, in a study of 210 salespeople, George (1989) found that people who tend to experience positive moods at work were less likely to be absent. As noted in the previous section, the features of green buildings can potentially promote positive moods and reduce stress, thereby having an impact on absenteeism and illness.

Further, there are anecdotal accounts of a relationship between improved indoor air, improved lighting, and reduced absenteeism in green buildings (Browning and Romm, 1995). Although the mechanisms for these positive outcomes have not been

identified, researchers suggest that the effects may be related to both physiological and psychological processes.

Organizational Impacts of Sustainability and Green Design

In addition to positive impacts on quality of work life, environmentally sensitive design may have other benefits to the organization. Sustainable practices have gained increasing attention in the mainstream organizational management literature, including the *Harvard Business Review* (Eccles, 1991; Magretta, 1997) and the *Academy of Management Review* (Russo and Fouts, 1997). These studies suggest that sustainable design and operations (especially energy efficiency and pollution prevention) can have far reaching impacts on an organization, including:

- ? Reduced legal and insurance costs associated with reduced risks to current and future generations
- ? Reduced regulatory inspection load
- ? Enhanced community livability
- ? Enhanced relationships with stakeholders
- ? Process innovation associated with the quest for resource efficiency
- ? Improved ability to market to pro-environmental consumers

In addition, there is a growing recognition that “green” buildings may play a significant role in promoting the organization as a whole. As noted by Hodgkinson (1993), in an extensive evaluation of companies in Great Britain and Europe:

Businesses will increasingly want their flagship premises to present a shining example of environmental friendliness in terms of energy efficiency, the use of building materials, and the impact on the wider environment....New aesthetics will undoubtedly be developed to make more visible the fact that green principles have been adopted. Key determinants of these aesthetics may include the use of more durable or recycled materials, or showing off energy efficient plant and passive solar design features, for example. (pg. 103).

What Evidence Exists for these Links?

If these hypothesized links between building attributes and features are real, then studies of buildings that vary along critical dimensions should show differential outcomes. This section provides an overview of key results from the DOE funded study of the ancillary benefits of green buildings.

Study Site

The study used a “before” and “after” approach in which data were gathered in both a standard building and a new, green building. Miller SQA in Holland, Michigan, was the case study used in the development of the protocol. Miller SQA, a wholly owned subsidiary of Herman Miller, Inc., is a fast-growing re-manufacturer, manufacturer and vendor of office furniture. It has a niche market providing “just in time” furniture products for small businesses and nonprofit institutions

The 290,000 sq. feet SQA building, designed by William McDonough, is almost half again as big as the old building. It is a manufacturing plant, warehouse, and headquarters building housing approximately 700 people (600 in the manufacturing plant across three shifts, and 100 in the office). The manufacturing plant has about 30-40% temporary workers. Energy efficient aspects of the building include large-scale use of daylighting, energy efficient fluorescent lamps, daylight controls, energy efficient glazing, and motion sensors in rooms that are intermittently occupied. The HVAC system features state of the art digital controls, including sensors, controllers, and data loggers. Green components include environmentally sensitive materials throughout the building, minimally invasive site utilization (including a wetlands and use of natural field vegetation rather than planted and mowed grasses), enhanced indoor air quality, and extensive recycling. In addition, building materials were obtained locally whenever possible to reduce transportation costs and energy. The SQA building also has a lunchroom, rest areas at each end of the manufacturing area, and a fitness center, including a full size basketball court.

Prior to its move into the new green facility, Miller SQA was housed in a smaller industrial type building about five miles away. The “old” building was also divided into an office area and a manufacturing plant. The building had high ribbon windows lining the perimeter walls in both the manufacturing and office areas. There was limited daylight in the building. The building had an employee lounge, a small outdoor seating area with picnic tables, and conference rooms. It did not have an exercise facility.

Worker Characteristics

A total of 262 workers completed the survey in the first building, about 46% of workforce. There were 106 males and 77 females in the manufacturing area, and 32 males and 49 females in the office area. The figures for the new building were 326 workers, about half of the total workforce. This included 138 males and 87 females in the manufacturing area, and 37 males and 38 females in the office area. The manufacturing plant has three shifts: 7 am to 3 PM (the daytime shift); 3 PM to 11 PM (the second shift); and 11 PM to 7 am (the night shift).

Study Measures

Individual Level Measures. The data on individual level outcomes were obtained from a questionnaire completed by workers in the old building in October, 1995, and in the new building, nine months after the move (in July 1996.) The survey instrument was organized around seven dimensions. The dimensions dealt with a range of satisfaction and perception questions as well as work and environmental experiences. Workers were asked to rate their comfort and satisfaction with a wide range of ambient, aesthetic, social and functional features of the environment as well as their behavioral, physical, social, and psychological experiences. These included illness symptoms (sore eyes, headache, sore back), psychological well being (fatigue, being in good spirits at work, opportunities for rest and relaxation), job satisfaction, and social relationships. In addition, workers were asked to “grade” the conditions and features of the environment (the Environmental Report Card).

Organizational-level outcomes. In addition to the survey, we tracked a number of organizational outcomes, using data collected by Miller SQA as part of its Total Quality Metrics Program (TQM).

The TQM dimensions include:

- ? On time shipment
- ? Efficiency (percentage of waste or “scrap” from the production process)
- ? Quality (the ratio of reported defects compared with the number of products shipped)
- ? Profitability (employees share of net profits in the form of bonuses)
- ? Productivity (ratio of total labor costs to the dollar value of sales)

The data were collected on a monthly basis. Due to the increases in the number of workers following the move to the new building, the TQM data were normalized for analysis.

We did not track turnover or absenteeism. The turnover rate is so low at Miller SQA that there would be insufficient data for analysis purposes. Although we had intended to track absenteeism, the data were not collected in a way that would separate out illness from other reasons for absence (including having a sick child, being on maternity leave, or taking a day off for personal reasons). In order to track absenteeism, we would have had to reorganize the database. This proved to be an insurmountable problem.

Summary of "Before" and "After" Results

The data presented in this article are summaries of more detailed reports. For further information see Heerwagen et al, 1997a, b; Heerwagen et al, 1996; Heerwagen and Wise, 1998).

Quality of Work Life. The results from the preliminary survey data analysis indicate that perceptions of and experiences in the two different buildings differed on many dimensions (see Heerwagen et al., 1996; Heerwagen and Wise, 1998). The data show that the new, green building was associated overall with higher quality of work life than the old building, and that it had a more positive impact on perceived work performance and job satisfaction. The new building was also perceived as “healthier” than the old building; however, there were few differences in self-reported illness symptoms (such as headaches and fatigue). The exception was a decrease in headaches for office workers in the new building. Whereas 16% said they had headaches often or always in the old building, only 7% did in the new building. There were no differences in the health and data reported for the manufacturing workers.

The windows and lighting received very high ratings by workers, particularly the presence of extensive interior and exterior views and the high daylight levels. Air quality in the new building was also rated more favorably, although there continued to be problems in the manufacturing area with low air movement in some locations.

The environmental features which were rated most negatively were temperature conditions and noise. The negative ratings for temperature conditions, especially complaints of overheating in the summer, came primarily from the manufacturing area, which is not air-conditioned. Noise was a problem in both the plant and office areas, largely due to a couple of high noise manufacturing processes and the openness of the design plan. (Since the survey findings, the high noise tasks were moved to a more distant area of the plant. In addition, six large fans, three intake and three exhaust, were added to the roof monitors to exhaust the hot interior air and bring in cooler outdoor air.)

One of the more interesting findings from the data is the substantial variation in response to the building between the office and manufacturing workers as well as variation among the three manufacturing shifts. These differences are discussed below.

Differences among Manufacturing Shifts

The differences between the manufacturing and office workers, as well as differences among the manufacturing shifts, are likely to be due to multiple factors. However, the features and attributes of the physical environment also vary in ways that are likely to affect a number of the study outcomes.

The naturalistic amenities associated with nature, windows, and daylight are lacking for those who work at night because they cannot see outdoors and there is no daylight available. Thus, the perceptual differences between the new and old building environments are not nearly as great as they are for the daytime workers. As a result, the benefits that would normally be associated with these features may not accrue equally among manufacturing workers. If this is true, we would expect to find differences in outcomes that are particularly relevant to these features, particularly those mediated through psychological mechanisms such as mood at work, work attitudes, and feelings about the work environment.

This is, in fact, what we found. The workers in the night shift had more negative outcomes on all of these dimensions; in fact, their responses in the new building were even more negative than they were in the old building (Heerwagen, 1998). Daytime workers had the most positive outcomes, and those in the second shift (3 p.m. to 11 p.m.) tended to have outcomes intermediate to the other shifts. (For more details see Heerwagen and Wise, 1998.)

Differences between Manufacturing and Office Workers

Whereas the differences among the environment experienced by the three manufacturing shifts was largely due to diurnal changes in daylight, the differences in the environments of the office and manufacturing areas relate to a number of design features. The office and manufacturing areas vary in spatial features, sensory variability, daylighting, windows, visual access, decor, and color. In part, this is due to the actual design, and in part to the way the space is altered by the addition of furnishings and equipment. For instance, high shelves and equipment in the

manufacturing area tend to block views to the outdoors and reduce daylight levels in many parts of the space. Large bay doors along the perimeter walls for loading and unloading trucks are kept open all day long when weather permits, even though workers are urged by facilities managers to close the doors so that the air handling system will function efficiently. The workers may be reluctant to close the doors if they provide an important source of contact with the outdoor environment (especially for fresh air, views, and increased daylight).

The office space, in contrast, is air conditioned, carpeted, brightly and evenly lighted, with extensive window views to the outdoors along the entire southwest-facing wall. It is also separated from the noise of the manufacturing area and is thus quieter. The office spaces also have interior windows looking out on the daylighted "street." The street is lined with bamboo plants along one side. As a result, office workers can see greenery on the exterior as well as interior of the building. Many of the offices also have additional plantings and colorful decor.

The physical attributes and properties of the office and manufacturing areas are likely to have affected differences in workers' responses to and experiences of the environment. Comparisons of the manufacturing and office workers show that office workers had more positive outcomes on almost all dimensions. Office workers rated the aesthetic and naturalistic features of the environment (daylight, windows, contact with nature, contact with wildlife) more favorably than did the manufacturing workers suggesting greater perceptual experience (see Heerwagen et al, 1996, 1997).

Office workers also had more positive work attitudes, and were more likely to be in good spirits at work. This outcome was true for both buildings. However, both manufacturing and office workers reported increased fatigue in the new building and increased feelings of being "overworked." This is very likely due to the large increase in sales associated with increased manufacturing capability.

Although there are likely to be many factors that influence these differences (including the work itself) it is also likely that differences in the physical environments also contributed to the variation in responses (see Heerwagen et al, 1996 for details).

Organizational level measures. Data from the TQM performance measures show high variability in both buildings across all organizational performance measures. This is due to the seasonal changes in sales that are typical throughout the furniture industry. For four of the TQM measures (effectiveness, efficiency, quality, and total productivity), there were increases in performance for at least five of the eight matched months. There were also modest increases of 0.5 to 2% on these four measures. Although they were not statistically significant, they may be very organizationally significant: any improvement at all can be highly relevant to an organization in a competitive market.

Thus, the data need to be interpreted not only through statistical processes, but also from an organizational perspective. If viewed in this way, the performance results actually show an increase across a number of dimensions when the data are matched according to the time of year (e.g., comparing December 1995 with December 1996

Can the Results be Attributed to the Building Features?

It is not unreasonable to ask whether the positive results are due to the particular features and attributes of the building highlighted in this article, or to other factors, such as a general “halo” effect associated with being in a new building. Another potential confounding factor is features that are not directly related to green design (such as color and aesthetics, spatial arrangements, new furniture) which could be a big contributor to the workers’ overall responses.

First, if there were a halo effect, we would expect to see it across all variables. This did not happen. The workers’ perceptions and experiences were not all consistently positive. Second, the results from the manufacturing workers are especially telling. For numerous outcomes, the non-daytime workers actually showed a more negative response to the new building compared to the old one.

Another potential explanation could be changes in organizational policies that took place between the old and new buildings. The biggest difference was the decrease in employees’ share of profits. The profits decreased in the new building because of the costs associated with the building itself. The employees clearly felt the economic impact of the investment. However, the decrease in profits affected everyone’s paycheck. Thus, if this were a critical factor, we would expect to a general negative effect. Further, we would expect to find the negative impact widespread and distributed equally across the workforce. This was not the case.

And finally, the more negative responses of the non-daytime manufacturing workers could be due to factors associated with working outside the normal daytime hours. This could explain the differences between shift workers to some extent, but it would not explain why the non-daytime workers tended to react more negatively to the new building than to the old one. It is possible that the night and evening workers see the new building as a cost, while daytime workers view it as an investment. Without further research, we cannot determine whether or not this is a reasonable explanation.

The strongest support for our interpretation of the results (e.g., that outcomes are related to the perception and experience of naturalistic features) is the consistent and logical connection between the results of this research and studies conducted by others. We know from the growing body of literature that contact with nature is beneficial to people, even when the contact is second hand through window views. The results of this research suggest that it is not only what is seen out the windows that is important, but what comes in – e.g., daylight, fresh air, nature sounds, and a sense of relatedness to the outdoors.

However, we cannot rule out the possibility that other, non green factors are influencing workers' responses. For instance, the aesthetic and spatial features of the building clearly differ between the two buildings and may be having substantial effects. Future research in other buildings, using the before and after approach, is clearly needed.

Conclusions

The conceptual framework presented here suggests that buildings have potentially far reaching impacts on human well being and on organizational effectiveness. More research is certainly needed to verify and extend these connections. To begin, we need to shift our focus from thinking of buildings as real estate costs to thinking of buildings as an employee benefit – one that contributes significantly to health, performance, well being, organizational attachment. It is time to also look at how facilities can contribute to organizational well being. In doing so, we need to move beyond the bottom line. Management experts have identified a broad set of criteria against which an organization's success is measured. The design profession must begin to look at buildings from this perspective and to design with these larger goals in mind. Although corporate image has always been a design goal, image has often been achieved at the expense of the workforce and of the surrounding community. Organizational success demands a more integrated approach, one that considers the building as part of a larger environment that includes not only the habitat on which the building sits, but the larger community as well.

Efficient use of community resources (water, electricity, land), pollution prevention and toxic reduction are key green design strategies that may well prove to be a vital link connecting the environment with people, organizations, and community livability.

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