Four Levels of Evidence-Based Practice
By D. Kirk Hamilton, FAIA, FACHA

The growing trend toward evidence-based design involves design work that is informed by data from a variety of sources. It is also a natural analog to the evidence-based decision making of our clients.

An evidence-based designer makes decisions—often with an informed client—based on the best available information from credible research and evaluations of projects. Critical thinking is required to draw rational inferences about design from information that seldom fits a unique situation precisely.

The process works especially well in the health-care field. It appeals to physicians, who practice based on medical evidence. It gives patients and families higher-quality experiences. It appeals to business-minded administrators by reducing costs and improving organizational effectiveness. It helps hospital boards as they seek evidence to justify costly decisions. And it benefits the public, consumer groups, and those paying the bills as they seek effective, lower-cost health care.

Indeed, a promising era of research-informed design already brightens this field. Evidence-based health-care architecture creates safe and therapeutic environments for patient care and encourages family involvement. It promotes efficient staff performance and is restorative for workers under stress. These designs ultimately should improve the organization’s clinical, economic, productivity, satisfaction, and cultural measures.

Researchers have reported about the relationship between the physical environment and health care for some time. A pioneering study by Roger Ulrich in 1984 found that surgery patients with a view of nature suffered fewer complications, used less pain medication, and were discharged sooner than those with a brick-wall view. Research also shows that heart patients with strong social support systems survive longer than those lacking such support.

Studies exist about the antimicrobial characteristics of carpet fibers, lighting for neonates, effects of noise on critical-care patients, and numerous subjects affecting health-facility design. The Center for Health Design has identified more than 600 credible studies with specific environmental design relevance.

Practical applications
Architects with a strong functional perspective should be comforted to know that concepts have been tested and data can inform their designs. With serious issues at stake, many architects welcome the emerging foundation on which to base important decisions. Like motherhood and apple pie, evidence-based design should be widely popular. Only the most jaded or ego-driven could object to basing design on knowledge that can help achieve predictably positive results.

Some architects worry that evidence-based methods limit creativity. This overlooks the challenge of continuously inventing responses to emerging results and new facts, requiring imaginative and ever-changing interpretations of the design implications. Research offers complex and sometimes contradictory findings, encouraging continuous testing of new ideas.

Another fear: Evidence-based design could lead to rules and limits. “Cookbook” architecture suggests dull, repetitious buildings stamped from a mold. Yet research-informed design is like the continuous search for truth in the world of science. Not static, it doesn’t easily conform to fixed regulations that will be made obsolete by new findings.

Entering Harvard medical students are reportedly told, “Half of what you will learn is wrong, but we don’t yet know which half.” As new environmental studies are published, some decisions may be questioned, but conscientious architects will experience fewer doubts as they increase the percentage of decisions based on research. Environmental research is more likely to result in performance guidelines than in prescriptive regulation.

Numerous information sources are potentially helpful. Architects have used literature from psychology, sociology, anthropology, economics, management, engineering, industrial design, and client-related sources. The Internet, press, industry data, conferences, and exemplary facilities are also good resources.

Architects are rarely taught research methods, and most believe they lack the training to fully understand, much less perform, serious research. The promise of high-quality projects demonstrating measurably better results is the “marketplace carrot” to differentiate research-informed architects for clients seeking higher performance from costly projects. This powerful means to convince decision makers to invest time and money to “build it right” can be a competitive advantage for both.

A conceptual model
To differentiate evidence-based types of practice, the model below illustrates four ways of dealing with research. The model identifies four increasingly rigorous levels of commitment and methods of using research on behalf of clients.

Level 1 practitioners. These architects make a careful effort to design based on available evidence. By staying current with literature in the field, they attempt to follow the evolving environmental research related to the physical setting. They interpret the meaning of the evidence as it relates to their projects and make judgments about the best design for specific circumstances. An example is the use of design concepts based on benchmark reviews of other projects and interpretations of published research. Most architects work at Level 1, producing work that advances the state of the art by developing tangible examples while delivering improved design.
Level 2 practitioners. These architects take the next important step. Based on readings, they hypothesize the expected outcomes of design decisions and subsequently measure the results. These less subjective designs require new design methods. Architects must understand the research, interpret the implications, and build a chain of logic connecting the decision to a measurable outcome, reducing arbitrary decisions. The potential for bias in gathering and reporting results means they must resist the temptation to report success and downplay failure.

Level 3 practitioners. In addition to following the literature, hypothesizing intended outcomes of design, and measuring results, these architects report their results publicly. Writing or speaking about results moves information beyond the firm or client team. It subjects methods and results to scrutiny from others who may or may not agree with the findings. Level 3 practitioners must understand research methods and may seek advanced education to enable greater rigor.

Level 4 practitioners. Scholar-practitioners perform the same tasks: following the literature, hypothesizing outcomes of design decisions, measuring results, and reporting. These architects go further by publishing their findings in peer-reviewed journals or collaborating with academic social scientists. They subject their work to the highest level of rigorous review.

It isn’t easy
The dark side of this trend is the appearance of practitioners who would like to be associated with evidence-based design but who haven’t done the hard work to become current. Given the almost endless potential sources of information, there is a need to reach speculative conclusions about the design implications of narrow studies. The architect’s role is crucial in translating and applying the research to useful designs. Inexperienced practitioners will find it difficult to make the leap from data to a successful design. Vast numbers of confounding variables in any setting make single-minded solutions suspect.

An architect has an obligation as a sacred public trust, granted with licensure, to use the most reliable information available. As in the story of Pandora’s box, which, once opened, could not be closed, an architect cannot avoid the moral responsibility for what he or she knows after encountering compelling evidence. Using research findings to improve design decisions comes naturally for many architects. Adding rigor to what we already do is fundamental to this shift to evidence-based practice. The clear business case for good design—and an even stronger case for design linked to positive performance and economic results—suggests that the trend is here to stay.

D. Kirk Hamilton, FAIA, FACHA, is a founding principal of Watkins Hamilton Ross Architects in Houston and an associate professor of Architecture and a Fellow of the Center for Health Systems & Design at the College of Architecture, Texas A&M University.

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Good communication and patient information (PI) are two facets of nursing that can't be overemphasized. Despite this, the transfer of patient data has recently been labeled faulty among caregivers. Because the communication of patient information during a hospital stay is constantly changing, it's important that the proper systems are in place to provide the nurse with complete and relevant information needed to care for the patient and communicate with the patient, family, nurses, physicians, healthcare team members, and others.

Over 2 years ago, the nursing organization at Parrish Medical Center (PMC), Titusville, Fla., embarked on a strategic planning process that involved identifying the core values and desired future for nursing in the organization. Researchers discovered that the patient information available to nurses as they provided care, interacted with physicians, and passed along information to other staff members needed significant improvement. To address this issue, an innovation team was formed to develop and implement solutions.

Problem areas

After considerable discussion, the team concluded that nurses lacked consistent, comprehensive, and accurate patient information. This inadequate information created three specific communication problems:

1. Nurses were dissatisfied with the level and type of information they had available to them as they cared for their patients.
2. Nurses felt that the shift handoff reports they were receiving (and giving) were providing an incomplete picture of the patient for the oncoming staff.
3. Physicians felt the reports they received from nursing staff weren’t adequate and complained that the information they provided to nurses wasn’t passed on to nurses on the next shift.

A review of the literature was conducted regarding these problems. Although relevant journal articles weren’t found regarding nurses having comprehensive patient information during their shift, the issue of adequate communication at the change of shift proved to be a universal problem. Information was incomplete, fragmented, and tended to be lost, especially when communicated orally. Inadequate handoffs between clinicians was noted to be one of the most common factors leading to adverse events. Additionally, the content of shift report was often found to be a ritualistic repetition of data available in the patient record. In examining handoffs, it was recommended that verbal and written communication occur together, as this combination provides multiple channels for information to be exchanged.

In terms of physician/nurse communication, several studies were uncovered that pointed to communication problems, lack of coordination, and fragmented care. The use of telephones and pagers has increased the opportunities for communication between the nurse and the physician, but it’s also created many interruptions that may negatively impact quality of care.

To determine why sufficient patient information was deficient on the part of nurses, the team found that PMC’s patient-information system mainly contained administrative data and physician orders and supplied insufficient information to provide nursing care. There was also a considerable amount of information that wasn’t pulled together for the nurses to access, such as separate documents for vital signs, fall risk, intake and output, I.V. therapy, educational needs assessment, and more. The problem was the nurse didn’t have the time to sort through all of the screens to find and record what he or she needed to be well informed about the patient.
Values-Driven Design and Construction: Enriching Community Benefits through Green Hospitals

Robin Guenther, FAIA, Gail Vittori, and Cynthia Atwood

The Center for Health Design is a nonprofit research and advocacy organization whose mission is to transform healthcare settings into healing environments that improve outcomes through the creative use of evidence-based design. We envision a future where healing environments are recognized as a vital part of therapeutic treatment and where the design of healthcare settings contributes to health and does not add to the burden of stress. For more information, visit www.healthdesign.org.

Health Care Without Harm is an international coalition of 440 groups in 55 countries working to transform the healthcare industry so that it is ecologically sustainable and no longer a source of harm to people and the environment. Since 1996, HCWH has been at the forefront of efforts to shift the healthcare sector toward safer, healthier products and practices. Major successes include: virtually eliminating the market for mercury fever thermometers in the United States; reducing the number of polluting medical waste incinerators in the United States from 5,000 in the mid-1990s to less than 100 today; shifting the medical-device market away from DEHP-containing PVC plastic; implementing the first green building system for hospitals, the Green Guide for Health Care; and working with hospitals to build markets for locally grown, sustainable healthy food. For more information, visit www.noharm.org.

The Robert Wood Johnson Foundation focuses on the pressing health and healthcare issues facing the United States. As the nation’s largest philanthropy devoted exclusively to improving the health and healthcare of all Americans, the foundation works with a diverse group of organizations and individuals to identify solutions and achieve comprehensive, meaningful, and timely change. For more than thirty years, the foundation has brought experience, commitment, and a rigorous, balanced approach to the problems that affect the health and healthcare of those it serves. When it comes to helping Americans lead healthier lives and get the care they need, the foundation expects to make a difference in your lifetime. For more information, visit www.rwjf.org.
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Introduction

For the past decade, the healthcare industry has been engaged in a transformation of design, construction, and operational practices with a goal of reducing environmental impacts. Quietly and without much fanfare, early industry leaders have begun a radical journey toward a new vision of the industry’s health mission. Ten years after the founding of Health Care Without Harm and with early adopters having completed their first sustainable buildings, this is a pivotal moment to assess the state of sustainable design and construction in the healthcare industry from a leadership perspective. Why have organizations taken this on? What challenges have they faced? How have they framed the benefits to their communities? What have been the anticipated, and unanticipated, outcomes?

Healthcare leaders and their organizations engaged in sustainable design and construction are doing so largely because it aligns with their humanitarian and stewardship mission and vision. They’ve been able to harness their community and/or personal attitudes about the environment toward this end and, very often, their concerns about the environment’s effect on their patients’ health. They are not primarily motivated by pristine wilderness and resource conservation for its own sake, but for the sake of their mission to serve and steward resources and health. For them, it’s more than saving energy. It’s fundamentally connected to health or to a basic human value.

In the paper that follows, we have identified healthcare leaders and allowed those leaders to tell this story in their words. Of the many organizations and teams engaged in sustainable design, we have located a key group of early adopters who are reaching beyond measures that have economic payback and who are achieving community benefit beyond their four walls. And for a disparate set of reasons, they’ve been able to overcome certain obstacles that could be framed as having to take on and/or embrace an environmentalist agenda and change the status quo. Those who have made it through the process are emerging transformed—both personally and on an organizational level.

Why this topic and approach

Sustainable design is driving both market transformation and organizational change. Each is necessary for the healthcare industry to sustain itself. There are many reasons the industry is overburdened and slow to change, but this paper begins with the notion that the industry is increasingly recognized as an outmoded system that pollutes. In fact, when viewed in this particular light, the system not only pollutes, it potentially participates in creating the very illnesses it is trying to cure.

Sustainability, or green building, calls into question the purpose of the healthcare system. Does it treat sickness or promote the conditions of health? Does it create sickness and prevent health? Is it a paradoxical situation that can be resolved and, if so, how? Do healthcare organizations that undertake green building recognize this paradox, and, if so, are they acting on it?
Can an ecological framework assist organizations in redesigning themselves to “rekindle a commitment to healing, hope, optimism, innovation, and creativity” as Hamilton and Orr (2006) describe it? Does a building program—in this case, a green building program, have the capacity to more broadly model change?

Organizations such as Health Care Without Harm that focus on operational initiatives to reduce environmental footprint think so. This paper supports the notion that building programs are agents of these—they are the vehicle by which organizations can transform themselves and/or much of the operational complexity that prevents them from changing course.

Not all green buildings are profoundly impacting the healthcare organizations that create them, but many are. Those are the leaders we sought for this paper, and their experiences confirm the power of sustainable design to guide transformation. They say it permeates their organizations. It affects everything that they do. And that the difference in capital costs between conventional and sustainable building practices is, in many instances, equal to the difference in time they have to spend persuading people to go forward with it. They often devote a lot of personal energy and political capital getting and keeping their organizations on board with this and contend that, if sustainable design practice was normalized, they could devote their organization’s energy to modeling this change more broadly in ways that would fundamentally affect healthcare, society, and global health.

Leaders recognize the high cost of inaction on matters of the environment—such as climate change and chemical contamination—on the health of our families, neighbors, and communities at hand and globally. By embedding sustainable design in a broader vision of leadership and mission, these projects and organizations are succeeding in delivering the first generation of sustainable healthcare projects.

We term these Tier 3 organizations, and for people in policy and philanthropy, these are the healthcare organizations worth investing in to model broader social and societal change.

### Part 1: Background

#### Status of sustainable design in healthcare

Since 2000, the healthcare sector’s engagement in sustainable design has moved at an impressive rate. What was ever so slightly registering in the minds of healthcare industry leaders just six years ago has emerged as a hallmark of better buildings, reflecting a commitment to create physical facilities that support improved patient care, staff productivity and well-being, and environmental stewardship—healthcare’s triumvirate. The Setting Health Care’s Environmental Agenda (SHEA) conference, held in San Francisco in October 2000, marked the starting line for this short history of remarkable accomplishment. As the first gathering of healthcare leaders to explicitly address environmental stewardship, SHEA set out to “inspire ambitious achievements in every healthcare institution” (Brody 2001, page v). Since then, the industry response to Brody’s challenge “to transform the healthcare industry into a model of environmental responsibility” has been overwhelming, creating the essential elements of twenty-first century hospital design.

In the years since 2000, a steady progression of practical, nuts-and-bolts green building tools and resources—customized for the healthcare sector and informed by health-driven values—along with inspirational, on-the-ground accomplishments, have coalesced to create a body of knowledge and know-how that has been set in motion.

In 2002, the American Society for Healthcare Engineering (ASHE) published the Green Healthcare Construction Guidance Statement, the first sustainable design guidance document emphasizing a health-based approach (ASHE, 2002). The Green Guide for Health Care, the healthcare industry’s first best-practices, voluntary green building tool, modeled with permission after the U.S. Green Building Council’s
Leadership in Energy and Environmental Design (LEED) rating system, was initiated in 2002, followed by periodic updates and the registering of pilot projects to bolster participation (Green Guide, 2004). While emphasizing the importance of integrated design, the Green Guide is organized in two sections—construction and operations—to facilitate its use. Using the Green Guide for Health Care as a foundational reference document, the LEED for Healthcare Application Guide development process began in 2004. With its release anticipated in 2007, LEED-Healthcare will represent the first third-party green building certification tool customized for the healthcare sector.

The rapid market uptake of these tools and resources is manifested today in more than 40 million square feet of green healthcare facilities, representing about 180 healthcare projects. These include more than 100 Green Guide pilots, six LEED-certified projects, and about eighty LEED-registered projects. By embracing a life-cycle view of human health and environmental stewardship as strategic definers of success, this new generation of healthcare tools—and the buildings they guide—is poised to accelerate the adoption of health-based green building standards in other sectors.

**Tiering environmental performance**

In a paper presented at CleanMed 2001, Ted Schettler, MD, MPH, identified three tiers of operational environmental performance evolving in hospitals.

- Tier 1: minimum local, state, and national environmental regulatory compliance
- Tier 2: beyond compliance to measures that save money
- Tier 3: informed by the inextricable link between environment and human health and moving beyond both compliance and monetary savings with a long-term plan to reduce environmental footprint

He contended that applying “triple bottom line” approaches to pollution-prevention initiatives—i.e., measuring economic, social, and environmental benefits—would deliver significant benefits for healthcare organizations and the communities they serve (Schettler 2001). Early Tier 3 hospitals supported this notion. Named one of the state’s top four recyclers, the University of Michigan Health System described its program’s social benefit as an institutionwide initiative that engages everyone (University of Michigan 2005). A 25 percent solid-waste reduction yielded $30,000 in year 2000 annual savings and diverted more than 830 tons of waste from the community landfill.

As building initiatives accelerate, it is clear that we can apply the same system of tiered performance to organizations engaged in sustainable building. Tier 1 organizations will not undertake green building until they are mandated to do so through legislative policy initiatives. They will not make the link, or the organizational leap, between the health of their facility and the patients they serve.

Tier 2 organizations—lacking perhaps leadership, the necessary internal structure to produce change, and/or the necessary decision support mechanisms to help move beyond regulatory compliance—can move no further than to embrace sustainable building strategies that deliver proven economic performance benefits. Where there is no business case, the effort falls short of its potential; that said, these organizations see the value of having a sustainable healthcare facility and grasp its potential community value.

Finally, Tier 3 organizations create leadership vision and harness all available talent in uniting construction and operations together in transforming their organization’s approach to the environment—resource use and stewardship. Comprehensively, they move toward a more fully realized and integrated performance level that achieves both patient and environmental health and returns those benefits back to the
building occupants and the community. These organizations recognize that they can’t build a green building and still have Styrofoam cups in their cafeteria. They create authentic stories of stewardship that spring from many levels simultaneously.

For the most part, this paper focuses on the experience of Tier 3 leaders and their organizations, based on the belief that these organizations will drive the necessary market transformation and social change. Their success is pivotal to moving the sustainable design and operational agenda in healthcare forward and forming the foundation for the next generation of Tier 3 leaders. While some Tier 3 leaders have used LEED as a green building framework and third-party certification tool, others have not, believing that it falls short of addressing the complex, overlapping design and operational improvement agenda unique to healthcare or not explicitly connecting buildings and human health. It is anticipated that LEED-Healthcare, with significant reliance on the healthcare-specific, health-based Green Guide for Health Care, will provide an important building and operational improvement tool for these leaders.

A perspective on community benefit

Hospitals and healthcare represent an essential societal function, with a fundamental mission to care for and heal the sick. In many respects, healthcare institutions are held to a higher ethical standard than virtually any other enterprise, as Hyman and Sage (2005) put it: to do good, not merely to do well.

Moreover, the public perception of a hospital’s mission and purpose is generally independent of whether it is for-profit or nonprofit. Commenting on the blurred perception of hospitals’ legal status, Everson (2005) stated, “We at the IRS are now faced with a healthcare industry in which it is increasingly difficult to differentiate for-profit from nonprofit healthcare providers.” While only tax-exempt healthcare institutions are legally obligated to provide and document community benefit, the healthcare sector as a whole is embracing an extended view of community benefit as aligned with its core mission and as a means to create a competitive advantage in an increasingly competitive marketplace.

The term community benefit, rooted in an 1891 legal decision, is defined as “charitable activities that benefit the community as a whole” (Everson 2005). For more than thirty years, nonprofit, tax-exempt hospitals in the United States have been required to provide community benefits in the public interest, expanding what constitutes community benefit beyond the original definition of providing indigent care. In 1969, the Internal Revenue Service (IRS) established a community benefit standard, later revised in 1983 (Everson 2005): “…the promotion of health…is deemed beneficial to the community as a whole.” The standard provides for broad latitude including any activity deemed as promoting health. Many states require nonprofit hospitals to submit annual reports beyond those required by the IRS. In California, for example, nonprofit hospitals are required to prepare a community benefit plan and an annual document describing activities undertaken “to address community needs within its mission and financial capacity and the process by which the hospital developed the plan in consultation with the community” (IOM 2004). Similarly, in New York, since 1990, nonprofit hospitals are required to prepare community-service plans including the hospital’s mission statement, publication of assets and liabilities, assessment of community needs and strategies to address them, and solicitation of input from community stakeholders (IOM 2004).

In light of the formidable financial advantages that come with tax-exempt status—most notably, property-tax exemption—(Keenhan 2005)—hospitals have been subjected to increased scrutiny as to what constitutes community benefit. To this point, in May 2006, the IRS issued questionnaires to more than 500 tax-exempt hospitals and healthcare organizations seeking, in part, details about the organizations’ provision of community benefits—services that “…promote health for the benefit of the community” (Pear 2006). The final question in the Community Practices section of the questionnaire—Did your hospital have any other programs or activities that promoted health for the benefit of the community?—opens the door
for hospitals to take credit for the multifaceted and measurable community benefits resulting from the implementation of green building practices increasingly playing out in healthcare today.

A study by Schlesinger and Gray (1998) offers a typology of community benefit, highlighting four different, but overlapping, perspectives:

- **Legal/historical** addresses historical responsibilities of nonprofit hospitals.
- **Market failures** addresses the cost and benefits of medical care.
- **Community health** addresses ways to develop evidence-based relationships between medical services and triggers of health problems.
- **Healthy community** addresses ways to strengthen the social institutions that influence health and quality of life in local communities.

Of the four perspectives, the *community health* and *healthy community* ones are intimately connected to green building. Community health is associated with offering preventive services and promoting health in local communities, with the benefit of reducing hospitalizations and demand for emergency services for what are often preventable illnesses. For example, promoting asthma awareness through community education on common building materials that are asthma triggers, as is the case with Children’s-Pittsburgh, supports community health.

Healthy community has a broader frame, extending to “support and sustain optimal health and quality of life” (Schlesinger and Gray 1998). Again, drawing from Children’s-Pittsburgh, employees are encouraged to consider moving to a neighborhood adjacent to their new facility, with the multiple benefits of neighborhood revitalization, ability to walk or bike to work, and reducing air emissions associated with automobile commuting.

In her May 2005 testimony to the House Committee on Ways and Means, Carol Keehan, chairperson of the Board of Trustees of the Catholic Health Association of the United States, Pensacola, Florida, and board chair of Sacred Heart Health Systems, also in Pensacola, addressed the issue of benchmarks for community benefit (Keehan 2005). Rather than establishing quantitative benchmarks, Keehan recommends assessing community benefit based on “the value we are providing to our communities,” which, as she points out, is not always well-measured by numeric benchmarks.

While we find many community benefits of green buildings can be quantified, others are more challenging. Those that can be quantified include a reduction in electrical-energy use and reduced storm-water runoff with an increase in permeable surfacing. Those with a less direct corollary include a measurable increase in health indicators by creating a walkable campus or a shortening in the patient’s length of stay with the addition of natural daylight. In such instances, it is difficult to isolate causal variables.

**Study methodology**

The goal of this study was to identify a group of participants who express an array of sustainable healthcare pursuits. We sought both geographic diversity, as well as project type differentiation in both scale and program. We included acute-care facilities, ambulatory and cancer centers, and children’s hospitals that may or may not include women’s services. We also sought those who had completed the first third-party-certified sustainable projects (BC Cancer, Boulder, Discovery, The Lacks Center) and heard stories of their unintentional leadership in this realm and the charmed consequences that followed.

Interview subjects also included representatives of the next generation of leaders and a range of completed (Boulder, Discovery), near completed (Dell Children’s, San Juan Regional, Dublin Methodist), and early-stage (Palomar, Spaulding) projects. We found it useful to compare and contrast stories within similar project types.
(Dell Children’s, U-M Mott), while others add intrigue and variety or are noted for a particular position on public health and the environment (Arkansas COPH, BC Cancer).

We conducted one-hour interviews via conference call. Each call was professionally recorded and transcribed by third-party groups; the content from these are presented in Part 2 of this paper. The complete list of participants, their organizations and their projects are identified in the appendix. We’ve included an alphabetized listing of our interview subjects, by project name. Throughout the report, we have attributed quotes to the organization, followed by the speaker’s last name.

The findings are organized into three sections: “Section A: Mission and vision,” “Section B: Connection to community,” and “Section C: Framing the benefits back to communities.” “Mission and vision” looks at motivation, leadership, organizational change management, and the move toward reuniting construction and operation. “Connection to community” explores how these leading organizations key into community values and their exploration of community benefit, whether those benefits accrue to patients, staff, the surrounding neighborhood, or global health. “Framing the benefits back to communities” examines how organizations frame the benefits that derive from the pursuit of sustainable design and construction, whether those are financial or expressed through enhanced community reputation.

Part 2: Dialogue

Section A: Mission and vision

On health care and environmental leadership
Summary Statement 1: As mission-driven organizations, Tier 3 hospitals and healthcare facilities emphasize environmental leadership.

At the onset of the twenty-first century, healthcare leaders are recognizing their environmental leadership as an essential component of a broader commitment to excellence. “It’s about what you value. How well do you know what you value? Are you concerned about the environment? Are you willing to reflect those values in what you’re building and show that you’ll do something about it? Our values are oriented toward a concern for the environment, a concern for people’s welfare, and a concern for excellence and quality delivery” (The Lacks Center, McCorkle).

“Most of us have a mission that encompasses improving the health and well-being of the constituents that we serve through excellence in research, teaching, and patient care. We have a further responsibility to give back to the community, and, as leaders in healthcare, sustainable building is one way that we can fulfill that responsibility” (Children’s-Pittsburgh, Oxendale).

For some, environmental stewardship is a legacy value well-embedded in the mission and goals of Tier 3 organizational and community culture. “The mission statement of our Trinity Health System has a phrase that says: ‘We will steward the resources entrusted to us’” (The Lacks Center, McCorkle).

“One of Providence Health System’s core values as a Catholic organization is stewardship, and a key operating principle is mission. And the last Pope had written encyclicals about care for the environment. I was actually able to stand up in front of the leadership team and say, ‘Our organization needs to commit to an environmental initiative, because this allows us to connect to our very mission as a Catholic organization’” (Providence, Glass).

For others, environmental leadership, while consistent with a mission of healing, requires cultivating a broader view of mission “It is our responsibility as healthcare providers, but, more importantly, as senior leaders in this industry, to lead our organizations in thinking as broad as we can about our mission” (Children’s-Pittsburgh, Oxendale).
“I always start by talking about our mission and vision. And they both encompass, without having to use the word directly, stewardship. The mission is to improve the health of those we serve. And the vision is to be the place where people want to work, physicians want to practice, and, most importantly, where people turn to when they need healthcare services. By building a better building, we are clearly going to improve the health of all those we serve—our patients, our families, our staff, and our physicians. Whether they’re there as customers or in service to customers” (Dublin Methodist, Herbert).

“We have an obligation to do it. People want us to do it. Green building is essential for good health. And the indoor environment is intrinsic to our whole mission of healing people and allowing them to do that in a better way. So it works to our benefit and the benefit of the larger society as a whole” (Palomar, Covert).

Environmental leadership is galvanized by a belief that transcends short-term thinking. “One of the community members said, ‘Don’t build what you can afford; build what you really think you need and want. And, the community will figure out a way to fund it.’ And, that’s exactly what happened” (San Juan Regional, Frary).

Since the SHEA conference in 2000—the first gathering of healthcare industry leaders with an environmental focus—the significance of environmental leadership as fundamental to healthcare’s mission and goals has gained prominence, recognition, and momentum. Environmental stewardship has emerged as a defining facet of leadership, excellence, and quality. “As we looked at the children’s hospital, we wanted to make a statement about how committed we are to the internal, as well as the external, environment. It was just the right thing to do” (U-M Mott, Kelch).

A commitment to an expanded view of quality that includes environmental stewardship is affirmed by each of the Tier 3 healthcare organizations interviewed for this paper and provides a compelling foundation for why they have embraced green buildings as an expression of organizational excellence. “The most compelling and resonant benefit of green building, other than constructing a building that works, is to promote environmental sustainability and, by doing so, be viewed as a leader in the industry. As a community resource, a hospital has to be taking a lead role in that” (Spaulding, Waterston).

In some instances, leadership motivates healthcare organizations to seek third-party certification for green buildings. “We felt that Austin and the Seton Family of Hospitals could benefit by not only being perceived as, but fulfilling a role as, community leaders” (Dell Children’s, Bonar).

With increasing acknowledgement of the linkages between buildings, development patterns, and human health, the hospital building as a manifestation of value becomes more than symbolic of mission. Indeed, the building sets in motion a connection to the experience inside the building and ramifications at the community and global scales. Healthcare leaders are joining the collective voice of leaders in other sectors in recognizing that buildings, through their life cycle, are significant definers of our ecological future. “As an industry sector, healthcare is uniquely positioned because it reaches across all classes, all economic strata, geographically. It’s mission-driven and we’re in the healing business. And it’s a natural, when you’re in the business of healing people, that you want to heal the Earth as well” (Providence, Beam).

“A lot of our mission is to approach everything in the context of environmental stewardship, because by identifying and controlling and, ultimately, preventing all these environmental factors that we’re exposed to, we can prevent disease, protect our children, and the environment. We know that” (Hackensack-Gabrellian, Imus).

On the built environment and health

Summary Statement 2: As mission-driven organizations, Tier 3 healthcare leaders are making the connections between the built environment and human health and acting on their awareness through the pursuit of sustainable design and construction.
For many, sustainable building is an extension of ongoing interest in the linkages between the built environment and human health. Initial moments of both personal and organizational awareness are expressed as vivid memories. “It brought into focus who and what we have been for thirty years. Twenty-five years ago, we had a national conference on infants at risk, with some of the smartest people in the country. They were talking about heavy metals and lead, air-quality issues and toxins” (Discovery, Dollard).

“Historically, Kaiser has been very cognizant of the connection between environmental issues and patient health. In 1964—a year after Silent Spring was published—Rachel Carson was the keynote speaker at a conference sponsored by Kaiser. It was her last public appearance before she died of cancer. At the end of her life, Carson was extremely controversial, and yet, because Kaiser understood the connection between environment and human health, they were willing to recognize and support her ideas” (Kaiser, Cooper).

“Green design lends guidance to aspects of site management and property ownership that are good for the healing environment; a clean jobsite, for example. You might ask how does that affect what’s going on? Well, in having a clean jobsite, we’re not only looking out for the health of the kids that come into the building that we design, but in having green products, the 500 workers that we have every day on site building this facility aren’t exposed. From our perspective, the benefits of green design begin with facilities’ design and construction, in preserving the health of our workforce” (Dell Children’s, Bell).

For people engaged in cancer care and pediatrics, there is growing recognition that the public understands the link between the built environment and human health; Tier 3 leaders are responding to their constituents’ concerns. “We talk about it a lot, and, in the cancer world, it is important. People are so paranoid about cancer. There are so many stories out there—and the focus more and more is on the environment” (BC Cancer, McNeil).

“My husband and I have a working cattle ranch for kids with cancer in New Mexico, where we spend all summer. We built it environmentally friendly and sustainable for health reasons. There are studies that have linked many pesticides and toxins—and the building materials that contain them—to why these kids are sick. Carcinogens and other toxins can lead to cancer and other childhood diseases, so when we built the ranch, we built it with all of that in mind. From the start, we have received most of our children from Hackensack Medical Center. I thought, ‘I wonder if hospital environments have considered all these things.’ We had to when we built the ranch” (Hackensack-Gabrellian, Imus).

For other Tier 3 organizations, this becomes a way to demonstrate commitment to the Hippocratic oath, “First, do no harm.” “No harm” has true meaning. Not only internally but externally. Building a sustainable building is such a great opportunity to set the tone for your hospital—in your community” (Boulder, Abelkis).

“Once you know that there are toxic chemicals in products you are purchasing and using in your buildings, you have an obligation to do something about it. Kaiser uses the precautionary principle partly to manage risk—in five or ten years, there may be the science to definitively prove that we should have avoided this material—we try to move away from it earlier” (Kaiser, Kouletsis).

On intentional leadership

Summary Statement 3: For the most part, early adopters of sustainable design have been unintentional leaders who engaged in sustainability because they viewed it as fundamentally the right thing to do in their community and for their organization as a whole.

The purpose of Tier 3 organizations is largely human, if not humanitarian, and done in the interest of the best possible outcome for serving the community’s needs. With a kind of enlightened pragmatism toward the design and construction process, these organizations have been able to harness their community and/or own personal attitudes about the environment toward this purpose. “I wasn’t forced to make it a
headline issue. Now, it’s the headline issue! Had I had to justify it early on, I’m not sure if it would have been viewed in the same way. I sympathize with organizations where they really have to try and create the business case; I did not” (Dublin Methodist, Herbert).

A Tier 3 organization’s understanding of how the environment affects patient health motivates them to seek action. “What I focused on more was to create a vision for the organization that was clearly inclusive of the evidence and is compelling both inside and outside the organization” (Dublin Methodist, Herbert).

Likewise, Imus was motivated by the connection of the patient’s healing environment to the health of the environment as a whole. She approached the hospital with the idea of a nontoxic housekeeping program after considering whether the cancer patients she and her husband receive at their New Mexico ranch through the Tomorrow’s Children Fund were exposed to carcinogenic cleaning products at the hospital.

Imus met with Hackensack University Medical Center Chief Executive Officer John Ferguson in his offices one afternoon. “Well, I got into five minutes, maybe, of telling him how important this was and why, and he said, ‘Wait a minute, just stop. This makes too much sense, just common sense, and we’re going to do it.’ Of course, that’s what we did. And successfully! In the spring of 2001, a matter of months, we literally revamped the entire campus at Hackensack. Mr. Ferguson had the right vision and saw the potential here. Immediately he thought, ‘Well, this is going to be better for our employees, be better for our patients, be better for the staff, be better for our visitors. Why wouldn’t we do it?’” (Hackensack, Imus).

In this and similar instances, sustainable design and healthy building operations become the building blocks for a new facility that yields improved health outcomes. These, then, are seen as a means to an end, not an end in itself.

Tier 3 organizations that were early pioneers of sustainable design rarely aspired to create a sustainable facility as a manifestation of their leadership agenda—it was viewed as simply the right thing to do. “When we were doing the clinic building, my friends and colleagues thought it was radically different. I never thought it was any more radically different than how we’ve run our agency. It really takes an organization with a green vision. I don’t think it’s possible to think of green as a hip thing to do and then just try to do it. I think the building has to be part of an overall vision. Now that it’s built, I have more colleagues that ask: How did you do this? How can we do it also?” (Discovery, Dollard).

“I didn’t really know we were a leader at the time. It just made sense. It was an opportunity that was presented to us that we could do something and build a building that was environmentally sustainable. I wasn’t aware that this was really leading edge at the time we actually made the decision” (BC Cancer, McNeil).

At the end of the day, there is a simple enlightened pragmatism, or matter-of-factness, about their ability to embrace sustainable design. “The singular belief system that drives the work that I do is the direct link between quality of the environment and the quality of health. It’s just that simple. Foothills has had a huge impact internationally and in the U.S. healthcare community. I can’t even tell you how many people have toured it” (Boulder, Abelkis).

The next generation of adopters can be identified as aspirational leaders who recognize the capacity of sustainable building to define Tier 3 leadership and transform organizations. They have learned from these groundbreakers and value these new ideas and their organization’s ability to push further: “Could we create this new hospital that incorporates all these ideas? Is there one in the United States? The answer was no. We’d like to be one of those destination sites where seeing is believing. We have taken the leap of faith” (Palomar, Covert).

**On managing change**

*Summary Statement 4: Tier 3 organizations see the design process as embodying a bold view of themselves and exhibit a variety of leadership styles to manage the change necessary to realize the vision.*
Leaders acknowledge the power of relatively small operational changes to inspire organizational transformation that resonates through the built environment. “No change that one can make is small, especially when it comes to our health or the environment or the impact it’ll have on our health immediately. I think we’ve proven that at Hackensack. This single fundamental change is a huge change and a significant one because it immediately changed the indoor air quality on campus” (Hackensack-Gabrellian, Imus).

“It’s really challenging to see if there are things we can do differently. What do we do in terms of pest control, environmental services? What do you do in terms of recycling, and how does that impact your purchasing policies?” (Children’s-Pittsburgh, Oxendale).

To achieve high-performance buildings, leaders are challenging their teams, both internal and outside consultants, to think differently. “This is not that complicated. It’s really common sense. All we are doing is challenging things that we’ve been doing for a long time, and why do we do things for a long time? Just because we are used to it” (Hackensack-Gabrellian, Ferguson).

“We wanted to challenge everything about we believed a typical hospital should look like, how it should act, how it should feel. My vision was to challenge the status quo at virtually every corner. And so that’s how we came to ‘Run until apprehended.’ Frankly, it’s hard for the designers, who have had the experience of working with owners, who, when the very first innovative idea that surfaces, say, no way. There was some trust building early on in the process between the owner and the designers to establish an environment that allowed good ideas to come forward. I wanted them to suggest everything. (Laughs) And then we’d go backward from the outer limits, where eventually even cost constraints do play a role but…” (Dublin Methodist, Herbert).

Tier 3 organizations have found local and community support for innovation. St. Mary’s Health Care (The Lacks Center) introduced the idea of sustainable design to its in-house design group because LEED had already begun to influence industry and impact design construction standards in the Grand Rapids, Michigan, area. “With Peter Wege’s involvement, the momentum and the spirit captured us all. He was giving us a tour, along with other Steelcase representatives, of Steelcase’s new facility and we began to think, ‘These are some of the same kinds of things that we should incorporate into our new building.’ He had not reached that point in his gift giving. But we said, ‘We think it’s important to do because we can see the benefits of it.’ Reduced gasoline, convenience for families...We also just sort of loved the challenge” (The Lacks Center, McCorkle).

Palomar exemplifies an organization inspired by the first wave of green building and primed to build on that early commitment. The organization is simultaneously engaged in a number of partnership and team-building activities, including with the Kresge Foundation, Kaiser Permanente, The Center for Health Design, and the Green Guide for Health Care. “Our champion teams went hard to work. Dealing with issues of sustainability, the healing environment and, as well, each group was charged to look at all the various aspects of our designs against finance, quality of the workplace, and making it better for our employees in general” (Palomar, Covert).

And for others, sustainable design taps into a germane set of cultural values that can be acted upon with the right decision supports in place. “It was at the Boston Design for Health Summit that it all came together. As a product of the 60s and 70s, I was very concerned with the environment while growing up in the Midwest. When I went to this Design Summit and started hearing what other hospitals across the country had done, or were contemplating, it seemed to me that we ought to put ourselves on a path to do likewise” (Spaulding, Waterston).
As the transformation occurs, Tier 3 organizations recognize their role in raising the bar for the larger industry. Within systems, demonstration projects resonate through the larger system. “The work we are doing is having an impact in the system, and it’s generally very well-received. With that comes the creak of the raising of the bar—it clearly is the sound we are hearing” (Dublin Methodist, Herbert).

Finally, these leaders acknowledge that the fear of change is not a reasonable excuse not to act. “People who are going through this process are realizing that change and the issues and pressures it brings with it are one thing. But to act on the fear of doing something different by doing nothing would be quite another problem. A lot of this is about stepping outside of the comfort zone… that’s what the journey involves” (Dublin, Herbert).

“Being a change agent requires a thick skin and a conviction that what you’re doing has value to your organization. And, eventually, what you start to see is hearts and minds changing” (Providence, Beam).

On bridging design and operations

*Summary Statement 5:* Environmental leadership among Tier 3 facilities is demonstrated through a mission-driven design process that integrates construction and operations in the service of continuous environmental improvement.

Tier 3 organizations consider the operational issues that define their environmental footprint and community messaging in the context of sustainable design and construction undertakings. “Our coffee shop that’s in the building refuses to use Styrofoam cups or containers. That’s one of the decisions we made early on, even though it doesn’t have anything to do with LEED. We all know that Styrofoam is not exactly an environmentally friendly material. So they’re using alternatives, which, in fact cost five or ten times as much” (The Lacks Center, Benz).

Furthermore, Tier 3 leaders understand that their communities require authenticity and honesty in approaching matters of environmental responsibility. “It’s about having the organization embrace the green hospital from a cultural and mission perspective. One of the fears I had was that we would decide that we were going to be green, have everybody work to get all the points, and then forget about it when the construction was over. Instead, we opted for a comprehensive approach—it’s a transformational process to have our staff thinking about everything that they’re doing as it relates to the environmental impact. And challenging to see if there are things that we can do differently” (Children’s-Pittsburgh, Oxendale).

Environmental awareness, once created, informs all the different aspects of community relations and leads to a culture of continuous improvement. In Tier 3 organizations, green committees, including representatives of design, construction, and operational departments, are spearheading initiatives to reduce environmental footprint. Organizations rely upon, and empower, these groups to challenge the status quo and raise the standard.

Kaiser Permanente has an active High Performance Building Committee that reviews sustainable design and operational initiatives. “Once the stakeholders—members, labor unions, caregivers—are educated about what’s going on, the demand increases internally to drive improvement. They’re the ones who will generate more demand internally. It’s a long journey—it’s a huge company—145,000 employees” (Kaiser, Koultsis).

Geoffrey Glass, director for facility and technology services at Providence St. Peter, launched a group called Stewards for a Sustainable Environment. “We borrowed on the idea of H2E [Hospitals for a Healthy Environment], and call it S2E. That’s been this interdisciplinary team of people, four of whom went to CleanMed. After that conference, we developed a listing of everything we wanted to achieve. We meet monthly at 7 a.m., and we’re all early. Amidst the rest of the work that we have to do in our jobs, we find time to chase down a number of initiatives simply because of our own passions for them!”
Often, operational improvement programs are implemented while capital projects are in design to ensure that improved operations are in place prior to move-in. For example, while Spaulding is only in the design-development phase, its Green Committee is actively engaging the hospital community through the monthly online newsletter that includes a column on “Greening the Hospital” and features articles on topics ranging from operational improvements to the debate on operable windows. Similarly, Children’s-Pittsburgh has been engaged in operational change initiatives for at least two years in anticipation of the opening of its sustainable building in 2008.

In organizations that can synthesize design and operational issues, operational improvements often lead to substantive changes in design and construction practices. Nowhere is this more evident than with Kaiser, which has researched material performance, purchasing contracts, and operational improvement in a comprehensive, coordinated manner.

“We started with a campaign to reduce the amount of material we were sending to landfill from Kaiser construction projects. As we learned more about carpet through the three companies we had national purchasing contracts with, we began to understand that there were a lot more environmental issues associated with carpet manufacture and emissions—indoor air quality. The indoor air-quality issues were connected to maintenance, the kinds of chemicals we were using. We asked tough questions: Is carpet a filter or a sponge, is carpet worse or better for the environment? We started looking more at the fibers as we talked to manufacturers about recycled content, what kind of backing they were using, and we used outside consultants to educate us beyond the waste issues associated with those materials. We now specify and purchase carpet differently” (Kaiser, Cooper).

Once the buildings are in place, their existence inspires continued environmental improvement. “I now have a director of environmental policy. We’re now putting out policy positions to bidders or contractors that won’t allow them to use certain materials. We don’t even have to talk about it anymore—we just implement it. I think the building has been this remarkable metaphor for us to say: We can do this…and more!” (Discovery, Dollard).

For many Tier 3 organizations, sustainable design has the capacity to positively impact the facility design process through policy enactment; creation of standards programs; or research, measurement, and verification activities. Within systems, the projects are universally seen as models for future system capital project initiatives. “There was an epiphany around our Newberg project. It’s fair to say that hearts and minds were changed within our organization about ecocharrettes and about building sustainability and energy efficiency into our facilities. And it was the genesis of what now has become a standard throughout Providence. We have a system here now that requires that an ecocharrette be conducted for every construction project over $5 million. It’s now embedded in how we do our business of construction” (Providence, Beam).

“I don’t think the goal of LEED certification has substantially altered our processes about inclusiveness of the design, but it has brought more people into the process and opened some minds to this in a very positive way” (U-M Mott, Kelch).

“Foothills has set the standard. We basically threw out our maintenance book when we opened our LEED-certified facility and adopted those new standards—everything else went out the window. Whenever we’re looking at upgrading something, we will look to the Foothills as our common denominator” (Boulder, Abelkis).

**On market transformation**

*Summary Statement 6: Tier 3 organizations recognize the power of the industry to transform markets through purchasing initiatives and wise use of resources.*
U-M Mott looked for demonstration opportunities to test and eventually grow the university’s basic building standards by selecting environmentally preferred materials. These would be used for cosmetic upgrades at existing facilities and in successive new facilities that fell under the planned new major buildings program. “In our planning we already were looking for product substitutes. We had put down rubber flooring in our current hospital in one of the floors because we wanted to test its durability and see whether the staff felt a difference. That’s an example of something we started before even registering our project with LEED” (U-M Mott, Warner).

This seeing-is-believing approach accrues other benefits as well. Manufacturers are incentivized at a much larger scale. They can respond easily to the communitywide expectation for their products and are encouraged to see new markets taking hold. Likewise, the design team is freed of many obstacles when the client gets involved.

“We need to really shake up, not only the architecture and design community, but also the manufacturers, because while they’re taking the steps, they’re baby steps. It’s like the automotive industry: the technology is there. We used cotton denim insulation as an example. There were no LEED points for it because we had to drive it across the country from Colorado and Arizona, but then when we thought about it, why would we want fiberglass, and fiberglass sitting in those walls for years and years and years?” (Hackensack-Gabrellian, Heeley).

“Unless you have a major purchaser or market for a product, I’m not certain that even architect/specifiers can push it—it’s really incumbent upon the owners—in this case, the healthcare industry—to demand these products. Kaiser, as a major voice for this industry, has taken a stand. Until we did, all of our visionary architects, interior designers, and supplier reps couldn’t get the attention of the manufacturing industry” (Kaiser, Kouletsis).

Often, Tier 3 leaders express frustration at the limited sustainable material choices in the marketplace. They long for innovative products that meet the performance needs of healthcare settings and transparent material evaluation protocols to ensure environmental benefit.

“I often wish that there were magic bullets that would allow us to make clear tradeoff decisions quickly—is the chemical pack in the waterless urinal worse for the environment than using the water to flush a conventional fixture? These are the kind of tradeoff decisions we are asked to make daily around these issues, and the data are just not forthcoming or simple. A lot of times the choices are not great—either the products don’t exist or they are so costly that they are not economically viable. One of my frustrations is that we are often forced to make the best of a range of poor choices” (Kaiser, Kouletsis).

They comment on the need to create industry demand for better, healthier materials—most have stories of battling the market for environmentally preferable options. Only with increased demand will the initial first-cost premiums for innovative materials be reduced or eliminated.

“We decided we’d try other than PVC (vinyl) materials. We went back through our materials palette and tried the rubber flooring experiment. That experiment failed. But we had migrated down the path of having decided, ‘Yes, we want to be green in our choice of materials. Now, let’s go out and learn what works and what doesn’t.’ And now we are saying, ‘If we’re going to have a resilient floor, it’s going to be an eco-polymer, even if it’s going to cause us to choke a little on the initial cost. We realize that we can service this economically and get a sustainable eco-polymer floor’” (Providence, Glass).

An appeal to commonsense knowledge of what patients would like and appreciate at hospitals and would positively affect their experiences as well as their health outcomes is causing officials in some instances to relax regulatory constraints and allow innovation to occur. “The Department of Public Health says you need, say, X-amount of foot candles for the doctor to examine the patient. But a green consultant might
say that a patient room should be able to get by with half that much. In negotiating with the DPH to separate the lighting circuits in the patient room into three separate circuits, we have a general room light, which is a couple of downlights that are dimmable and that are decorative, we have a reading light over the bed for the patient, and we have standard 2x4 fluorescent lights for the examination” (The Lacks Center, McCorkle).

Section B: Connection to community

Connection to community values

Summary Statement 7: Tier 3 healthcare leaders view their buildings as manifesting the values embedded in the communities they serve; within environmentally progressive communities, the healthcare sector’s environmental leadership is essential.

Organizations in environmentally progressive communities are compelled to demonstrate environmental leadership or lose their community connectivity. Many of the early adopters are community hospitals—organizations with close local ties—located in environmentally progressive regions or in cities with a public commitment to sustainable development. The Pacific Northwest and northern Michigan are regions described as having strong support for environmental improvement. “We’re blessed in Olympia to have a very progressive environmental community. People move here for the environment, sitting where we do in South Puget Sound, at the gateway to the Olympia River and the Cascade Mountains. Lots of folks enjoy the outdoors” (Providence, Beam).

Community environmental awareness is rapidly increasing; early adopters noted that standing with or being ahead of the community awareness level is key to maintaining market leadership. “We’re seeing a huge shift in awareness out in the general public about our impacts—both the hospital’s and their own. The City of Boulder is renowned for the idea of environmental stewardship. We’re trying to reflect a sense of community through what we value. You define values as a community. And to me, this community represents the values of people who live here. I’m a firm believer that, in life, you are the choices that you make” (Boulder, Abelkis).

Pittsburgh, Pennsylvania; Vancouver, British Columbia; Boston, Massachusetts; Boulder, Colorado; Grand Rapids, Michigan; Little Rock, Arkansas; and Austin, Texas—all have progressive, successful local green building initiatives that provided both context and local support for healthcare sector green building initiatives:

“One of the things that’s interesting about the Grand Rapids area is that it has a larger-than-normal number of green buildings. If you go to the U.S. Green Building Council’s site and look up Michigan, you’ll find a huge concentration of green buildings in this area. It’s part of our heritage. It stems from the forest industry and from living off the land in Michigan. It’s also tied to the psyche of the Grand Rapids population. As a result, we receive a lot of community support” (The Lacks Center, Benz).

In progressive communities, organizations that engage in sustainable building initiatives align themselves with leading peers in other private industries approaching sustainable building. “What’s happened since in the community has been astonishing; we have several LEED-certified buildings in Little Rock. When our staff see the success of the Heifer Project, the Clinton Library, and so forth, they say, ‘Yeah, we want that too’” (Arkansas COPH, Gehring).

In regions where sustainable building is under way, healthcare is redefined as a civic function and a pivotal community economic partner. As nonprofits, healthcare organizations are using their environmental leadership to maintain and enhance community support for programs, services, development, and expansion in the service of promoting health for the benefit of the community. “By charting the responsible path and replacing facilities within the construct of the City of Austin’s goals for a cleaner environment, we could add to our public image in the community” (Dell Children’s, Bonar).
“As we got closer to building the College of Public Health, it was all about, How do we do this as a demonstration project for what’s good for the community? What’s good for the nation? What’s good for our environment? All those questions” (Arkansas COPH, Gehring).

“We think that a sustainable, high-efficiency building makes a statement to our community about our commitment to them to provide the very best healthcare, in a healing environment that they will all benefit from” (Providence, Beam).

“We look at how we can serve our community. This LEED facility is just one more aspect of our hospital, as a community hospital, people feel connected to. People contribute, donate, volunteer, and that’s the reason why we can go forward. Our environmental stewardship is again just another natural extension of our community values” (Boulder, Abelkis).

**Community connectivity and presence**

*Summary Statement 8: Tier 3 healthcare organizations, through sustainable siting, design, and construction, become visible advocates for Smart Growth initiatives, sustainable development patterns, site restoration, healthy-lifestyle options, and community revitalization.*

Sustainable design initiatives provide a mechanism to engage in and be recognized for supporting community economic revitalization and healthier lifestyles. Initiatives range from encouragement of staff to purchase neighborhood housing (Children’s-Pittsburgh) to hosting farmers markets on site (Kaiser). As a first step in aligning values, Tier 3 projects have consciously chosen urban and semi-urban sites (Children’s-Pittsburgh, Dell Children’s, Boulder, BC Cancer, Dublin Methodist, Palomar, Spaulding) over ex-urban and suburban locations to avoid greenfield development and/or to reduce transportation burdens. In nearly all other instances, a site was carefully chosen on an existing campus.

Pittsburgh opted to rehabilitate a vacant downtown hospital campus rather than to develop a greenfield site in a suburban location, citing concerns about loss of community connectivity. They are now working with their Community Development Corp. on incentive programs for staff to purchase housing in the immediate Lawrenceville area. For Palomar, creating solutions to address the affordable housing challenges confronting staff in the immediate area of the Palomar replacement hospital site are viewed as a priority: “Now we’re talking about how to create housing opportunities for our staff and for others” (Palomar, Covert).

Where projects are located in less densely populated areas, or where mass transit is already widely in use, Tier 3 leaders seek creative solutions to mitigate reliance on automobiles. They become vocal, active advocates in support of public transportation systems. “We will have to work with the city on public transportation. I would say over 60 percent of our staff and patients come by public transportation. Right now, the Navy Yard is not a very densely populated area, so buses don’t run frequently enough for our staff. Given our site and the budget, we know we can’t build more than 300 parking spaces” (Spaulding, Waterston).

In urban areas well-served by public transportation networks, organizations are successful at reducing the required on-site parking. “The City of Vancouver waived the parking requirement because we had a good argument, based on the idea that most of the people in the building do not use their cars. They’re post docs; they take the bus. We wanted to encourage bus use. So did they” (BC Cancer, McNeil).

Even in areas with limited options for public transportation, Tier 3 leaders think creatively about alternatives to private auto use. “We are expanding van pools and are in discussions with North County Transit Authority about connecting with the Sprinter (a light-rail system). Part of solving the transportation problem is through the creation of a mixed-use site—we see an opportunity for assisted-living capacity and other commercial business opportunities” (Palomar, Covert).
In some instances, Tier 3 leaders move toward consolidating services as a strategy for reducing transportation burdens for staff and patients. “Before the creation of The Lacks Cancer Center, cancer patients and their families needed two things: they needed reliable transportation and they needed a good map—a road map—because they were going twenty-six places. This was the idea behind The Lacks Cancer Center, that all of these services, the complete continuum of care, could be provided right here in this one extraordinary facility” (The Lacks Center, McCorkle).

In completed green projects, alternative transportation use often exceeds projected demand, further demonstrating that a strongly articulated environmental stewardship mission resonates with building users. “I do believe that, for a number of our employees, that idea of green building and living in a sustainable world is now a reality for them. It comes to mind regarding bicycles. I’ve had to put two or three more bike racks out at Foothills. It keeps expanding because more and more people are bicycling. We’re connected to a terrific bike path that literally almost directly connects to our Broadway facility. Some doctors who ride their bikes can get from here to there in 15 minutes” (Boulder, Abelkis).

Sustainable design programs reward healthcare organizations for remediating environmentally damaged properties and restoring damaged ecosystems. Dell Children’s, for example, revisited an initial decision to move to a suburban greenfield site and instead opted for a more central brownfield site in the city’s desired development zone. “We took it as an opportunity to be particularly careful about what kind of development example we set, and the city encouraged us to set a high bar for the construction that would come after us in the development of the site” (Dell Children’s, Bonar).

Likewise, Spaulding is remediating a brownfield site in the long-abandoned Boston Navy Yard. The City of Boulder encouraged Boulder Community Hospital to take on an environmentally damaged site in the hope of achieving its restoration. “Much of the site was wetlands—it had been really destroyed by cattle grazing. And so we created additional wetlands. A portion of the land is just not touched anymore; it’s going back to its natural state of being—We will never develop it, nor do we want to” (Boulder, Abelkis).

This concept of stewardship leads us to a final group of Tier 3 leaders who actively advocate for protecting valuable natural sites and habitat for their communities. “When people arrive at Providence St. Peter, the entire building campus is shrouded in a forest of trees. Of our 154 acres, only about 60 acres are developed as the building site, and the balance of it is second-growth forestland—150-foot trees. We border a class I salmon wetlands. We own it. And probably 40 percent of our property is undevelopable. There’s this little creature called an Olympic mud minnow we protect—we hear that half the world’s population lives in this creek that borders our hospital. We regard our site as a precious resource—our community agrees with that” (Providence, Glass).

As Tier 3 organizations engage in green building, they become more empowered, visible, and active participants in wider community sustainability initiatives.

“Our local community college has now put together an energy park. And we’re there with them trying to recruit energy companies, wind, solar, geothermal interests, to set up in the energy park at the college and start to have students get more involved in green stuff. We are the largest employer in our county, and we do a lot of construction. We’ve been asked to set up a laboratory there that would help train plumbers and electricians and other trades people to know how to install and better understand this green technology or sustainable technology. That could have remarkable payoff for us. So we’re trying to better educate contractors in our region. It’s a very practical step” (Discovery, Dollard).

**Connecting to community and its behaviors**
*Summary Statement 9: Tier 3 organizations see the opportunity to model behaviors about healthier living and, conversely, model themselves after community needs and values.*
Hospitals engaged in sustainable building have the opportunity to create meaningful examples that are tangible demonstrations of doing the right thing for environmental and human health. For Kaiser, sustainable building is directly linked to its marketing and education campaign focused around healthier lifestyles: “We have the Thrive campaign, which is looking at people’s health and lifestyle. Our marketing folks are very interested in the sustainability program because it fits in perfectly with Kaisers’ ‘interest in improving your health and your lifestyle.’ By building smarter, better buildings that have fewer harmful impacts on the communities we serve, we’re promoting that same view that the campaign is projecting to potential members” (Kaiser, Cooper).

San Juan Regional removed a publicly visible facility that had unintentionally become a smoker’s hangout, held smoking-cessation classes, and is implementing a campuswide nonsmoking program, benefiting patient and community health. In this instance, the healthcare provider is able to effectively implement programs and policies from the top down in an effort to protect and advocate for health needs. Interestingly, San Juan Regional is also able to take from the community a healthy behavior that it then models back into the patients’ healing environment. Farmington, New Mexico, has a large Native American population with a need for gathering spaces large enough to accommodate families’ practices, social customs, and healing rituals. After receiving community input, a meditation room was provided on each floor.

Many Tier 3 leaders are using sustainable building and operation to catalyze larger organizational transformation in the service of the patient experience. In the landmark book, *The Experience Economy*, co-authors Joseph Pine and James Gilmore contend that people seek transformation in their healthcare encounter and that they look to hospitals in part to guide this transformation. “Patients don’t want to feel less sick, they want to be well” (Pine and Gilmore 2004).

Hospital patients and their families are looking for an environment that supports a transformational experience, and sustainable building is viewed as having the capacity to catalyze this change. “Another major theme that emerged in our design process was that of transformation, whether it was from a patient’s standpoint coming in ill and leaving well or from an employee’s standpoint coming in saying, ‘This day I want to be able to have a significant impact on the care of this organization and an impact on people’s lives’” (Children’s-Pittsburgh, Oxendale).

Many view the healing process as a teachable moment in the lives of patients and staff. The building and its operation can positively create healthy experiences that trigger behavioral changes.

“One of the interesting aspects of a sustainable healthcare facility is the number of people who come in and out of the doors. And where they are in their lives at the moment that you have them. You have people in an educable moment, that is, I think, a really compelling argument. You have so many staff, and so many patients, and the patients are there because they’re vulnerable. And they’ve just gone through some potentially life-and-death situation and are coming out on the side of life, but are at a moment to think about quality of life” (Spaulding, Waterston).

Tier 3 providers are major employers in communities and regions and have the potential to reach and influence large numbers of people in their communities with sustainable building initiatives. “Hospitals are such an integral part of every community. We’re the largest health system in Alaska, Washington, and Oregon. And so when we have this philosophy, it tends to have an impact that is disproportionate because of how close we are to our communities” (Providence, Koster).

In many instances, this is about allowing people to live their environmental values while in the building. “We allow people to reflect their community values by recycling, taking their bike to work, the bus to work, using products that are more environmentally sound, whatever. A majority say this is what they believe in and this is how they want to live—they’re very proud of that and they tell me that themselves” (Boulder, Abelkis).
On building community within

Summary Statement 10: Tier 3 organizations recognize that medical spaces and technologies are in the service of humans and that a broader vision of health and wellness is a program imperative—not a program addition. This broader focus of creating community, healing environments, and experience inherently requires consideration of both evidence-based design and sustainable measures.

Some Tier 3 organizations take a largely sustainable approach, while others focus on an evidence-based design approach—in fact, most are drawing from both. For all intents, one does not happen without consideration of the other since each encompasses a broad vision of occupant health and personal well-being as essential components of a twenty-first century better building.

San Juan Regional, which is neither formally engaged in evidence-based design nor sustainable-design processes, drew heavily on both in the design of its new bed tower. For example, it engaged almost 10 percent of its staff in the design process. It conducted multiple open houses with the community and three charrettes—one on sustainability, one on patient-room design, and one on healing-garden design. As a result, it included meditation rooms on each floor (see Summary Statement 9) and developed a building that stressed connection to the outdoors (see Summary Statement 13). It also included child-care amenities for staff. “As we designed the tower, we also kept in mind that need, or want, to personalize the experience for not only the patient, but also for the employee” (San Juan Regional, Frary).

This primary focus on people throughout both processes is what differentiates twenty-first century design approaches from those of the past. “Remember you are putting people in this building—remember who you are really serving. We always worry about whether we get everything we need for an X-ray unit. What if we just get the things we need for the humans who are going to work and live in this building for the point in time beyond our own?” (Arkansas COPH, Gehring).

As such, Tier 3 organizations today recognize that medical spaces and technologies are in the service of humans, not the other way around. For example, at BC Cancer, architects were charged with stirring interaction among the researchers, and, subsequently, designed a central, open stair. Initially seen as controversial program move, the communicating staircase is now a focal point for the building community. “We are building a bridge that reaches bench to bedside. … We didn’t want them to go to the lab, stay there all day, and then leave. … We wanted to encourage them to use the staircase and not the elevators as much, but you don’t do that by putting the staircase in the middle of the building in the dark. People do use it, but it’s much better if the staircase is attractive” (BC Cancer, McNeil).

“Today, medical centers talk about a tripartite mission, where your focus is not only on your patient care/operations but also your teaching and your research” (Children’s-Pittsburgh, Oxendale).

For many projects, this requires defining nontraditional spaces that create community within the buildings and on the grounds: “We visualized a meeting space that we called the Bruce Commons for Arkansans to come together on health issues. It’s named for one of the people deeply involved in the process, Dr. Bruce. We wanted to do this in a way that illustrated all those facets of health prevention and early treatment, so we included the open stair to encourage walking and interaction” (Arkansas COPH, Gehring).

In fact, it is unlikely that a Tier 3 organization will embrace the concept of patient-centered and family-centered care and not also embrace a connection to nature, the patient experience, healing, and the healing environment in its design approach. “One of the lenses we look through is around being environmentally conscious. We also ask ourselves if this is this going to be a healthcare facility that will last through the changes of healthcare over the next twenty years. And if so, does the business model make sense within the context of the demographics of the market … Hospitals are big, huge investments. So when we have the opportunity to build one, we have to be able to build something that can really express what we stand for” (Providence, Koster).
“In our conversations we focused on the human aspects of LEED certification. We did not talk very much about what the advantages are of having the co-generation plant. While meaningful to us, it wouldn’t mean much to the brain surgeons” (Dell Children’s, Bonar).

And last, in embracing a comprehensive sustainable design approach, unexpected outcomes occur. “Interestingly enough, green design lends guidance to aspects of site management and property ownership that are good for the healing environment as well. ... It’s even likely we’ll have a struggle on our hands when this hospital opens. Nurses and recruits who’ve been in small hospitals with no access to daylight will easily say, ‘You know, I’d really like to go work at Children’s’” (Dell Children’s, Bell).

“What we are finally doing is putting the client in the center of the process instead of the technology. I think the College of Public Health started that process” (Arkansas COPH, Gehring).

On medicine and public health

Summary Statement 11: As a shift in medicine and medical education continues to occur, a new generation of medical professionals, with interest in the environment and health, are beginning to reintegrate the disciplines of medicine and public health. Increasingly, Tier 3 healthcare organizations are taking on a visible advocacy role with regard to public and community health.

An ecological framework for construction and operations brings with it not simply a concern for impacts of the built environment on the local community and its resource base, but also a greater emphasis on community health. “Our responsibility as a pediatric healthcare organization is not just to care about the kids that come into our organization, but to care about all the kids in the community and what impacts their lives. ... There is a larger imperative for healthcare systems to advocate for the broader public on public-health and community-health issues. I don’t think it’s widely acknowledged, but it’s important for us as leaders in the community” (Children’s-Pittsburgh, Oxendale).

In this instance, a larger academic medical center brings forward a connection between sustainable design, operations, and the provision of medical services in a systemwide approach to improve community health. “Every one of our patients depends on us to advocate on their behalf. They cannot advocate for themselves because they’re children,” (Dell Children’s, Bonar). In both instances, these Tier 3 leaders are advocating a community health agenda that ripples through their respective systems (University of Pittsburgh Medical Center and Seton Healthcare Family of Hospitals, respectively).

Leaders in environmental medicine and public health are impacting decisions to pursue sustainable design and operational initiatives in healthcare organizations. In academic medical centers, these questions are prompting healthcare organizations to navigate the reconvergence of public health, medicine, and environmental health to “accomplish the synergies that we need to within the broader organization” (Children’s-Pittsburgh, Oxendale).

Some see it as fundamental to a physician’s value system:

“In healthcare, sustainable building represents a fairly bold move toward precaution and prevention. The building stands for health. In creating it, the organization is essentially saying, ‘We’re investing in keeping people healthier.’ And that is a difference in the way that the United States has approached healthcare. But it’s consistent with a physician’s value system. It represents a mindset and a culture of health as opposed to sickness treatment. Healing is something that is so intangible. Creating the right environment for people mentally, physically, spiritually is so important. Really being attentive to sustainability and wellness and developing a holistic view of healthcare has an impact that we may not be able to measure or test, but I’m convinced it has a tremendous impact on somebody’s ability to attain health. Not just to be not sick, but to be in health” (Providence, Koster).
Likewise, sustainable design and construction is energizing medical education. “Our residents and faculty members are very interested in the fact that we’re building a green hospital, and they’re enthused about the kinds of research questions that might be asked and the implications for the resident-training process” (Children’s-Pittsburgh, Oxendale).

“Many of the students going through medical school are getting master’s degrees in public health along with their doctorate in medicine. It used to be that they’d get it in biochemistry or research of some kind. Now they’re looking into public health” (Arkansas COPH, Gehring).

In academic settings, medical students are becoming champions for sustainable design and operational initiatives. “There is a lot of interest amongst our medical students and other students. They’re very, very bright; they’re influential; they’re persuasive. They may not be fully informed about all of the economics of healthcare, but they are very well-informed about environment and sustainable design. They brought a lot of information to the table” (U-M Mott, Kelch).

“Our second- and third-year residents heard that we were doing a sustainable building and asked to meet with me. They planned six different lunch-and-learn sessions around environmental impact on healthcare for this year. They initiated it on their own” (Children’s-Pittsburgh, Oxendale).

On an urgency to act

Summary Statement 12: As sustainable buildings explicitly message health, organizations recognize a massive culture change toward a broader, long-term view of mission and more proactive stance on global health and resource stewardship.

Healthcare infrastructure and operations have both enormous impact on and responsibility to oversee change. “People in general are reluctant to embrace change. At some point in time, the idea is so pervasive it becomes the common wisdom. Being an environmentalist no longer is seen as radical—it’s just a component of being a responsible citizen. Global warming, recent unfortunate weather events—[hurricanes] Rita and Katrina—people are beginning to connect the dots. Some of the reaction is fear, but the majority of people is jumping on and saying it’s the right thing to do” (Kaiser, Kouletsis).

“I certainly sense it in our organization, that there’s a grassroots effort at Providence. It’s bubbling up all over the place. We’re starting to see programs emerge all around the Providence health system. … And people are sensing that these resources that we all hold in trust for future generations, that we need to do something positive, to save the world from ourselves, I guess” (Providence, Beam).

Beam recalls a meeting with Janine Benyus, author of Biomimicry: Innovations Inspired by Nature. “I met with her at an inland Northwest sustainability conference in Boise, Idaho, last year, and I asked her to inscribe something in my copy of her book about her work and how her work and mine really meshed in some way. She wrote: ‘Providence Health and Services has two patients, the medical patient and the earth. To heal one without the other will not last. It’s true for healthcare. We have to do both’” (Providence, Beam).

As an energy- and water-intensive sector, Tier 3 leaders grapple with the imperative to manage resources wisely and effectively. Sustainable design offers a way to more effectively quantify and manage energy and water use and communicate those improvements to the communities impacted by their operation. “When the architects were out here for their first few visits there was no water in the river. In terms of the environment, we knew we had multiple stressors. We knew that we needed to be very good neighbors when it came to water, so all of the landscaping features are designed for low water use” (San Juan Regional, Frary).

Across the country, early adopters recognize both the high cost of energy and the wider impact of fossil-fuel use on community health. “There’s a diabolical thing that’s hanging over all of us, if you pay attention. Energy itself is only going to get more expensive, and more complex to manage. For the long-term,
particularly in the Northeast, it’s important to have control and a handle on what your energy source is
going to be. Everybody has to move away from oil. It’s critical” (Discovery, Dollard).

“Our health system operates in weather zones from Southern California to Alaska. It’s interesting to note
how different utilities view the environmental impacts of global warming and what they’re trying to do
about it in their communities. In the Northwest, particularly, there is this great sense that it’s the right
thing to do make energy efficiency or energy conservation part of a utility company’s least-cost plan to
provide electricity, both now and in the future, to their community” (Providence, Beam).

“The local newspaper environmental reporter and I are regularly in communication because John writes a
weekly one-page paper that’s dedicated to the environment. A couple years ago, when energy costs accel-
erated wildly, we were one of the first ones that John called. ‘What have you done to save energy?’ Of all
the things I’ve done that have connected with our senior administration, it’s been that behind-the-scenes,
positive recognition to our community for something that is important to them” (Providence, Glass).

As the science converges on the intersection between chemicals and human health, leaders are challeng-
ing themselves to take a broader view and more proactive stance on global human health. Clearly, Tier 3
children’s hospital chief executive officers and their spokespeople view the science as important to their
constituents and communities. “People look at children’s hospitals and expect them to be leaders in areas
like this” (Dell Children’s, Bonar).

“We approach everything from an environmental perspective because by identifying, controlling, and, ulti-
mately, preventing all these environmental exposures, we can prevent disease. We know that. We can protect
our children, the environment, and ourselves. It is the whole global picture” (Hackensack-Gabrellian, Imus).

“There are many, many examples where the environment has affected and can affect children in negative
ways. Look at lead poisoning—leded gasoline in the past; today lead paint is still doing damage. And
when you damage the developing brain, it’s often permanent. We’re learning more and more that children
are precious when they’re developing, and they’re more susceptible for all sorts of insults—including envi-
ronmental insults. So as a pediatrician, I feel that we need to construct the best environment possible
in the hospital” (U-M Mott, Kelch).

Finally, these Tier 3 leaders agree that reducing the sector’s environmental impacts requires a long-term
view of mission, responsibility, and resource use. “Try to take a very, very long term view...Sometimes we
find ourselves forced to develop a shorter term fix-it-now-as-fast-as-you-can plan. And those usually are
not the best plans. That has helped me think through situations and allowed me to say, ‘We really need
to do this because it’s the right thing for the long term’” (U-M Mott, Kelch).

This requires commitments that extend for years. “In order to keep sustainability from becoming the fla-
vor of the month, you have to have a commitment to the resources to keep an ongoing focus. As we have
all discovered, even a simple issue requires research, specification, and selection, embedding in the stan-
dards program, and then successful education of teams toward implementation—that’s two years, three
years, five years—so, unless you have the commitment from leadership and the resources to sustain a
multiyear effort, you’ll be disappointed. It will fail because you didn’t understand the commitment
required” (Kaiser, Kouletsis).

“Once you head down this path, you’re in it for the long run. You can’t suddenly say, ‘Hey, now that there’s
a new administrator and he doesn’t want to do this so now we’ve got to make changes.’ By this time, you’re
so far along, you can’t go in and change out the glass because that means you’ve got to change your
mechanical system because everything is so integrated: materials, glass, window locations, heat gain, heat
loss. Not to mention there’s a lot at stake in creating this environment, from its architecture and engineer-
ing, and with the expectations that have already been created for the doctors that you’re trying to recruit.
Once they get involved in the process, they have their stake in the place they’re going to go work” (Dell Children’s, Bell).

Section C: Framing the benefits back to communities

On recruitment, retention, and performance

Summary Statement 13: The multiple benefits associated with sustainable building reflect a comprehensive breadth of financial indicators beyond what is conventionally accounted for in return-on-investment analyses. Sustainable buildings create work environments that positively impact staff recruitment, performance, and retention.

For an industry historically challenged by higher-than-average turnover rates (and higher-than-average associated risks, given the nature of hospital operations), enhancing recruitment and retention is a compelling bottom-line, measurable financial benefit. “If we provide the right workplace environment for staff, and they are able to focus on taking care of people instead of themselves, then we ought to be able to measure it in terms of our customer service without patient loyalty scores and all the other measurables. So we need to create an environment where people want to work. We can hire the best and the brightest” (Palomar, Covert).

In fact, some Tier 3 early adopters are already seeing evidence that their green buildings are positively impacting recruitment. “In the first six months of this year, three cancer surgical specialists contacted us. They heard about St. Mary’s and The Lacks Cancer Center. They wondered what it was about, having heard about it from family members, and wanted to promote their surgical specialty” (The Lacks Center, McCorkle).

“I’ve been told that two or three of our latest recruits have come because of the building. I truly believe the fact that because we achieved a LEED standard, and then went above and beyond, is one of the reasons they’re coming. Environment is huge, and it helps us recruit and retain our researchers” (BC Cancer, McNeil).

“I believe that a lot of folks come to work at this hospital, believe in this hospital, stay in this hospital because a lot of what they want to do is steward the environment” (Boulder, Abelkis).

Even before the buildings are completed, improved recruitment through a better work environment is a perceived benefit. “Nurses who’ve been in small hospitals with no access to daylight will say, ‘I’d really like to go work at Children’s.’ We have already started getting so many calls from physicians from out of town who have heard about this project, who want to come here, that it’s creating a difficulty because we only need so many heart surgeons, for example. I’m sitting on two resumes right now for people in two different surgical subspecialties that I don’t think we have enough clinical throughput to support. But they want to come here” (Dell Children’s, Bonar).

Another consideration associated with green building design features and operational protocols is occupant and staff well-being. Creating a workplace that models an environment of care protective of the well-being of building occupants—such as using nontoxic cleaners, providing day-lit workspaces and breakrooms, and ensuring enhanced air quality—contributes to staff retention and also boosts performance, including reducing sick days and workers’ compensation claims. “We wanted to personalize the staff’s experience so that they would choose us over someone else” (San Juan Regional, Frary).

“We did a research study that confirmed that the cleaning products we were using before caused the employees to call in sick a lot. This is before the Greening the Cleaning program was implemented. Their eyes were all red, and different illnesses were happening. When we changed the program, it all went away, and our workers’ compensation claims went down” (Hackensack-Gabrellian, Imus).
“My environmental services people are the happiest people in the agency lately. And I wonder if it’s not because they’re working with such nice materials. There’s a sort of worker-respect aspect of green cleaners that sends a message to a group of people who generally feel undervalued that somebody actually cares about their occupational exposure and the materials they work with. It makes them more energized to do their jobs, the way respect energizes all of us. If you can cut sick days and absenteeism by 10 percent, you’re saving tens of thousands of dollars” (Discovery, Dollard).

Staff recruitment, retention, and performance are among the most impressive benefits derived from sustainable building initiatives. These benefits are well-documented in the green commercial office-building sector, though not yet broadly recognized in the healthcare sector. Our sector-specific results, demonstrated through these interviews, reveal a consistent positive correlation between green buildings, staff recruitment and retention, and performance and provide a bottom-line justification for green building on financial payback terms.

“Understanding that the people who work for us are also members, that their health is important to our success and mission, and that they are in our buildings for extended time periods. If you can reduce sick days, reduce injuries, there’s a business case around those issues that both benefits the bottom line and improves the relationship with employees. The same thing is true with patient safety. A lot of these new sustainable materials appear to improve patient safety and connect to other environmental initiatives as well. This program fits well into a larger program at Kaiser: The Three Safety’s: Patient Safety, Workplace Safety, and Environmental Safety” (Kaiser, Cooper).

On the occupant experience

Summary Statement 14: Tier 3 organizations provide for an improved occupant experience in their facilities with better connection to nature, occupant control, and enhanced air quality.

Healthcare facilities have an extraordinary opportunity to create an experience that enhances patient healing and motivates the highest level of staff performance. “What we’ve found in green design is that we make a commitment from the very beginning about the job and what it means. There’s a lot at stake in creating this environment, from an architecture and engineering side, in terms of working here, and with the expectations that have already been created for the doctors that you’re trying to recruit. Once they get involved in the process, they have their stake in that this is the place they’re going to work” (Dell Children’s, Bell).

While contributing to delivering the essential programmatic functions, these results also yield favorable financial outcomes. In creating a coherent template for twenty-first century hospitals, these high-performance, Tier 3 facilities rely on a consistent palette of design features, healthy materials, and attention to building orientation and form that contribute to an enhanced human experience.

From the patient perspective, benefits associated with sustainable buildings include decreased length of stay, reduced reliance on medication, and lessened mental and physical stress. While our interviewees were not asked to evaluate this, many offered anecdotal evidence of satisfied patients.

“We’ve asked our patients how they rate the environment of the building and have seen a dramatic shift in response toward ‘acceptable’ and ‘appreciative.’ So it is with the creation of different spaces and the increase in light, and the quietness, and with all these different kinds of materials that we have created this environment” (The Lacks Center, McCorkle).

“Many of the students going through medical school are getting master’s degrees in public health along with their doctorate in medicine. It used to be that they’d get it in biochemistry or research of some kind. Now they’re looking into public health.”

— Leo Gehring
“One of our goals was to bring natural light into 100 percent of the occupied spaces in the building, and we have achieved that in the area of probably 90 to 95 percent. Within our organization we have framed that in the context of research that demonstrates the positive impact for patient, families, and staff” (Dublin Methodist, Herbert).

“Since we have such nice weather, we definitely wanted to have outdoor spaces. We kept shade in mind, also. For the patients, we built a healing garden. With each private room, we have a balcony for accessing fresh air. The balcony itself overhangs the floor below and provides shade. The rooms are oriented to reduce heat gain. Plus, the balconies are great spaces for patients and families to walk outside right off the room” (San Juan Regional, Frary).

These measures also create improved working conditions for the facilities’ medical and management staff. “Having a green building has been this remarkable opportunity for 1,000 staff to experience the building and realize how remarkable air quality can be if it’s handled right” (Discovery, Dollard). “I asked Mr. Ferguson whether we could replace all toxic cleaning agents with nontoxic ones. As soon as that was all eliminated, they felt better, and it said to them, ‘My boss is looking out for me’” (Hackensack-Gabrellian, Imus).

Providing opportunities for building occupants to control their environment is an expression of respect and enables people to act on their values through choices that are offered. “It’s the little things that make a difference. Both the operable windows and the dual-flush toilets are moments where a person interacts with the building to elicit control over resource use. ‘How much water am I going to use?’ You’ve given them more than personal control—you’ve provided them with a way to live their values” (BC Cancer, McNeil).

On financial effectiveness

Summary Statement 15: Sustainable building improves financial effectiveness in part because it fortifies team buy-in and public support.

For Tier 3 organizations such as Dell Children’s, the goal is not to create a green facility as a public display (i.e., a trophy), but rather to create one as part of a sound development plan where the financial effectiveness of reducing long-term operating costs is as important as being a good neighbor. Many are developing life-cycle cost analyses or cost methodologies that recognize operational savings in making first-cost decisions.

“What we’ve found in using LEED is that we make a commitment from the very beginning about the job and what it means. It’s not about buying points. We’re not going to throw money or do meaningless things for the sake of points. The financial assessment that was completed showed we would save $6 to $8 million in operating expenses in about the first fifteen years of operations. And in working with Austin Energy to develop energy costs, we came to the conclusion that the project had to pay back in less than eight years. So that was part of the business decision on some of the LEED points” (Dell Children’s, Bell).

“Life-cycle cost assessment is thoroughly embraced, because we understand that it’s about the total cost of ownership—not only the first cost. We are a healthcare company and it permeates throughout the system—that the benefits you get from best practice, efficient operations accrue to the system” (Kaiser, Cooper).

In some instances, sustainable building assists organizations in obtaining public financial support for their capital project. One example is Palomar Health, which garnered tremendous public support to back a $250 million revenue bond package for a proposed new hospital, campaigning on a commitment to deliver an unprecedented level of care to the community.
“When we passed Proposition BB, the community invested in us. This is what makes that significant: 70 percent of the people in our district voted for us, even though only 60 percent actually use our services. That means other people who don’t come here were willing to take money out of their pockets to invest in us as an organization” (Palomar, Covert).

Boulder is a telling example of earning community support. The benefit of being able to provide services in a town where residents had come to expect them was an undeniable asset for the city. In Boulder, the city incorporated the parcel, allowed the hospital to mitigate wetlands issues, and collaborated with the hospital to assure acquisition of all necessary federal permits.

“The City of Boulder votes in council members who are strong in the arena of quality of life and environmental stewardship. They’re willing to improve upon those and, with Boulder and Boulder County growing in leaps and bounds, we felt this was the perfect time to build a new standalone hospital. It was an unincorporated parcel that the city had already identified for development. So, we readily wanted to support that” (Boulder, Abelkis).

BC Cancer worked with the city to overcome floor-area limitations and parking requirements, waive property taxes, and, in exchange, create a facility for top-level scientists from around the world that messaged both health and quality of life. Spaulding opted for the former Boston Naval Yard site to gain a waterfront location that supports its aquatic programs and partnered with the City of Boston and other public authorities to facilitate zoning changes and site remediation.

Dell Children’s was motivated to shift its campus from a suburban, greenfield site to a downtown site with the City of Austin’s incentive to put the project on a fast track. “We came back downtown when the city council indicated that they would work collaboratively with us and try to speed up the process that would allow us to acquire the downtown parcel” (Dell Children’s, Bell).

The list goes on. The most significant aspect is summed up well by Dollard’s statement, whose goal was to create a facility on a site that once contained an industrial operation: “We had a good partnership with Governor [George] Pataki’s office and the health department. We all were convinced it might be really beneficial to create a green building. All the while, I felt I needed to convince my board that this was the right thing to do. Or actually, they never need to be convinced. I needed to work hard with my board to find a way to help fund this” (Discovery, Dollard).

The health benefits of a sustainable facility are immediately understood. But for many organizations, garnering board support still requires the chief executive officer to make a compelling financial case for the sustainable building. Increasingly, that financial justification can be bolstered by the economic bottom-line benefits that accrue from healthy building and environmental stewardship.

For others, sustainable building is seen as a market differentiator—a way to separate healthcare organizations in an often-crowded marketplace. “The marketing people are taking companies that might want to join Kaiser through the facility and talking about how the design answers the mission statement. There was a local small company that had always said there wasn’t enough market differentiation between Kaiser and our competition—after the visit to Modesto, they signed up on the spot. Another broker reported that the initiatives were really going to resonate with their business customers” (Kaiser, Kouletsis).

Palomar is using sustainable design as a featured selling point and, more importantly, as a tool for broad organizational alignment. “It takes about eighteen months to get our plans through the state here, and we’ll have the plans to them in the fall. Then it will be another eighteen months before we can even get started. … It’s a $987 million project that, because of a Kresge planning grant, was able to host a community charrette. We decided it would be a great opportunity for us to bring in some of the potential community partners who might help us think more broadly because of their expertise. [These partners
included people representing energy and water utilities, pollution control, and future-oriented businesses. There were some good practical recommendations. The question becomes, How do we start working with it now in terms of our renovation projects?” (Palomar, Covert).

On fund raising and development

Summary Statement 16: Insofar as healthcare relies on public support and private philanthropy for its capital projects, sustainable design will continue to drive and invigorate the process.

Few Tier 3 organizations tied their early funding and development campaigns to the quest for a sustainable facility. But for those that did, dollars tied to green building positioned them ahead of the curve. One of these pioneers is Dollard, who, because of his agency’s nonmedical purpose as, essentially, a residential campus and school, immediately searched for supplemental funding sources. “From day one we needed to be alert to the budget. ... It was and continues to be a challenge to build green.” He explains that receiving a Kresge Foundation grant became a “major boost, because it validated to my board that this was a good thing to do.”

The same is true for the Children’s-Pittsburgh. Very early in the fund-raising process, leaders were able to obtain a state grant $5 million toward the greening of the hospital. It was management’s sense that getting the grant well before finishing the preliminary design alleviated a lot of questions about possible tradeoffs between first dollar and longer-term operating costs. “I haven’t had to go through that same justification process that some of the others have done,” says Oxendale (Children’s-Pittsburgh).

Collaborations such as these are truly a hallmark of the pioneering process Tier 3 organizations use to manifest their vision. The Arkansas COPH received a large sum of money through the nationwide tobacco lawsuit settlement. COPH administration, together with the Colleges of Medicine and Nursing Deans and Department of Health officials, agreed to direct the settlement funds to construct the school at a time when others were opting for roads and airports. “When we started the project, it was absolutely based on the idea that what we needed was a process and an enlightened view of public health” (Arkansas COPH, Gehring).

For Tier 3 healthcare organizations, reliance on a healthcare mission as the singular justification for green building is often not enough. “Locally, even nationally, we’re blessed to have a very progressive environmental community” (Providence, Glass). Providence operates in five western states from Alaska to California. The system includes twenty-seven acute-care facilities and employs 46,000 people. The Providence Newberg Medical Center in Newberg, Oregon, is the first medical facility to receive LEED gold certification. “Our employees and our community really had tapped into the idea of a sustainable building in healthcare being a more healing place” (Providence, Beam).

Indeed, for many, having a sound business model in place is essential. “We had available to us about $195,000 in business energy tax credits, but we didn’t have the tax burden to take advantage of it,” remarks Providence’s Beam. With the foundation, he pulled together a philanthropic venture, a public-private sector partnership of sorts, whereby a privately owned company in Newberg was able to take the $195,000 in tax credits and return, in exchange value, $143,000 for the construction of energy conservation features that were budgeted into the hospital and later built.

Numerous other instances of creative financing and structuring of a business case exist. Dell Children’s received a $25 million gift to support construction of a replacement facility. Even with those unanticipated funds in hands, the project team was tasked with delivering a project that was financially compelling. In working with Austin Energy on an on-site combined heat and power plant, Dell Children’s was able to reinvest about $6 million that otherwise would have been part of the capital cost of providing a central plant. “Since they built our central plant, and we’re paying for it over the years through our utility costs, we were able to roll back the savings into the project for other green features” (Dell Children’s, Bell).
The hospital is expecting to set precedent with a LEED platinum rating. “We’re less than 1 percent of the overall number of hospitals in the United States, but we train over half of all pediatric specialists. So people look at children’s hospitals and expect them to be leaders” (Dell Children’s, Bonar).

Similarly, The Lacks Center was primarily funded through philanthropy. Richard S. Lacks Sr. provided the lead gift and had approached the hospital after both his father and grandfather had died of cancer. His primary focus was that any family should not have to be inconvenienced by traveling out of state for care, as his family had done. But, in addition to the lead gift, Peter Wege, a local environmentalist and major benefactor throughout the process, made his gift contingent upon sustainable design. “We have had lots of requests from press to talk about the LEED factor. But remember, it’s a cancer center that’s LEED-certified, not a LEED-certified building that happens to be a cancer center” (The Lacks Center, Benz).

For those who entered the design process without a firm commitment to sustainable building, they were transformed by what they learned and are moving forward with a firm resolve that green building fundamentally resonates with mission. “Frankly, we’re getting used to doing it this way. … So we have another building coming up, a major building, a cancer hospital, and we’re going to do it again,” (Hackensack-Gabrellian, Ferguson).

Hackensack University Medical Center, like others, will continue to aggressively seek financial assistance to pursue this agenda. “There’s a real sense out there that if we could just find that capital, that incremental capital to make better choices about how we build and operate facilities, we should do that. And I think there’s a demand out there for it” (Providence, Beam).

**On certified performance**

*Summary Statement 17: Tier 3 organizations are increasingly using green building rating tools. Their use accelerates market transformation, normalizes sustainable design practice, and aggregates benefits.*

Since the release of the U.S. Green Building Council’s LEED in 1999 and the *Green Guide for Health Care* in 2003, green building initiatives have benefited from common frameworks and accessible methodologies to guide design, construction, and operations decisions. “It’s certainly a very efficient, environmentally friendly building that we delivered, using the LEED standards as a tool for figuring out how we can deliver a better building” (Arkansas COPH, Gehring).

With thousands of projects now engaged nationwide in virtually every market segment, these tools establish thresholds, measure performance, and generate market signals to shift toward a bill of materials, products, and equipment informed by a life-cycle view of environmental impacts.

“Using the Green Guide, we developed a checklist—Category 1 points are items incorporated in our Kaiser standards—these become the minimum requirements for our project teams. Category 2 are items that are reasonably simple to implement with a modest amount of research by us or our project teams. Strategies that teams are looking at include operable windows, renewable energy, or hybrid chiller plants, or innovative materials. We believe the process will produce a stronger base of better, smarter buildings for Kaiser, based on a standard, while responsive to local community and individual team vision” (Kaiser, Cooper).

Indeed, in mid-2006, there are six LEED-certified healthcare facilities, with dozens more in the pipeline, and more than one hundred *Green Guide* pilot projects. Collectively, these represent more than 40 million square feet of healthcare construction. Projects registered with LEED are seeking independent, third-party certification, and those in the *Green Guide* pilot are using a voluntary, self-certifying toolkit of best practices for design, construction, and operations.

Interview participants include the first in the healthcare sector to achieve LEED certification (BC Cancer, Boulder, Discovery, The Lacks Center, Providence ), a signifier of Tier 3 leadership.
Others are LEED-registered and are pursuing LEED certification, to be awarded at completion of construction. These include Children’s-Pittsburgh, Dell Children’s, and Hackensack-Gabrellian. Virtually all of these used the Green Guide informally, or as a registered pilot, as a source of healthcare-specific guidance and for internal baselining and benchmarking to support continuous improvement.

“There’s a wonderful trend among people who are very interested in the environment, including those who set up the criteria for certification, and for planners in healthcare to look at the criteria and then make them more appropriate for our needs. The Green Guide for Health Care is one of those wonderful happenings right now” (U-M Mott, Kelch).

Part III: Closing

Lawrence (2000) sums it up this way: “Just as we have responsibility for providing quality patient care, just as we have responsibility for keeping our facilities and technology up to date, we have a responsibility for providing leadership in the area of the environment. The stakes are extraordinarily high. We have to keep folding these questions and these considerations back into our leadership. We have to incorporate them into our incentives, into what it is we’re held accountable to do, how we measure our impact. We all know the old saw, ‘No margin, no mission.’ But as a colleague said, ‘Without the mission I don’t want to get up in the morning.’ Competing effectively is a need that we all have, but it isn’t what healthcare is about. It’s about improving the health of the communities we serve.”

The Tier 3 leaders interviewed for this paper demonstrate that the industry is responding to Lawrence’s challenge. All these institutions demonstrate that sustainable values are embedded in their mission and vision, and, as market awareness, tools, and incentives evolve, this massive industry is rising to realize its fundamental objective to improve the health of the communities it serves. This recognition builds environmental leadership and awareness of the linkages between human health and the environment. Out of this awareness, a comprehensive vision of improved performance is emerging—one that unites construction and operation to yield triple bottom-line benefits—economic, social, and environmental.

Recognition for these activities builds leadership. When the Green Guide was developed, it was based on the assumption that health-based green building standards—standards grounded on the idea of protecting occupant, community, and global health—would resonate with leading healthcare organizations and that those organizations would move forward to actualize better buildings that respond to this mission. What was less apparent then, but is now becoming clear, is how this goal of improved performance would resonate with the communities surrounding these institutions—and how these healthcare leaders would move past sustainable strategies that deliver operational improvements to seek a broader, more meaningful set of health benefits—or, in the legal parlance of community benefit, promoting health for the benefit of the community.

“These organizations are connecting to their communities in new ways. Sustainable building demonstrates, in bricks and mortar, that healthcare organizations can reflect the values of the communities they serve—in environmentally progressive communities, their environmental leadership is considered essential to maintaining and increasing market share.

These leaders are advocating for Smart Growth policies, economic development, and remediating environmentally damaged sites. They are modeling healthier lifestyle choices to their patients and staff, through initiatives ranging from transportation alternatives to housing relocation incentives,
organic food to open stairs that encourage walking behaviors. As this century unfolds, they are recognizing that their buildings are in the service of humans, rather than simply receptors of the latest medical technology. And finally, these leaders recognize the high cost of inaction on matters of the environment on the health of our families, neighbors, and communities at hand and globally.

As they begin to understand the benefits, Tier 3 leaders recognize that sustainable building and operation has the capacity to keep generating benefits, from the inception of design through occupancy and beyond. Many already report positively around recruitment and retention. A high degree of occupant satisfaction—often associated with choice, control, and the ability to live one’s values—accompanies the completed projects. Financial benefits, ranging from reduced operating expenses associated with energy and water reduction to lower staff turnover—are proudly recounted.

For the most part, leaders report that there are modest first-cost increases attributable to their sustainable building initiatives—but there are varying approaches to dealing with those challenges and successfully overcoming them. As Providence’s Beam so succinctly framed it: “There’s a real sense out there that if we could just find that capital, that incremental capital to make better choices about how we build and operate facilities, we should do that. And I think there’s a demand out there for it.”

How do these Tier 3 organizations emerge from their Tier 2 counterparts? For some, it’s the connection to an expressed stewardship mission. For others, its visionary leadership, either from the chief executive officer or board level. For still others, it’s the opportunity that a private philanthropic gift presents, tied to a broader vision of health and the environment. However it occurs, once these leaders come forward, they continue to move forward through multiple projects and operational improvement initiatives. Without exception, they find that their leadership vision inspires and transforms their organizations. No one emerges from the process unchanged.

Throughout history, there are traceable, identifiable moments when, upon reflection, a critical mass is in place that creates conditions for transformation. Such a moment—healthcare’s tipping point—is approaching. The resurgence of healthcare institutions as definers of community wellness and public health reinforces their civic leadership stature. The opportunity to rekindle healthcare’s values-driven legacy to “First, do no harm” deserves the environmental health community’s full acknowledgement and support.

**Author Biographies**

**Robin Guenther**, FAIA, is principal of Guenther 5 Architects, a twenty-person New York City firm with extensive experience in healthcare design. Her work has been published nationally and internationally in magazines such as *The Architectural Review, Interior Design, Contract, Architectural Record*, and *Healthcare Design*.

Last year, Guenther was awarded The Center for Health Design’s Changemaker Award for her efforts to continuously improve and support change in the healing environment. She is a co-coordinator of the *Green Guide for Health Care* and serves on the LEED for Healthcare Committee. She is currently co-authoring (with Gail Vittori) her first book, *Sustainable Architecture for Health*, to be released in 2007 by Wiley and Sons.

**Gail Vittori** is co-director of the Center for Maximum Potential Building Systems, a nonprofit sustainable planning and design firm established in 1975, located in Austin, Texas. Since 2000, Vittori has been engaged in numerous green healthcare initiatives and currently is a co-coordinator of the *Green Guide for Health Care* and chair of the U.S. Green Building Council’s LEED for Healthcare Committee.

Vittori was a Loeb Fellow at Harvard University’s Graduate School of Design from 1998-1999 and serves as secretary of the U.S. Green Building Council’s board of directors. She is co-author (with Robin Guenther) of *Sustainable Architecture for Health*, to be released in 2007 by Wiley and Sons.
Cynthia Atwood is a designer and special projects coordinator who directs much of the creative and communications activity of New York City-based Guenther 5 Architects. In addition, Atwood is an adjunct professor with Pratt Institute's Interior Design Department in Brooklyn, New York.

Notes

1 A recent study by PricewaterhouseCoopers' Health Research Institute estimates that the total tax benefit of exemption (federal, state, and local) for a 300-bed average community hospital equals about $6.5 million annually.

References


## Appendix: Table of Interview Subjects

<table>
<thead>
<tr>
<th>BC Cancer Agency Research Centre [BC Cancer]</th>
<th>DESIGN FACTS</th>
<th>SCOPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vancouver, BC</td>
<td>- LEED gold (CaGBC) clinical research laboratory facility owned by the foundation</td>
<td>$95 million/230,000 sf with an expected Phase II 160,000 sf facility adjacent</td>
</tr>
<tr>
<td>Operated by the BC Cancer Agency</td>
<td>- Completed one day ahead of schedule and $6 million under budget</td>
<td>Open: 2005</td>
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<tr>
<td>Mary McNeil, President &amp; CEO</td>
<td>- 42% energy reduction with no use of HCFCs and 43% water use reduction, including waterless urinals</td>
<td>Accommodates 60 principal scientists and up to 600 scientific and medical personnel</td>
</tr>
<tr>
<td>BC Cancer Foundation (Owner)</td>
<td>- Diverted 98.5% of the construction waste from the landfill; 24% recycled construction and finishing materials</td>
<td></td>
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</table>

### ANECDOTES

- A concerned citizens’ group established the British Columbia Cancer Foundation over 70 years ago at a point when the cancer survival rate in B.C. was the lowest in Canada
- The first recorded donation to the foundation was $50 from the Native Daughters of BC, Post 1, in 1935

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<table>
<thead>
<tr>
<th>Boulder Community Foothills Hospital [Boulder]</th>
<th>DESIGN FACTS</th>
<th>SCOPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder, CO</td>
<td>- ASHE Vista Sustainable Design Award 2005</td>
<td>Three-story 60-bed, 154,000 sf facility includes a 24-hour emergency department</td>
</tr>
<tr>
<td>Kai Abelkis, Environmental Coordinator</td>
<td>- LEED silver community acute-care hospital, the first hospital in the nation to receive USGBC third-party LEED certification</td>
<td>Complemented by a new 67,000 sf outpatient services building</td>
</tr>
<tr>
<td>Boulder Community Hospital</td>
<td>- Cost of achieving LEED estimated at 2% of construction cost</td>
<td>49-acre site is master planned for 400,000 sf and will occupy 17 ac of the site</td>
</tr>
<tr>
<td></td>
<td>- Central Utility Plant expected payback of 7 years</td>
<td>Cost: $52 million</td>
</tr>
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<td></td>
<td>- 2006 Environmental Leadership Award from Hospitals for a Healthy Environment (H2E)</td>
<td>Operational since 2003</td>
</tr>
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</table>

### ANECDOTES

- Has an active reduce, recycle, reuse program since 1990 that has saved 4,524,300 gallons of water, 2,848,400 kilowatt hours of electricity, and more
- Central utility plant supplies energy efficiently with an expected savings at $95,000 year and at 30% lower use than ASHRAE standards
- 32 acres of the 49-acre site have been dedicated back to the city as permanent open space; the site was an unincorporated parcel, formerly used to graze cattle; portions lie within a federally designated floodplain
<table>
<thead>
<tr>
<th>Hospital</th>
<th>Design Facts</th>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Children’s Hospital of Pittsburgh of UPMC [Children’s-Pittsburgh]</strong> Lawrenceville, PA  &lt;br&gt; Roger A. Oxendale, President &amp; CEO  Children’s Hospital of Pittsburgh</td>
<td>- Project employs the principles of sustainable design and construction (seeking LEED), using innovative practices such as off-site parking and shuttle services for construction crews due to the site’s location in a densely populated residential area.  &lt;br&gt; - The new Clinical Services Building will tie into the 330,000 sf of existing space in the south wing of the former St. Francis Medical Center it is scheduled to replace.  &lt;br&gt; - Relocation to an expanded and renovated prior hospital site in central Pittsburgh.</td>
<td>$425 million, 1.287 million sf complex includes an 883,000 sf nine-story hospital and ambulatory-care facility (Clinical Services Building)  &lt;br&gt; Project includes an eight-story 174,000 sf research facility, parking for 1,400 vehicles, and 200,000 sf combined for faculty and administrative offices  &lt;br&gt; 40,000 employees (UPMC), the largest employer in the region.  &lt;br&gt; Last year it provided $175 million to academic programs and $200 million in uncompensated care and community services.  &lt;br&gt; Scheduled to complete in 2007</td>
</tr>
<tr>
<td><strong>C.S. Mott Children’s &amp; Women’s Hospitals [U-M Mott]</strong> Ann Arbor, MI  &lt;br&gt; Robert Kelch, MD, CEO, U-M Executive Vice President for Medical Affairs  + Patricia Warner, MPH, Associate Hospital Director, Children’s &amp; Women’s Services  University of Michigan Health System</td>
<td>- The Children’s &amp; Women’s project is registered through LEED and is part of a 3 million sf master plan across three locations in Ann Arbor owned by the university.  &lt;br&gt; - Project received a $25 million contribution from the C.S. Mott Foundation.  &lt;br&gt; - Project will replace the facility that currently houses the Mott and Women’s Hospitals; both hospitals have grown outdated since their respective 1969 and 1950 openings and are unable to meet the current demand.</td>
<td>264-private bed, $523 million facility  &lt;br&gt; Planned 1.1 million sf facility includes a nine-story clinic tower and a twelve-story inpatient tower.  &lt;br&gt; 855,000 sf are designated for in-patient space, 245,000 sf for clinic and office space, 180,000 sf shell space to accommodate growth.  &lt;br&gt; Groundbreaking scheduled for fall 2006, with a scheduled completion by early 2011.</td>
</tr>
</tbody>
</table>
Dell Children's Medical Center of Central Texas
[Dell Children's] 
Austin, TX
Robert Bonar, 
President & CEO
Children's Hospital of Austin
+ Alan Bell, Director of Design & Construction
Seton Family of Hospitals

**DESIGN FACTS**
- Anchors the redevelopment of the former Robert Mueller International Airport brownfield site in central Austin and replaces the current Children's Hospital of Austin upon completion
- Seeking LEED platinum certification for innovative and comprehensive sustainable strategies; project is a registered pilot of the *Green Guide for Health Care*
- Recipient of a $25 million gift from the Michael and Susan Dell Family Foundation

**ANECDOTES**
- The construction site has reduced the use of Portland cement by 31% and has also diverted two-thirds of its construction debris
- Seton Family of Hospitals collaborating with the City of Austin and Austin Energy to build a district energy plant on site
- Chose location to conform to Austin's Smart Growth initiative
- Catalyst for adoption of sustainable design and construction strategies in other new Seton facilities

**SCOPE**
$110 million, 169-bed, 455,000 bgsf hospital to serve 46 counties
Includes a 35,500 bgsf combined heat and power plant (CHP) at a cost of $18 million
Open: June 2007

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Dublin Methodist Hospital [Dublin Methodist] 
Dublin, OH
Cheryl L. Herbert, RN, President
Dublin Methodist Hospital, OhioHealth

**DESIGN FACTS**
- A Pebble Project of The Center for Health Design
- Located just outside Columbus, OH, and in a projected growth market for the OhioHealth System, the new community hospital will provide care to community residents and support the practice of evidence-based design in the construction of its facility

**ANECDOTES**
- Achieves daylighting in 90% of all occupied spaces in the building
- Utilized a team process based on the slogan “Run until apprehended” to invigorate and inspire design innovation and contractor diligence

**SCOPE**
$150 million, 94-bed facility with expansion capacity to 300 beds
300,000 sf facility on an 89-acre campus
Scheduled to open late 2007
Kaiser Permanente Templated Hospital [Kaiser] Modesto, CA
John Kouletsis, AIA, National Director, Planning & Design Services + Tom Cooper, Manager, Strategic Sourcing & Technology Kaiser Permanente

DESIGN FACTS
• Kaiser Permanente’s Templated Hospital Project will guide construction and renovations of more than 20 Kaiser healthcare facilities by 2013
• The Kaiser Permanente Modesto Medical Center is one of four templated hospitals currently under construction whose designs were based on the Green Guide for Health Care’s principles of environmentally friendly, sustainable design

ANECDOTES
• Kaiser’s Modesto Medical Center is part of a greater than $20 billion capital spending program that includes 27 new or replacement hospitals over a 12-year plan; in 2006 alone, Kaiser Permanente plans to spend more than $3 billion
• The Templated Hospital Project helps to ensure hospitals are built for the future; emphasize patient, staff, and environmental safety; and contribute to improved workflow and patient outcomes

SCOPE
Kaiser Permanente Modesto Medical Center
Anticipated completion: early 2008
670,000 sf on 50 acres, including a 386,000 sf five-story hospital with two nursing towers, a 254,000 sf medical office-ancillary services building with ambulatory surgery, and a 29,000 sf central utility plant

Palomar Medical Center West [Palomar] Escondido, CA
Michael Covert, CEO + Carrie Frederick, Director, Performance Excellence Palomar Pomerado Health

DESIGN FACTS
• Registered as both a Green Guide for Health Care pilot project and as one of The Center for Health Design’s Pebble projects
• Received a Kresge Foundation Planning Grant to conduct a pre-planning ecocharrette
• The planned new facility is scheduled for 35 acres at the Escondido Research and Technology Center business park, west of Interstate 15

ANECDOTES
• Both city and hospital district officials will work together on the design and have proposed forming a citizen’s committee from each to advise during the design phase
• The new medical center is the cornerstone of a 10-year, $1 billion master plan for the public hospital district and is the largest such undertaking in its history

SCOPE
A planned 453-bed, 1.2 million sf flagship medical center
Anticipated cost: $690 million
Anticipated groundbreaking: 2007 with a planned opening date in 2010
<table>
<thead>
<tr>
<th>PROVIDENCE HEALTH &amp; SERVICES [PROVIDENCE]</th>
<th>DESIGN FACTS</th>
<th>SCOPE</th>
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</thead>
<tbody>
<tr>
<td>NORTHWEST USA, INCLUDING NEWBERG, OR, AND OLYMPIA, WA</td>
<td>• LEED gold — PROVIDENCE NEWBERG MEDICAL CENTER, NATION’S FIRST</td>
<td>PROVIDENCE NEWBERG MEDICAL CENTER (PNMC) IS A 56-ACRE, 41-BED, 143,000 SF LICENSED HOSPITAL + 44,000 SF MEDICAL OFFICE BUILDING</td>
</tr>
<tr>
<td>JOHN KOSTER, MD, CEO, PROVIDENCE HEALTH &amp; SERVICES</td>
<td>• ASHE VISTA AWARD FOR 2005, RENOVATION CATEGORY – PROVIDENCE ST. PETER</td>
<td>COST: $70 MILLION</td>
</tr>
<tr>
<td>RICHARD BEAM, DIRECTOR, ENERGY MANAGEMENT SERVICES, OFFICE OF SUPPLY CHAIN MANAGEMENT, PROVIDENCE HEALTH &amp; SERVICES</td>
<td>• PILOTED SUSTAINABLE DESIGN PRINCIPLES IN THE EXPANSION/RENOVATION OF ST. PETER</td>
<td>OPEN SINCE JUNE 2006</td>
</tr>
<tr>
<td>+ GEOFFREY GLASS, PE, DIRECTOR, FACILITY AND TECHNOLOGY SERVICES PROVIDENCE ST. PETER HOSPITAL</td>
<td></td>
<td>PROVIDENCE ST. PETER CAMPUS RENEWAL PROJECT (PSPH)</td>
</tr>
<tr>
<td>SAN JUAN REGIONAL MEDICAL CENTER [SAN JUAN REGIONAL]</td>
<td>DESIGN FACTS</td>
<td>SCOPE</td>
</tr>
<tr>
<td>FARMINGTON, NM</td>
<td>• 2004 US EPA ENERGY STAR PARTNER OF THE YEAR FOR LEADERSHIP IN ENERGY MANAGEMENT</td>
<td>MULTILEVEL 156,000 SF ADDITION AND MAJOR RENOVATION PROJECT</td>
</tr>
<tr>
<td>DOUG FRARY, VICE PRESIDENT OF SUPPORT SERVICES</td>
<td>• FINANCIAL SUPPORT FOR PNMC INCLUDED BUSINESS ENERGY TAX CREDITS THROUGH THE OREGON OFFICE OF ENERGY, GRANTS THROUGH THE ENERGY TRUST OF OREGON’S BUILDING EFFICIENCY PROGRAM, AND FUNDING APPROVAL THROUGH PGE’S EARTH ADVANTAGE PROGRAM FOR A COMBINED 14-MONTH RETURN ON INVESTMENT</td>
<td>EXISTING 168-BED ACUTE-CARE HOSPITAL WITH A $55 MILLION RENOVATION AND EXPANSION</td>
</tr>
<tr>
<td>SAN JUAN REGIONAL MEDICAL CENTER</td>
<td>ANECDOTES</td>
<td>PHASE 1 OCCUPANCY: AUGUST 2006</td>
</tr>
<tr>
<td>• 2004 US EPA ENERGY STAR PARTNER OF THE YEAR FOR LEADERSHIP IN ENERGY MANAGEMENT</td>
<td>• SJRMC IS A PRIVATELY OWNED, COMMUNITY-GOVERNED NONPROFIT HOSPITAL AND IS ONE OF THE LARGEST EMPLOYERS IN THE STATE</td>
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<tr>
<td>• FINANCIAL SUPPORT FOR PNMC INCLUDED BUSINESS ENERGY TAX CREDITS THROUGH THE OREGON OFFICE OF ENERGY, GRANTS THROUGH THE ENERGY TRUST OF OREGON’S BUILDING EFFICIENCY PROGRAM, AND FUNDING APPROVAL THROUGH PGE’S EARTH ADVANTAGE PROGRAM FOR A COMBINED 14-MONTH RETURN ON INVESTMENT</td>
<td>• HOUSE BILL 266 CREATED A $4.7 MILLION TRAUMA FUND TO SUPPORT EXISTING AND INCENTIVIZE NEW TRAUMA FACILITIES TO JOIN THE STATE’S SYSTEM</td>
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<tr>
<td>• UPDATED, EXPANDED, AND NEW FACILITIES AND PROGRAMS ARE PART OF A $1.2 BILLION INVESTMENT OVER 3 YEARS</td>
<td>• STEVE ALTILLER, CEO, HONORED AS NEW MEXICO GRASSROOTS CHAMPION BY THE NEW MEXICO HOSPITALS AND HEALTH SYSTEMS ASSOCIATION</td>
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<tr>
<td>• SJRMC IS A PRIVATELY OWNED, COMMUNITY-GOVERNED NONPROFIT HOSPITAL AND IS ONE OF THE LARGEST EMPLOYERS IN THE STATE</td>
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<td>• STEVE ALTILLER, CEO, HONORED AS NEW MEXICO GRASSROOTS CHAMPION BY THE NEW MEXICO HOSPITALS AND HEALTH SYSTEMS ASSOCIATION</td>
<td>• HOUSE BILL 266 CREATED A $4.7 MILLION TRAUMA FUND TO SUPPORT EXISTING AND INCENTIVIZE NEW TRAUMA FACILITIES TO JOIN THE STATE’S SYSTEM</td>
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**VALUES-DRIVEN DESIGN AND CONSTRUCTION/ 35**
<table>
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<tr>
<th>Hospital</th>
<th>Design Facts</th>
<th>Scope</th>
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</thead>
</table>
| **Spaulding Rehabilitation Hospital [Spaulding]** Boston, MA  
Judith Waterston, President  
Spaulding Rehabilitation Hospital Network, a member of Partners HealthCare System and a teaching affiliate of Harvard Medical School | - Project is registered as a pilot of the *Green Guide for Health Care* after having been introduced to this document and other sustainable design principles at the Boston Design for Health Summit  
- The new facility will replace the current Spaulding facility on Nashua Street and will join a growing neighborhood of preeminent biotech and life-sciences companies in the Charlestown community  
- Working in partnership with City of Boston, Mayor Thomas Menino, and the Boston Redevelopment Authority to locate the $100 million facility into the former Charlestown Navy Yard brownfield site | Preliminary plans: $100 million, 150-private room facility with indoor aquatics, conferencing, a public green space, and underground parking  
Planned opening: 2011 |

| **The Discovery Health Center [Discovery]** Harris, NY  
Patrick H. Dollard, CEO  
Center for Discovery | - ASHE Vista Sustainable Design Award 2004  
- LEED v2.0 Certified; *Green Guide for Health Care*  
- The first Department of Health licensed medical facility in New York State to implement green standards; first LEED-certified diagnostic and treatment facility  
- Awarded grants through the New York State Energy & Research Development Authority and the Kresge Foundation | SCOPE  
$6 million, 28,000 bgsf specialized diagnostic and treatment facility  
Open: 2003  
Located on a 350-acre campus that includes residential services for more than 250 medically fragile and developmentally disabled adults and children  
1,000 employees; largest employer in Sullivan County |

**ANECDOTes**  
- 42% additional energy savings over base model comparison using ground source heating and cooling (geothermal)  
- Material selection based upon low-emitting and healthier materials for improved indoor air quality
The Lacks Cancer Center at St. Mary's Health Care
[The Lacks Center]
Grand Rapids, MI
Philip H. McCorkle Jr.,
President & CEO
+ David Hathaway,
Manager of Construction Projects
+ Micki Benz,
Vice President for Development
St. Mary’s Health Care

DESIGN FACTS
• Certified LEED 2.0 silver facility, making it the second hospital and fourth healthcare facility in the nation
• Site selection: new comprehensive cancer center on an existing medical center campus
• A $10 million donation by the family of Richard S. Lacks Sr. jumpstarted the campaign

ANECDOTES
• Peter Wege, a Grand Rapids philanthropist and environmentalist set the goal for St. Mary’s Health Care to create a green building and become a steward of health with construction of this facility
• The project received points from LEED because food cooked to order uses less energy and results in less waste than the traditional cafeteria model
• Self-cleaning windows not only save energy and human resources, but result in a healthier, cleaner environment for patients

SCOPE
175,000 sf facility
42 private rooms, four surgical suites, a chapel, a rooftop garden, and the Warren Reynolds Patient Information library
Open: January 2005

The Sarkis and Siran Gabrellian Women’s and Children’s Pavilion at Hackensack University Medical Center [Hackensack-Gabrellian]
Hackensack, NJ
John Ferguson,
President & CEO
+ Deirdre Imus,
Founder, Deirdre Imus Environmental Center for Pediatric Oncology
+ Suzen Heeley,
Director of Design & Construction
+ Anne Marie Campbell,
Chief Public Affairs Officer/Director, Public Relations
Hackensack University Medical Center

DESIGN FACTS
• Seeking LEED certification and registered as a pilot of the Green Guide for Health Care
• Project awarded a $1 million Kresge Foundation challenge grant used toward the construction of the Pavilion
• Project includes The Joseph M. Sanzari Children’s Hospital, The Women’s Hospital, and The Mark Messier Skyway for Tomorrow’s Children

ANECDOTES
• The Environmental Oncology Center has made significant strides in raising awareness among lawmakers about the potential hazards of environmental toxins; Imus has helped them sign into law several related bills
• HUMC adopted the use of environmentally friendly cleaning products throughout by implementing the Deirdre Imus Environmental Center Greening the Cleaning environmental protocols

SCOPE
HUMC is a 781-bed facility and is Bergen County’s largest employer (workforce: 7,100)
Hackensack-Gabrellian is a 300,000 sf facility with two separate and distinct lobbies for each of the hospitals
192 private rooms
Cost: $117 million
Operational since 2005
**UAMS College of Public Health**  
[Arkansas COPH]  
Little Rock, AK

**Leo M. Gehring, CHFM, SASHE**  
Vice Chancellor for Campus Operations  
University of Arkansas for Medical Sciences

**DESIGN FACTS**
- ASHE Vista Team Award 2005
- Academic educational facility used principles of sustainable design throughout to improve health of building occupants: healthier materials, reduced energy demand, and modeling of health behaviors
- Built a facility to represent a statewide stance on public and environmental health

**ANECDOTES**
- Facility recently named for the late Dr. Fay Boozman, director, Arkansas Department of Health [Fay W. Boozman College of Public Health for Arkansas]
- Boozman played a key role in steering millions of dollars to this and other health-related causes
- The college is responsible for developing programs that reach into the communities and make Arkansas a healthier state

**SCOPE**
- 120,000 sf, partially funded by $15 million from the state’s tobacco settlement money
- Operational since 2002
- 9,000 employees (UAMS), the largest public employer in the state
- Economic impact: $4.3 billion per year (UAMS + affiliates)
- Occupancy: 2,220 students + 660 residents
The Impact of the Environment on Infections in Healthcare Facilities

Anjali Joseph, Ph.D., Director of Research, The Center for Health Design

This paper was funded by a grant from the Robert Wood Johnson Foundation.
The Center for Health Design is a nonprofit research and advocacy organization whose mission is to transform healthcare settings into healing environments that improve outcomes through the creative use of evidence-based design. We envision a future where healing environments are recognized as a vital part of therapeutic treatment and where the design of healthcare settings contributes to health and does not add to the burden of stress.

The Robert Wood Johnson Foundation focuses on the pressing health and healthcare issues facing our country. As the nation’s largest philanthropy devoted exclusively to improving the health and healthcare of all Americans, the Foundation works with a diverse group of organizations and individuals to identify solutions and achieve comprehensive, meaningful and timely change.

For more than 30 years, the Foundation has brought experience, commitment, and a rigorous, balanced approach to the problems that affect the health and healthcare of those it serves. When it comes to helping Americans lead healthier lives and get the care they need, the Foundation expects to make a difference in your lifetime. For more information, visit www.rwjf.org.
Abstract

Objective: To examine how nosocomial infections spread among hospitalized patients via environmental routes and whether the design of the hospital plays a part in preventing the incidence and spread of infections.

Methods: Literature review of peer reviewed journal articles and research reports published in medicine, infection control, architecture, and epidemiology publications. Interview with industry experts.

Key findings

Hospital-acquired infections, or nosocomial infections, are one of the leading causes of death in the United States and typically affect patients whose immune systems are compromised. Nosocomial infections are transmitted in hospitals through three main environmental routes — air, surface contact and water. Airborne infections are spread when dust and pathogens are released during hospital renovation and construction activities and due to contamination and malfunction of the hospital ventilation system. Providing clean filtered air and effectively controlling indoor air pollution through ventilation are two key aspects of maintaining good air quality. HEPA filters are highly effective in preventing airborne infections from entering the hospital environment. Most nosocomial infections are transmitted through contact with the hands of nurses and physicians, and poor handwashing compliance poses a serious problem in this regard. There is some evidence that environmental support for handwashing — by providing numerous, conveniently located alcohol-rub dispensers or washing sinks — can increase compliance. Single-bed rooms are strongly recommended from an infection-control perspective—it is easier to isolate infectious pathogens and disinfect single-bed rooms than multi-occupancy rooms once a patient has been discharged. Waterborne infections spread through direct contact (e.g., for hydrotherapy), ingestion of contaminated water, indirect contact, and inhalation of aerosols dispersed from water sources. Regular cleaning, maintenance, and testing of water systems and point-of-use fixtures is important for preventing the spread of waterborne infections such as Legionnaires’ disease.

Conclusions

Careful consideration of environmental routes for transmission of infection — air, surface and water — can help in reducing nosocomial infection rates in hospitals.
**Introduction**

Hospital-acquired infections, or nosocomial infections, are one of the leading causes of death in the United States—killing more Americans than AIDS, breast cancer, or automobile accidents. In 1995 alone, nosocomial infections contributed to more than 88,000 deaths—one death every six minutes—and cost $4.5 billion (Weinstein, 1998).

Nosocomial infections typically affect patients who are immunocompromised because of age, underlying diseases, or medical or surgical treatments. According to Weinstein (1998), the highest infection rates are usually among intensive-care-unit (ICU) patients, with nosocomial infection rates in adult and pediatric ICUs being three times higher than anywhere else in the hospital (Weinstein, 1998).

Some of the key factors that have led to increasing nosocomial infection rates in American hospitals include

- low handwashing rates by staff between patient contacts,
- sicker and more immunocompromised patients in hospitals,
- infrastructure repairs and renovations to aging hospitals and new construction on existing campuses creating risk of airborne fungal diseases caused by dust and spores released during demolition and construction, and
- increasing antimicrobial use in hospital and long-term care facilities creating a large reservoir of resistant microbial strains (Weinstein, 1998).

Further, Weinstein (1998) found that at least one-third of nosocomial infections are preventable. A strong body of research shows that the built environment in particular influences the incidence of infection in hospitals and that, by careful consideration of environmental transmission routes—air, surface and water—in the design and operation of healthcare facilities, hospital-acquired infections can be reduced dramatically. This paper examines how nosocomial infections spread among hospitalized patients via environmental routes and how the design of the hospital plays a critical part in preventing the incidence and spread of infections.

**Air: Airborne pathogens and infection control**

**How are airborne infections transmitted?**

Vulnerable patient populations are exposed to a variety of airborne infectious pathogens. Airborne pathogens are transmitted in three main ways.

- When an environmental reservoir of a pathogen (i.e., soil, water, dust, decaying organic matter) is disturbed, fungal spores (e.g., *Aspergillus*) may be released into the air and make their way into the hospital environment.
- Microorganisms can also be transmitted directly from person to person in the form of

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**Nosocomial infections**

- Are infections acquired in the hospital.
- Account for more than 88,000 deaths every year.
- Typically affect immunocompromised patients.
- Are transmitted through three main pathways:
  - air
  - surface
  - water
droplets in the air. When droplets are produced during a cough or sneeze, a cloud of infectious particles is released into the air, resulting in potential exposure of susceptible persons within three feet of the source person (Sehulster & Chinn, 2003).

- Other infectious diseases such as tuberculosis are transmitted via residuals of droplets that remain indefinitely suspended in the air and can be transported over long distances. The microorganisms in the droplet residuals persist in dry cool conditions with little or no exposure of light or direct radiation. Susceptible individuals who come in contact with high concentrations of the microorganism may get infected.

What are the sources of airborne pathogens?

Construction and renovation activities

Airborne pathogens such as *Aspergillus* survive well in the air, dust, and moisture present in healthcare facilities and are usually released into the air during site construction and renovation. Ulrich and colleagues (2004) identified several studies that have linked increased levels of atmospheric dust and fungal spores during renovation and construction activities with healthcare-associated infections in immunocompromised patients.

In one study, high spore counts were found within and outside construction sites in a hospital. After control measures were instituted, no further cases of disseminated aspergillosis were identified (Opal et al., 1986). In another study, a nosocomial (hospital-acquired) outbreak of invasive pulmonary aspergillosis (IPA) occurred in acute leukemia patients treated in a regular ward with natural ventilation during extensive hospital construction and renovation. The observed infection rate was 50%. At this point, some of the patients were moved to a new hematology ward with high-efficiency particulate air (HEPA) filters. During the following three years, none of the patients hospitalized exclusively in the hematology ward developed IPA, although 29% of leukemia patients still housed in the regular ward contracted IPA (Oren, Haddad, Finkelstein, & Rowe, 2001).

<table>
<thead>
<tr>
<th>Airborne pathogen sources</th>
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<tbody>
<tr>
<td>Construction and renovation activities.</td>
</tr>
<tr>
<td>Ventilation system contamination and malfunction.</td>
</tr>
<tr>
<td>• Accumulation of dust and moisture in Heating, Ventilation and Air Conditioning (HVAC) systems.</td>
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<tr>
<td>• Failure or malfunction of HVAC systems.</td>
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<tr>
<td>• Pigeon droppings.</td>
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</table>

Ventilation system contamination and malfunction

Many incidents and outbreaks of nosocomial infection have been linked to malfunctions and contamination of the ventilation system in hospitals (Abzug et al., 1992; deSilva & Rissing, 1984; Kumari et al., 1998; Lutz, 2003; McDonald et al., 1998; Simmons, Price, Noble, Crow, & Ahearn, 1997; Uduman et al., 2002). Several studies have identified the type of air filter, direction of airflow and air pressure, air changes per hour in room, humidity, and ventilation-system cleaning and maintenance as factors related to air quality and infection rates.

Accumulation of dust and moisture within HVAC systems increases the risk for the spread of environmental fungi and bacteria. For example, in one study where six patients and one nurse were involved with an outbreak of epidemic methicillin-resistant *Staphylococcus aureus* (EMRSA-15),...
an environmental source was suspected, and the ventilation grilles in two patient bays were found to be harboring EMRSA-15 (Kumari, et al., 1998). The ventilation system, at that time, was working on an intermittent cycle from 4 p.m. to 8 p.m. Daily shutdown of the system created negative pressure, sucking air in from the ward environment into the ventilation system and contaminating the outlet grilles. The contaminated air blew back into the ward when the ventilation system was started. In another case, the source of infection was the exhaust ducting of the adjacent isolation-room ventilation system that allowed the contaminants to enter the unit via a partially open window positioned above a particular bed.

A failure or malfunction of the HVAC system may expose patients and staff to airborne contaminants. However, only limited information is available from studies on the infection-control implication of a complete air-handling failure or shutdown for maintenance. The American Institute of Architects' (AIA) Guidelines for Design and Construction of Hospital and Health Care Facilities prohibits U.S. hospitals and surgical centers from completely shutting down their HVAC systems except in the case of routine maintenance, filter changes, and construction (AIA, 2001). Even in such situations, required pressure relationships must be maintained (Sehulster & Chinn, 2003).

Pigeons, their droppings, and roost and are also associated with the spread of infections. There have been at least three outbreaks linked to contamination of the filtering systems from bird droppings (Burton, Zachery, & Bessin, 1972; Gage, Dean, Schimert, & Minsley, 1970; Kyriakides, Zinneman, & Hall, 1976).

**How to control and prevent airborne infections**

The importance of good air quality in controlling and preventing airborne infections in healthcare facilities cannot be overemphasized. Providing clean filtered air and effectively controlling indoor air pollution through ventilation are two key aspects of maintaining good air quality.

**HEPA filtration**

The control of air pollutants (microorganisms, chemicals, dust, and smoke) at the source is the most effective way to maintain clean air. Filtration, the physical removal of particulates from air, is the first step to achieving acceptable indoor air quality (Sehulster & Chinn, 2003). The figure below shows the steps involved in providing clean filtered air in the hospital.

The second filter bank (Figure 1) usually consists of high-efficiency filters. This filtration system (90% efficiency filters) is quite adequate for most patient-care areas in ambulatory-care facilities and hospitals, including the operating-room environment and areas providing central

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**Figure 1: Steps involved in providing clean filtered air in the hospital** (Source: Author)
services (Sehulster & Chinn, 2003). Once the frames for the filters are in place, it is possible to increase the efficiency of the filters by adding HEPA filters for special-care areas of the hospital such as surgical areas, burn ICU units, and protective environments for immunocompromised patients (Petska & Yeong, 2006). HEPA filters are at least 99.97% efficient for removing particles 0.3 µm (as a reference, Aspergillus spores are 2.5–3.0 µm in diameter) (Sehulster & Chinn, 2003). The filter efficiency can be increased to 99.99% where needed.

<table>
<thead>
<tr>
<th>HEPA filter costs</th>
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<tbody>
<tr>
<td><strong>32-bed unit with 90% efficiency filters</strong></td>
</tr>
<tr>
<td>Additional first cost is about $15,000.</td>
</tr>
<tr>
<td>Additional operating cost is about $4,000 per unit per year for increased power.</td>
</tr>
<tr>
<td>HEPA filter replacement is about is $6,000 per year for materials and labor (Petska &amp; Yeong, 2006).</td>
</tr>
</tbody>
</table>

There is convincing evidence that immunocompromised and other high-acuity patient groups have lower incidence of infection when housed in HEPA-filtered isolation rooms (Passweg, et al., 1998; Sherertz, et al., 1987; Sherertz & Sullivan, 1985). In one study, bone-marrow transplant recipients were found to have a tenfold greater incidence of nosocomial Aspergillus infection, compared to other immunocompromised patient populations, when assigned beds outside of a HEPA-filtered environment (Sherertz, et al., 1987). HEPA filters are suggested for healthcare facilities by the Centers for Disease Control and Prevention (CDC) and Healthcare Infection Control Practices Advisory Committee (HICPAC), but are either required or strongly recommended in all construction and renovation areas (Sehulster & Chinn, 2003).

The health benefits of infection-control measures are undeniable. But often, when considering state-of-the-art infection-control measures, hospital administrators are forced to also consider the costs. Some infection-control measures, such as preventing and controlling surface transmission of infection can be addressed relatively cheaply through staff education, number and location of handwashing sinks, and careful selection of materials and appropriate cleaning strategies. Other measures, on the other hand, are more costly. For example, using HEPA filters is a reliable way to reduce airborne infections. However, HEPA filters are more expensive than standard 90% efficient filters and are also more expensive to maintain. According to Sehulster and Chinn (2003), the life of HEPA filters can be increased by approximately 25% by using in-line disposable prefilters. Alternatively, if a disposable prefILTER is followed by a filter that is 90% efficient, the life of a HEPA filter can be increased ninefold. This concept, called progressive filtration, allows HEPA filters in special-care areas to be used for 10 years (Sehulster & Chinn, 2003). From an operational standpoint, HEPA filters need a powerful fan to operate—which leads to increased energy costs as compared to less-efficient filtration systems.

**Ventilation**

After filtration, the second most effective way of controlling the level of pathogens in the air is through ventilation. Ventilation guidelines are defined in terms of air volume per minute per occupant and are based on the assumption that occupants and their activities are responsible for most of the contaminants in the conditioned space. Most ventilation rates for healthcare facilities are expressed as room air changes per hour (ACH). Peak efficiency for particle removal in the air space occurs between 12 ACH–15 ACH (Sehulster & Chinn, 2003). Ventilation rates vary among different patient-care areas of a healthcare facility, and ventilation standards are provid-

Air contamination is least in laminar airflow rooms with HEPA filters, and this approach is recommended for operating-room suites and areas with ultraclean-room requirements such as those housing immunocompromised patient populations (Alberti et al., 2001; Arlet, Gluckman, Gerber, Perol, & Hirsch, 1989; Dharan & Pittet, 2002; Friberg, Ardnor, & Lundholm, 2003; Hahn et al., 2002; Sherertz et al., 1987). Laminar flows are very even, smooth, low-velocity airflows that are used in clean-rooms and other settings where high-quality ventilation is critical.

Single-bed rooms

Single-bed rooms are clearly superior to multibed rooms in preventing the transmission of airborne pathogens from one patient to others. This is because of the ease in isolating a patient and providing high-quality HEPA filters, negative room pressure to prevent a patient with an aerial-spread infection from infecting others, or maintaining positive pressure to protect an immunocompromised patient from airborne pathogens in nearby rooms.

A study by Passweg, et al. (1998) found that the combination of room isolation and HEPA filtration reduced infection and mortality in bone-marrow transplant patients and significantly increased their one-year survival rates. Ulrich and colleagues (2004) identified several research studies that showed that single-bed rooms and good air quality substantially reduce infection incidence and reduce mortality among burn patients. They also found studies that showed that, for contagious airborne diseases such as influenza, measles, and tuberculosis, placing patients in single-bed rooms is safer than housing them in multibed spaces (Ulrich, et al., 2004).

Multibed spaces were extremely inadequate for controlling and preventing severe acute respiratory syndrome (SARS) outbreaks both for patients and healthcare workers in Asia and Canada. SARS is transmitted by droplets that can be airborne over limited areas. Approximately 75% of SARS cases in Toronto resulted from exposure in hospital settings (Farquharson & Baguley, 2003). Most Canadian and Asian hospitals have multibed spaces in emergency departments. That, taken with the scarcity of isolation rooms with negative pressure, severely hindered treatment and control measures. Toronto hospitals were forced to create additional negative-pressure isolation rooms by quickly constructing wall barriers to replace bed curtains and making airflow and pressure adaptations (Farquharson & Baguley, 2003).

Effective control measures during construction and renovation

Other than providing good quality air and ensuring adequate ventilation in patient-care areas, instituting effective prevention and control measures during construction and renovation is critical. Effective measures include

- using portable HEPA filters,
- installing barriers between the patient-care and construction areas,
- using negative air pressure in construction/renovation areas relative to patient-care spaces, and
- sealing patient windows.
There is strong evidence of the impact of using HEPA filters for air intakes near construction and renovation sites (Loo, et al., 1996; Mahieu, De Dooy, Van Laer, Jansens, & Leven, 2000; Opal, et al., 1986; Oren, et al., 2001). A study by Humphreys et al. (1991) demonstrates that HEPA filters are not by themselves an adequate control measure and must be employed in conjunction with other measures such as enhanced cleaning, the sealing of windows, and barriers. Cornet et al. (1999) concludes that carefully directed airflow (e.g., laminar airflow) is important. However, in their extensive literature review, Ulrich and colleagues (2004) were unable to find and document cost-benefit analysis in the literature to justify the expense versus effectiveness of laminar airflow for patient-care areas near construction and renovation sites. The CDC and HICPAC guidelines (Sehulster & Chinn, 2003) emphasize the importance of a multidisciplinary team (including environmental services, employee health, infection control and design, and construction teams) approach to coordinate the various stages of construction activities.

### Surface: Contact pathways of infectious pathogens

Although infection caused by airborne transmission poses a major safety problem, most infections are now acquired in the hospital via the contact pathway (Bauer, Ofner, Just, Just, & Daschner, 1990; Institute of Medicine, 2004). Microbiologically contaminated surfaces can be reservoirs of pathogens. However, these surfaces are generally not associated with the direct transmission of infection to patients or staff (Sehulster & Chinn, 2003). It is the hands of healthcare staff that is the principal cause of contact transmission from patient to patient (Larson, 1988). The importance of assiduous handwashing by healthcare workers, accordingly, cannot be overemphasized for reducing hospital-acquired infections. In this context, the fact that rates of handwashing by healthcare staff are low represents a very serious patient-safety challenge. Some facts regarding handwashing practices among staff and physicians (Ulrich, et al., 2004):

- Compliance rates in the range of 15%–35% are typical, rates above 40% to 50% are the exception.
- Rates are lowest among physicians and nursing assistants.
- Rates are lower in units that are understaffed, have a high patient census or bed occupancy rate, or have high-acuity patients.
- Rates are lower in units with automated sinks.

Education programs have not been successful in increasing handwashing compliance among healthcare workers. Even intensive education or training programs (classes, group feedback, for example) produce only transient increases in handwashing (Conly, Hill, Ross, Lertzman, & Louie, 1989; Dorsey, Cydulka, & Emerman, 1996; Dubbert, Dolce, Richter, Miller, & Chapman, 1990). Behavioral interventions, including environ-
mental design, that make handwashing practices easier and more convenient may be more effective in producing sustained increases in handwashing compliance.

Along with providing environmental support to improve hand hygiene to reduce the transfer of pathogens to patients, the choice of materials for environmental surfaces and proper cleaning and disinfecting of surfaces is critical to reducing their potential contribution to the incidence of infection.

**Environmental support for handwashing**

Hospital staff report several reasons for poor handwashing compliance including inconvenient sink location, shortage of sinks, lack of time, lack of soap or paper towels, and not thinking about it/forgetfulness (Pittet, 2000). These factors clearly have environmental implications, and designing healthcare facilities to make handwashing practices more convenient may increase compliance.

<table>
<thead>
<tr>
<th>Barriers to handwashing</th>
<th>Environmental implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inconvenient sink location.</td>
<td>Location, accessibility, and number of handwashing sinks and soap dispensers.</td>
</tr>
<tr>
<td>Lack of time.</td>
<td>Conveniently located sinks in single-bed rooms.</td>
</tr>
<tr>
<td>Lack of soap or paper towels.</td>
<td></td>
</tr>
<tr>
<td>Not thinking about it/forgetfulness.</td>
<td></td>
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</tbody>
</table>

Ulrich and colleagues (2004) identified six studies that examined whether handwashing is improved by increasing the ratio of the number of sinks or hand-cleaner dispensers to beds and/or by placing sinks or hand-cleaner dispensers in more accessible locations. According to the authors, there is some support for the notion that providing numerous, conveniently located alcohol-rub dispensers or washing sinks can increase compliance. In particular, the evidence suggests that installing alcohol-based hand-cleaner dispensers at bedside usually improves adherence (Ulrich, et al., 2004).

In one study, a combination of bedside antiseptic hand-rub dispensers and posters to remind staff to clean their hands was effective in increasing compliance (Pittet, 2000). On the other hand, Muto and colleagues (2000) found that placing alcohol-gel dispensers next to the doors of patient rooms was not effective. When sink-to-bed ratio was higher, a higher frequency of handwashing was observed (Kaplan & McGuckin, 1986; Vernon, Trick, Welbel, Peterson, & Weinstein, 2003). Providing automated water/soap sinks, however, appears not to increase handwashing rates compared to traditional nonautomated sinks (Larson, et al., 1991; Larson, Bryan, Adler, & Blane, 1997).

Ulrich and colleagues (2004) identified three studies that suggest that providing single-bed rooms with a conveniently located sink in each room reduces nosocomial infection rates in ICUs, such as neonatal intensive-care or burn units, compared to when the same staff and comparable patients are in multibed open units with few sinks. The authors (Ulrich, et al., 2004) indicate that handwashing frequency was not measured in these studies. However, the studies identified increased handwashing as an important factor in reducing infections in the units with single-bed rooms and more sinks. A comparison of an ICU converted from an open unit with few sinks to single-bed rooms with one sink per room found a nonsignificant tendency for handwashing to increase (from 16% to 30%), but no decline in infection incidence (Preston, Larson, & Stamm,
1981). These results are perhaps explainable by the fact that several sinks in the single-bed unit were placed in comparatively inaccessible or inconvenient locations, such as behind doors or away from staff work paths.

Despite the encouraging overall pattern of findings in these studies, it is not clear how much of the effectiveness in terms of increased handwashing or reduced infection rates can be attributed to the installation of more numerous and/or accessible sinks and alcohol-gel dispensers.

**How to control and prevent surface contamination**

While most infections are not directly transmitted to patients from environmental surfaces, these surfaces come in contact with the hands of caregivers frequently. As discussed earlier, low hand-washing compliance is a problem in healthcare facilities. Hence, regular cleaning and disinfection of environmental surfaces as appropriate is critical to controlling surface contact transmission of infections.

Environmental surfaces that are likely to get contaminated by pathogens can be divided into two groups—those with frequent hand contact (such as surfaces of medical equipment and high-touch housekeeping surfaces such as doorknobs, bedrails, light switches, wall areas around the toilet in the patient room, and edges of privacy curtains) and those with minimal hand contact (e.g., floors and ceilings). The number and type of organisms present on the surface depends upon (Collins, 1988)

- the number of people present in the environment,
- amount of moisture,
- amount of activity,
- presence of material capable of supporting bacterial growth,
- rate at which organisms suspended in the air are removed (ventilation), and
- type of surface and orientation (horizontal or vertical).

High-contact surfaces in patient-care areas need to be cleaned and disinfected more frequently than minimal contact surfaces. Typically, the infection-control specialists in the organization use a risk-assessment approach to identify high-touch surfaces and then coordinate an appropriate cleaning and disinfecting strategy and schedule with the housekeeping staff. The CDC and HICPAC Guidelines for Environmental Infection Control in Healthcare Facilities (Sehulster & Chinn, 2003) provides recommendations for cleaning and maintaining different types of environmental surfaces to prevent the spread of infection.

Compared to single-bed rooms, multibed rooms are far more difficult to decontaminate thoroughly after a patient is discharged, and, therefore, worsen the problem of multiple surfaces acting as pathogen reservoirs. Because different staff members who enter a room can touch the same contaminated surfaces, the risk of a nurse unknowingly becoming contaminated should be greater in multi-bed rooms (Ulrich, et al, 2004). Circumstantial support for this point is provid-
ed by research on contamination of nurses in units having patients infected by MRSA. Boyce et al. (1997) found that 42% of nurses who had no direct contact with an MRSA patient but had touched contaminated surfaces contaminated their gloves with MRSA.

The ease of cleaning is clearly an important consideration in the choice of materials for healthcare facilities, and this applies to materials for floors, ceilings, and walls as well as furniture and furnishings. But the kind of material to use is not always clear-cut. For example, the type of flooring—carpet or vinyl—is one area that is often discussed.

<table>
<thead>
<tr>
<th>Using carpet</th>
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<tbody>
<tr>
<td><strong>Advantages</strong></td>
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<tr>
<td>Noise reduction.</td>
</tr>
<tr>
<td>Ease of walking.</td>
</tr>
<tr>
<td>Reduction in falls and injuries.</td>
</tr>
<tr>
<td>Homelike ambience.</td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>Supports growth of fungi and bacteria.</td>
</tr>
<tr>
<td>Effect of cleaning is transient.</td>
</tr>
<tr>
<td>Air over carpeted areas tends to have higher pathogen levels as compared to hard flooring.</td>
</tr>
<tr>
<td><strong>Verdict</strong></td>
</tr>
<tr>
<td>There is little evidence linking carpet contamination with nosocomial infection in patients.</td>
</tr>
<tr>
<td><strong>Guidelines</strong></td>
</tr>
<tr>
<td>Avoid carpet use where spills are likely to occur and in high-risk patient-care. Employ appropriate carpet-cleaning methods.</td>
</tr>
<tr>
<td>Use vacuum cleaners fitted with HEPA filters.</td>
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</table>

Carpet versus vinyl

The advantages of using carpet include noise reduction, ease of walking, and possibly reduction in falls and resultant injuries (Counsell et al., 2000; Willmott, 1986). The other benefit of carpet is that it provides a more homelike/non-institutional ambience as compared to vinyl (Cheek, Maxwell, & Weisman, 1971; Glod et al., 1994). One study found that family and friends stayed substantially longer during visits to a rehabilitation unit when patient rooms were carpeted rather than covered with vinyl flooring (Harris, 2000).

However, the decision to use carpet in patient-care areas often meets with resistance from staff during design committee meetings. This is because, compared to hard floor surfaces, carpet is more difficult to keep clean, especially after spills of body and blood substances. Staff also experience difficulty in pushing carts, gurneys, and wheelchairs down carpeted hallways.

Several studies have documented the presence of different fungi and bacteria in carpeting in hospitals (Anderson, Mackel, Stoler, & Mallison, 1982; Beyer & Belsito, 2000; Gerson, Parker, Jacobs, Creger, & Lazarus, 1994; Skoutelas, Westenfelder, Beckerdite, & Phair, 1994). New carpeting becomes contaminated very quickly, and the effect of cleaning carpet is transient—bacterial levels soon return to precleaning levels. Bacterial contamination increases with higher levels of activity, and soiled carpet that is damp or wet provides the ideal setting for bacteria to proliferate. Studies have also found that the air above carpeted areas tended to have more consistent concentrations of microorganisms as compared to the air above hard flooring (Anderson, Mackel, Stoler, & Mallison, 1982).
But, there is little epidemiological evidence linking carpet contamination with incidence of nosocomial infection among immunocompromised patients. The CDC and HICPAC guidelines (Sehulster and Chinn, 2003) provide no recommendations against use of carpeting in patient-care areas. However, the guidelines suggest avoiding the use of carpet in areas where spills are likely to occur (e.g., laboratories, sinks, and janitor closets) or where patients may be at greater risk of infection from airborne pathogens (e.g., burn units, ICUs, and operating rooms).

In this context, proper methods of carpet cleaning are critical to minimize or prevent production of aerosols and dispersal of carpet microorganisms into the air. This includes maintenance of vacuum cleaners to prevent dust dispersal and using vacuum cleaners fitted with HEPA filters, especially in patient-care areas.

One study provides limited evidence that chemically treated carpet may have helped to keep the rates of nosocomial aspergillosis low in one patient-care unit (Gerson, Parker, Jacobs, Creger, & Lazarus, 1994). In general, carpet treated with bactericidal and fungicidal chemicals has not proven to be effective in reducing the rates of hospital-acquired infection among immunocompromised patients, and the CDC HICPAC guidelines provide no recommendations regarding the use of such carpets.

**How are waterborne infections spread?**

Waterborne microorganisms proliferate in moist environments and aqueous solutions, especially under warm temperature conditions and presence of a source of nutrition. Waterborne infections spread through

- direct contact (e.g., for hydrotherapy),
- ingestion of contaminated water,
- indirect contact, and
- inhalation of aerosols dispersed from water sources.

Waterborne infections caused by gram-negative bacteria and nontuberculous myobacteria (NTM) are transmitted via the first three modes. Inhalation of aerosols from water sources contaminated with *Legionella* spp. may cause a respiratory illness called Legionnaires’ disease—a multisystem illness with pneumonia, especially among immunosuppressed patients (e.g., transplant patients, cancer patients), immunocompromised patients (e.g., surgical patients, patients with underlying chronic lung disease, dialysis patients), elderly persons, and patients who smoke (Sehulster & Chinn, 2003).

**What are the sources of waterborne infections?**

Potable water, water used for treatment (such as dialysis), lab solutions, ice, and hydrotherapy tanks may harbor gram-negative bacteria and NTM that then infect the individuals through the routes described above. The CDC and HICPAC guidelines (Sehulster & Chinn, 2003) recommend against using tap water for medical care (e.g., in direct patient care, for diluting solutions, as a water source for medical equipment and instruments, and for disinfection of instruments) as this might directly expose patients to these pathogens.
How to prevent waterborne infections

An important aspect of preventing contamination through the water supply involves designing the water supply system to minimize stagnation and back flow as well as provide temperature control to prevent growth of bacteria.

Regular maintenance and inspection of water in holding tanks is also recommended (Sehulster & Chinn, 2003).

Legionella enter healthcare facilities most often through aerosols generated by cooling towers, showers, faucets, respiratory therapy equipment, and room-air humidifiers. Factors that encourage the colonization and amplification of Legionella in water sources include stagnation and warm temperature (77°F–107 °F). To prevent growth of Legionella and other bacteria in the water system, healthcare facilities are required to maintain cold water at a temperature below 68°F and hot water at a minimum temperature of 124°F. In addition, other methods, such as chlorine treatment or copper-silver ionization and UV light, may be used to treat water that is distributed in healthcare facilities (Sehulster and Chinn, 2003).

Point-of-use fixtures, such as sinks, showers, aerators, and toilets, may serve as reservoirs for pathogens such as Legionella. The wet surfaces by these fixtures and production of aerosols during use may result in multiplication and dispersion of microbes into the air.

Many studies have linked aerosols from shower heads and aerators with the outbreak of infection including Legionnaires’ disease among immunocompromised patients (Bollin, Plouffe, Para, & Hackman, 1985; Cordes, A.M, & Gorman, 1981; Kappstein, Grundmann, Hauer, & Niemeyer, 2000; Weber, Rutala, Blanchet, Jordan, & Gergen, 1999). Healthy immunocompetent individuals (e.g., staff) were not infected when exposed to Legionella in shower water. ASHRAE (2000) recommends regular cleaning and disinfection of faucet aerators, especially in areas with high-risk patients to prevent and control for Legionella.

Decorative fountains and water features are increasingly being incorporated in healthcare facilities. They serve as landmarks, wayfinding elements, and create positive distractions. Many designers believe that water and water features provide a connection to nature for patients and help reduce the stress of a hospital visit (Rogers, 2006). However, such features are often strongly opposed by the infection-control department in the hospital on the grounds that water fountains and water features may harbor microorganisms that may cause nosocomial infections due to inhalation of aerosolized bacteria such as Legionella. According to a recent review by Rogers (2006), there are no documented cases of hospital-acquired Legionnaires’ disease or any other waterborne infectious diseases that resulted from the indoor placement of a water fountain or water feature in hospital spaces. The only documented outbreak of Legionnaires’ disease was

<table>
<thead>
<tr>
<th>Waterborne infection prevention</th>
</tr>
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<tbody>
<tr>
<td>Ensure regular maintenance and inspection of water supply system to minimize stagnation and back flow and for temperature control.</td>
</tr>
<tr>
<td>Use proper water treatment.</td>
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<tr>
<td>Regularly clean and maintain faucet aerators to prevent and control for Legionella.</td>
</tr>
<tr>
<td>Avoid decorative water fountains in high-risk patient-care areas.</td>
</tr>
<tr>
<td>Where fountains are used, water temperature should be kept cold, and fountains should be regularly cleaned and maintained.</td>
</tr>
</tbody>
</table>
among a group of older adults in a hotel. This was associated with a decorative water fountain that was not properly maintained and was lit by submerged lighting that caused the water to become warm—providing the ideal condition for the growth of * legionella* bacteria (Hlad et al., 1993).

According to Rogers (2006), decorative fountains would pose minimal risk in healthcare settings if facilities were to follow basic precautions.

- Keep water temperature cool to cold and avoid the use of submerged lighting.
- Perform routine fountain cleaning and maintenance in accordance with manufacturer’s instructions.
- Avoid placing water fountains in areas that house high-risk patients.
- Install a glass barrier or maintain an appropriate distance between the water feature and the general public to minimize potential contact with droplets or aerosols.

**Summary**

Infections are transmitted in the hospital environment through air, surface, and water. Some key considerations for preventing and controlling the spread of nosocomial infections in hospitals include the following.

- Careful design and maintenance of the HVAC system including incorporation of HEPA filters reduces the threat of airborne diseases.
- Proper precautions during design and construction activities are also critical to preventing the spread of airborne infections.
- Single-bed rooms are strongly recommended from an infection-control perspective—it is easier to isolate infectious pathogens and disinfect single-bed rooms than multi-bed rooms once a patient has been discharged.
- The threat of infections spread through contact transmission of pathogens is also reduced in single-bed rooms.
- An important aspect of reducing infections spread through surface contact involves providing environmental support for handwashing—visible, conveniently placed sinks, handwashing liquid dispensers, and alcohol rubs.
- Regular cleaning, maintenance, and testing of water systems and point-of-use fixtures is important for preventing the spread of waterborne infections such as Legionnaires’ disease.
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The Impact of Light on Outcomes in Healthcare Settings

Anjali Joseph, Ph.D., Director of Research, The Center for Health Design

This paper was funded by a grant from the Robert Wood Johnson Foundation.
The Center for Health Design is a nonprofit research and advocacy organization whose mission is to transform healthcare settings into healing environments that improve outcomes through the creative use of evidence-based design. We envision a future where healing environments are recognized as a vital part of therapeutic treatment and where the design of healthcare settings contributes to health and does not add to the burden of stress.

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Abstract

Objective: To identify the mechanisms by which light impacts human health and performance and review the literature linking light (daylight and artificial light) with health outcomes in healthcare settings.

Methods: Literature review of peer-reviewed journal articles and research reports published in medicine, psychology, architecture, ergonomics, and lighting design periodicals and books. Keywords used to search for articles included light, lighting, daylight, sunlight, healthcare, hospitals, depression, circadian rhythm, health, patients and nurses.

Key findings: Light impacts human health and performance by enabling performance of visual tasks, controlling the body’s circadian system, affecting mood and perception, and by enabling critical chemical reactions in the body. Studies show that higher light levels are linked with better performance of complex visual tasks and light requirements increase with age. By controlling the body’s circadian system, light impacts outcomes in healthcare settings by reducing depression among patients, decreasing length of stay in hospitals, improving sleep and circadian rhythm, lessening agitation among dementia patients, easing pain, and improving adjustment to night-shift work among staff. The presence of windows in the workplace and access to daylight have been linked with increased satisfaction with the work environment. Further, exposure to light is critical for vitamin D metabolism in the human body. Light exposure also is used as a treatment for neonatal hyperbilirubinaemia.

Conclusions: Adequate and appropriate exposure to light is critical for health and well-being of patients as well as staff in healthcare settings. A combination of daylight and electric light can meet these needs. Natural light should be incorporated into lighting design in healthcare settings, not only because it is beneficial to patients and staff, but also because it is light delivered at no cost and in a form that most people prefer.
Introduction

Light is critical to human functioning in that it allows us to see things and perform activities. But it is also important because it affects human beings psychologically and physiologically. Several studies have documented the importance of light in reducing depression, decreasing fatigue, improving alertness, modulating circadian rhythms, and treating conditions such as hyperbilirubinemia among infants (Ulrich, Zimring, Joseph, Quan, & Choudhary, 2004). Further, the presence of windows in the workplace and access to daylight have been linked with increased satisfaction with the work environment (Boyce, Hunter, & Howlett, 2003; Edwards & Torcellini, 2002). Studies also show that adequate light levels are linked to reduced medication-dispensing errors in pharmacies. Thus, incorporating light into healthcare settings can be beneficial for patients as well as the staff who work there.

This paper considers the mechanisms by which light impacts human health and performance and reviews the literature linking light (daylight and artificial light) with health outcomes in healthcare settings. Studies conducted in other settings that are relevant to the discussion also are examined. Several studies have addressed the technical, architectural, and energy aspects of providing optimal lighting conditions in different areas of a healthcare facility and are not reviewed here.

Light in buildings

Most healthcare settings, as well as other buildings, are lit by a combination of daylight entering through windows and skylights and electric-light sources. It is important to understand how these two types of light sources differ to understand their relative impacts on human health and performance. Sunlight is electromagnetic radiation in the wavelength range that can be absorbed by the photoreceptors of the eye. Sunlight provides a balanced spectrum of colors with elements in all parts of the visible wavelength range. The actual wavelengths present in daylight vary over the day with latitude, meteorological conditions, and seasons (Boyce, Hunter, & Howlett, 2003; Edwards & Torcellini, 2002).

In contrast, light from most artificial electric-light sources, such as cool white fluorescent light and incandescent lights, are composed of wavelengths of lights that are concentrated in limited areas of the visible light spectrum, for example, yellow to red end or orange to red end of the spectrum (Edwards & Torcellini, 2002). Full-spectrum electric-light sources such as xenon lamps and some filtered incandescent lights that have a spectral content similar to daylight, though their spectral content does not vary over time, are now available. Studies suggest that daylight is not inherently superior to artificial lighting for performance of most visual tasks (Boyce, Hunter, & Howlett, 2003). However, natural light has benefits over electric-light sources in regulating circadian rhythms and maintaining overall health.
How light impacts human health and performance

Light impacts human health and performance by four main mechanisms:

- Enabling performance of visual tasks
- Controlling the body’s circadian system
- Affecting mood and perception
- Facilitating direct absorption for critical chemical reactions within the body (Boyce, Hunter, & Howlett, 2003; Veitch & McColl, 1993).

In this paper, each of these mechanisms is described and the specific impacts on human health and performance are outlined.

Enabling performance of visual tasks

The most obvious effect of light on humans is in enabling vision and performance of visual tasks. According to Boyce and colleagues (2003), the nature of the task—as well as the amount, spectrum, and distribution of the light—determines the level of performance that is achieved. Performance on visual tasks gets better as light levels increase (Boyce, Hunter, & Howlett, 2003). A study by Santamaria and Bennett (1981) shows that, if the amount and distribution of light are controlled, most everyday visual tasks (such as reading and writing) can be performed as well under artificial light sources (such as fluorescent light) as under daylight conditions. However, daylight is superior for tasks involving fine color discrimination when it is provided at a high level without glare or any reduction in task visibility caused by veiling reflections or shadows (Boyce, Hunter, & Howlett, 2003).

Another factor that affects performance on visual tasks is age, and the need for light increases as a function of age due to reduced transmittance of aging eye lenses (Edwards & Torcellini, 2002). This is significant in that the workforce in American hospitals is aging, and, therefore, there may be a need to critically assess the lighting provisions for different types of tasks performed by nurses and other staff.

Reducing errors

The work environment for nurses and physicians in hospitals is stressful. They are required to perform a range of complex tasks—charting, filling prescriptions, administering medication, and performing other critical patient-care tasks. Inadequate lighting and a chaotic environment are likely to compound the burden of stress and lead to errors. However, very few studies have focused specifically on the impact of different types of lighting conditions on staff work performance in hospitals.

One study examined the effect of different illumination levels on pharmacists’ prescription-dispensing error rate (Buchanan, Barker, Gibson, Jiang, & Pearson, 1991). They found that error rates were reduced when work-surface light levels were relatively high (Buchanan et al., 1991). In this study, three different illumination levels were evaluated (450 lux; 1,100 lux; 1,500 lux). Medication-dispensing error rates were significantly lower (2.6%) at an illumination level of 1,500 lux (highest level), compared to an error rate of 3.8% at 450 lux. This is consistent with findings from other settings that show that task performance improves with increased light lev-
Visual task performance
- Task performance improves with increased light levels.
- The need for light for visual task performance increases with age.
- Higher lighting levels were associated with fewer medication-dispensing errors in a pharmacy.

Controlling the body’s circadian system

Light falling on the retina and being transmitted to the hypothalamus controls the body’s circadian rhythm (biological events that repeat themselves at regular intervals), which are responsible for synchronizing the body’s internal clock to 24 hours. If the internal rhythms do not match the workday rhythms, which is the case for many healthcare workers, staff can feel drowsy, tired, and distracted. For example, for individuals working during night shifts, a 24-hour cycle that keeps most people awake and alert in the day and sleepy in the night would result in fatigue and a complete inability to perform during the night shift.

The human circadian system consists of three components: an internal oscillator, which is located in the suprachiasmatic nucleus of the hypothalamus in the brain; a number of external oscillators (external stimuli such as light-dark cycle between day and night) that can reset (entrain) the internal oscillator; and a hormone, melatonin, secreted by the pineal gland that carries “time” information to all parts of the body through the bloodstream (Boyce, Hunter, & Howlett, 2003; Edwards & Torcellini, 2002). Light activation of the pineal gland results in the suppression of melatonin (Veitch & McColl, 1993). Melatonin levels in the body determine a person’s activity and energy level. Where daylight or artificial light is inadequate during the day, the natural suppression of melatonin production fails to occur and is accompanied by feelings of depression and sleepiness (Lewy et al., 1985). High melatonin levels cause drowsiness, while low melatonin levels are related to a state of alertness (Edwards & Torcellini, 2002; Veitch & McColl, 1993).

Exposure to daylight
- Reduces depression among patients with seasonal affective disorder and bipolar depression.
- Decreases length of stay in hospitals.
- Improves sleep and circadian rhythms.
- Lessens agitation among dementia patients, ease pain.
- Improves adjustment to night-shift work among staff.

Exposure to outdoor daylight is a key factor in determining the phase of the circadian rhythm. According to Boyce and colleagues (2003), daylight provides a higher light level at the eye that is matched to the spectral sensitivity of the circadian rhythms than most electric-light sources. By controlling the circadian system, light—both natural and artificial—impacts many health outcomes among patients and staff in hospitals such as depression, sleep, circadian rest-activity rhythms, as well as length of stay in the hospital.

Reducing depression

At least 11 strong studies suggest that bright light is effective in reducing depression among patients with bipolar disorder or seasonal affective disorder (SAD). A major-
ity of the studies have examined the impact of artificial bright light on reducing depression. Artificial light treatments usually range between 2,500 lux and 10,000 lux (Beauchemin & Hays, 1996). The treatment is believed to be effective by suppressing the onset of melatonin. Two studies have shown that exposure to natural bright light is similarly effective in reducing depression (Beauchemin & Hays, 1996; Benedetti, Colombo, Barbini, Campori, & Smeraldi, 2001). Benedetti and colleagues (2001) found that bipolar depressed inpatients in east-facing rooms (exposed to bright light in the morning) stayed an average of 3.67 days less in the hospital compared with similar patients who stayed in west-facing rooms.

There is strong evidence that exposure to bright light in the morning is more effective than exposure to bright light in the evening in reducing depression (Beauchemin & Hays, 1996; Benedetti et al., 2001; Eastman, Young, Fogg, Liu, & Meaden, 1998; Lewy et al., 1998; Oren, Wisner, Spinelli, & Epperson, 2002; Sumaya, Rienzi, Deegan, & Moss, 2001; J. S. Terman, Terman, Lo, & Cooper, 2001; M. Terman, Terman, & Ross, 1998; Wallace-Guy et al., 2002). An experimental study that compared the effect of morning and evening light on patients with winter depression found that morning light was twice as effective as evening light in treating SAD (Lewy et al., 1998).

**Light & depression**

- Bipolar depressed patients in east-facing rooms stayed 3.67 days less than patients in west-facing rooms (Benedetti et al., 2001).
- Morning bright-light exposure is more effective in reducing depression than evening-light exposure.

**Decreasing length of stay**

Beauchemin & Hays (1996) and Benedetti et al. (2001) documented the impact of light on length of stay among depressed patients. A couple of other studies suggest that exposure to light may be linked to length of stay among clinically nondepressed patients as well. A retrospective study of myocardial infarction patients in a cardiac intensive-care unit treated in either sunny rooms or dull rooms found that female patients stayed a shorter time in sunny rooms (2.3 days in sunny rooms, 3.3 days in dull rooms) (Beauchemin & Hays, 1998). Mortality in both sexes was consistently higher in dull rooms (39/335 dull, 21/293 sunny). Another study found that Veterans Health Administration medical centers located in warmer and drier climates had shorter length of stay of patients (Federman, Drebing, Boisvert, & Penk, 2000). Hospitals in colder climates had longest lengths of stay in winter and fall.

**Improving sleep and circadian rhythm**

A small number of studies have found that timed exposure to artificial bright light might be helpful in improving sleep and circadian rhythms. In one study, community-dwelling older adults exposed to either bright white light or dim red light on 12 consecutive days experienced substantial changes in sleep quality (Satlin, Volicer, Ross, Herz, & Campbell, 1992). Waking time within sleep was reduced by an hour, and sleep efficiency improved from 77.5% to 90%, without altering time spent in bed (Satlin et al., 1992). Two other studies showed that exposure to evening bright light was related to improved rest-activity rhythms among persons with dementia in nursing homes (Satlin et al., 1992; Van Someren, Kessler, Mirmiran, & Swaab, 1997). When the daytime environmental illumination level was increased in different living spaces of a dementia unit, it was found that, during increased illumination periods, the stability of the rest-activ-
ity rhythm increased in patients with intact vision, but not in visually impaired patients (Van Someren et al., 1997).

Three studies show that providing cycled lighting (reduced light levels in the night) in neonatal intensive-care units results in improved sleep and weight gain among preterm infants (Blackburn & Patteson, 1991; Mann, Haddow, Stokes, Goodley, & Rutter, 1986; Miller, White, Whitman, O’Callaghan, & Maxwell, 1995). In one study, 41 preterm infants in structurally identical critical-care units were provided either cycled or noncycled lighting (constant light levels during the day and night) during a lengthy hospital stay. Compared to infants in the noncycled lighting condition, infants assigned to the cycled lighting condition had a greater rate of weight gain, were able to be fed orally sooner, spent fewer days on the ventilator and on phototherapy, and displayed enhanced motor coordination (Miller et al., 1995).

**Lessening agitation**

Sloane and colleagues (1998) found that residents in facilities with low light levels displayed higher agitation levels. La Garce (2002) studied the impact of environmental lighting interventions (full-spectrum lighting, microslatted glazed windows, and electronic controls to maintain a constant level of light intensity) on agitated behaviors among residents with Alzheimer’s disease. She found a significant drop in disruptive behaviors when residents were in the experimental setting (constant light levels) rather than the control setting (varying light levels) (LaGarce, 2002).

Exposure to bright morning light has been shown to reduce agitation among elderly patients with dementia. When elderly patients with dementia were exposed to 2,500 lux for 2 hours in the morning for two 10-day periods, their agitation reduced. Patients were significantly more agitated on nontreatment days (Lovell, Ancoli-Israel, & Gevirtz, 1995).

**Easing pain**

A recent randomized prospective study assessed whether the amount of sunlight in a hospital room modifies a patient’s psychosocial health, quantity of analgesic medication used, and pain medication cost (Walch et al., 2005). Patients undergoing elective cervical and lumbar spinal surgeries were admitted to the bright or the dim side of the same hospital unit postoperatively. The outcomes measured included the standard morphine equivalent of all opioid medication used postoperatively by patients and their subsequent pharmacy cost. Patients staying on the bright side of the hospital unit were exposed to 46% higher-intensity sunlight on average. This study found that patients exposed to an increased intensity of sunlight experienced less perceived stress, marginally less pain, took 22% less analgesic medication per hour, and had 21% less pain medication costs (Walch et al., 2005).

**Improving adjustment to night-shift work among nurses**

There are approximately 8 million workers in the United States who regularly work at night, and, for many of these individuals (e.g., nurses and physicians, airline pilots), peak functioning is critical at all times (Horowitz, Cade, Wolfe, & Czeisler, 2001). Night-shift workers not only experience loss of sleep and misalignment of circadian phase, they also suffer greater risk of gastric
and duodenal ulcers and cardiovascular diseases (Horowitz et al., 2001). Their decreased alertness, performance, and vigilance may be responsible for more errors on the job (Smith-Coggins, Rosekind, Buccino, Dinges, & Moser, 1997).

The timing of the sleep–wake schedule and work schedule of night-shift nurses remains permanently out of phase with the natural light/dark cycle, and this causes health problems. Several studies show that exposure to intermittent bright light during the night shift is effective in adapting circadian rhythms of night-shift workers (Baehr, Fogg, & Eastman, 1999; Boivin & James, 2002; Crowley, Lee, Tseng, Fogg, & Eastman, 2003; Horowitz et al., 2001; Iwata, Ichii, & Egashira, 1997; Leppamaki, Partonen, Piironen, Haukka, & Lonqvist, 2003). Exposure to bright light during the night shift may also improve mood and sleep. In one study, 87 female nurses were exposed to brief periods (4 x 20 minutes) of bright (5,000 lux) light during scheduled times every night during a 2-week night shift. The treatment alleviated the nurses’ subjective distress associated with night-shift work (Leppamaki et al., 2003). In addition to bright-light exposure during the night, studies have shown that additional measures such as using dark sunglasses during the commute home and a regular early daytime sleep schedule ensure complete circadian adaptation to night-shift work (Boivin & James, 2002; Crowley et al., 2003; Horowitz et al., 2001).

Affecting mood and perception

Boyce and colleagues (2003) describe studies that clearly show that people’s moods are affected by different types of lighting conditions. Changes in mood are likely to affect changes in behavior and performance at work. However, mood changes do not remain the same across different people with the same lighting conditions. Rather, for the same lighting conditions, an individual’s discomfort, preferences, expectations, and gender impact how mood changes (Boyce, Hunter, & Howlett, 2003).

Studies have shown that people prefer daylight to artificial sources of light for work and like to be close to windows (Heerwagen & Heerwagen, 1986). Heerwagen and Heerwagen (1986) found that office occupants preferred daylight over electric lighting for seven different purposes: psychological comfort, office appearance and pleasantness, general health, visual health, color appearance of people and furnishings, work performance, and jobs requiring fine observation. Greater sunlight has also been linked to higher job satisfaction (Leather, Pyrgas, Beale, & Lawrence, 1998).

Windows are a source of daylight and views, and it seems natural that the presence of windows at work would be related to improved mood and work performance. However, this has been challenging to prove. In some studies, having access to a window reduced negative mood in some people, though not in other studies (Boyce, Hunter, &
Howlett, 2003). Boyce and colleagues (2003) suggest that the findings from these studies vary because people’s preferences and expectations may impact how they respond to different lighting conditions. Also, factors such as glare and thermal discomfort may actually affect mood and task performance negatively. While there isn’t convincing evidence linking the presence of windows to improved mood and performance outcomes, it is clear that natural light is the preferred source of light for most people. It is important to provide access to daylight along with opportunity to control glare and lighting levels (Boyce, Hunter, & Howlett, 2003).

**Affecting perceived stress and satisfaction**

There are few empirical studies that have examined the impact of light—artificial or natural—on mood or task performance in healthcare settings. A study of 141 nurses in Turkey found that nurses who were exposed to daylight for at least 3 hours a day experienced less stress and were more satisfied at work (Alimoglu & Donmez, 2005). A survey conducted at a new medical center incorporating many daylight-enhancing features (such as atriums and windows in patient rooms and operating rooms) examined the impact of natural light on staff satisfaction. Forty-three percent of the staff rated the increased natural light in the new facility as having a very positive impact on their work life, and 27% rated it as having a positive impact (Mroczek, Mikitarian, Vieira, & Rotarius, 2005). However, in most hospitals, nurses’ stations and break rooms do not have windows or access to natural light. There is need for further research to understand the importance of natural light to staff, as well as the impact of artificial light on staff mood and performance.

**Facilitating direct absorption for critical chemical reactions in the body**

Light radiation is absorbed directly by the body through the skin, and this stimulates chemical reactions in the blood and other tissues. There are two implications of this on health outcomes in healthcare settings. It

- supports Vitamin D metabolism and
- prevents jaundice.

**Supporting vitamin D metabolism**

One of the well-known beneficial photochemical process that occur this way in the body is the metabolism of vitamin D. Research shows that most of the vitamin D in the blood can only be derived by exposure to light (McColl & Veitch, 2001). The ultra violet (UV) radiation in the daylight is considered to be important for this process to occur. Most people are able to metabolize vitamin D by exposure to light. However, some people, such as chronically ill institutionalized individuals, elderly, shift workers, and those living in extreme polar latitudes, may not be able to obtain that necessary sunlight exposure. McColl and Veitch cite a couple of studies that suggest that full-spectrum fluorescent lighting might be able to support this important bodily function, but conclude that there is insufficient evidence for the use of such lighting for vitamin D metabolism (McColl & Veitch, 2001).
Preventing neonatal hyperbilirubinaemia

Studies suggest that exposure to light is an effective treatment for neonatal hyperbilirubinaemia (neonatal jaundice) (Giunta & Rath, 1969). This disorder is common to premature infants who lack the ability to metabolize bilirubin, a product of the decomposition of hemoglobin in dead red blood cells (McColl & Veitch, 2001). Exposure to light bleaches the bilirubin into a form that can be excreted from the body. In a controlled study of 96 preterm infants, 47 unclothed (except for diapers) babies were exposed to bright light (90 footcandles) and 49 fully clothed babies to dim light (10 footcandles). The group of infants exposed to light showed lower serum bilirubin as compared to the infants who were not exposed to the light (Giunta & Rath, 1969).

One potential negative outcome that might occur as a result of overexposure to light in health-care settings is retinal damage in preterm infants, and a few studies suggest that reducing ambient lighting conditions in hospital nurseries might improve outcomes (Ackerman, Sherwonit, & Fisk, 1989; Mann et al., 1986). Neonatal infants have thinner eyelids and usually have not developed the ability to constrict their pupils in response to light exposure. The high intensity of illumination in their environment makes them susceptible to retinal damage. However, studies that have examined the impact of reduced ambient lighting conditions on the development of retinopathy among premature infants have failed to detect a causal link (Kennedy et al., 2001; Reynolds, Hardy, Kennedy, & Spencer, 1998; Seiberth, Linderkamp, Knorz, & Liesenhoff, 1994).

Implications

There is strong evidence that light is critical to human functioning and can be extremely beneficial to patients as well as staff in healthcare settings. Adequate lighting conditions are essential for performance of visual tasks by staff in hospitals, and poor lighting conditions can result in errors. A point that must be noted in this regard is that lighting levels preferred by people are significantly higher than today’s indoor lighting standards and correspond to levels where biological stimulation can occur (Begemann, van den Beld, & Tenner, 1997). Begeman and colleagues (1997) suggest that biological lighting needs of humans are different from visual lighting needs, and lack of adequate light for biological stimulation can lead to health and performance problems. This is particularly important for staff who work during night shifts, but is also relevant for staff who work for long periods of time without exposure to daylight. There is also strong evidence that shows that exposure to light helps in reducing depression, alleviating pain, and improving sleep and circadian rhythms among patients and, thus, supports the healing process.

Clearly, an important goal for facility designers should be to fulfill human needs for light and provide a high-quality lighted environment. Building interiors are lit by a combination of daylight and electric lighting. There is clearly a strong preference for daylight over electric light. Daylight

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**Lighting in healthcare settings**

- Provide windows for access to natural daylight in patient rooms, along with provisions for controlling glare and temperature.
- Orient patient rooms to maximize early-morning sun exposure.
- Assess adequacy of lighting levels in staff work areas.
- Provide high lighting levels for complex visual tasks.
- Provide windows in staff break rooms so staff has access to natural light.
entering through windows can be extremely beneficial to patients, provided there is no glare and it is possible to control light levels. However, in addition to natural light, electric light is needed in all parts of the hospital, though the need for artificial lighting can be reduced by efficient utilization of sunlight wherever possible.

While making decisions regarding lighting, economic factors (first costs, energy consumption, and maintenance) must also be taken into consideration (Veitch, 1993). Proponents of full-spectrum fluorescent lighting argue that this lighting source is superior to other artificial light sources (e.g., cool white lamps) because it provides a full-spectral wavelength similar to natural light and has the advantages of natural light for health and performance. However, there is inadequate evidence to support this claim except in special situations (e.g., for tasks requiring fine color discrimination) (Veitch & McColl, 1993). Further, Veitch (1993) suggests that full-spectrum fluorescent lighting is not feasible from an economic standpoint. Compared to cool white lamps, full-spectrum fluorescent lights are about 6 times more expensive and provide less light per unit electrical energy (Veitch, 1993). To maintain current recommended light levels, full-spectrum lights would result in higher electricity costs than other lamp types. Also, lamp life for full-spectrum fluorescent light in some installations may be less than other lamp types (Veitch, 1993).

Where good color rendering and bright, changing, visual environments are desirable, energy-efficient natural light is ideal. Wherever possible in healthcare settings, natural light should be incorporated into lighting design not only because it is beneficial to patients and staff, but also because it is light delivered at no cost and in a form that is preferable to most people.

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The Role of the Physical and Social Environment in Promoting Health, Safety, and Effectiveness in the Healthcare Workplace

Anjali Joseph, Ph.D., Director of Research, The Center for Health Design

This paper was funded by a grant from the Robert Wood Johnson Foundation.
The Center for Health Design is a nonprofit research and advocacy organization whose mission is to transform healthcare settings into healing environments that improve outcomes through the creative use of evidence-based design. We envision a future where healing environments are recognized as a vital part of therapeutic treatment and where the design of healthcare settings contributes to health and does not add to the burden of stress.

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Graphic Design: Glenn Ruga, Visual Communications
Abstract

Objective: To examine how the physical environment, along with other factors such as culture and social support, impact (a) the health and safety of the care team, (b) effectiveness of the healthcare team in providing care and preventing medical errors, and (c) patient and practitioner satisfaction with the experience of giving and receiving care.

Methods: Literature review of peer-reviewed journal articles and research reports published in medicine, nursing, psychology, ergonomics, and architecture periodicals and books. Different combinations of keywords were used to search for articles including workforce, nurses, healthcare team, work environments, ergonomics, staff health, staff safety, medical errors, transfers, and communication.

Key findings: There is an urgent need to address the inherent problems in the healthcare workplace that lead to staff injuries and hospital-acquired infections, medical errors, operational failures, and wastage. The physical environment plays an important role in improving the health and safety for staff, increasing effectiveness in providing care, reducing errors, and increasing job satisfaction. These improved outcomes may, in turn, help in reducing staff turnover and increase retention — two key factors related to providing quality care in hospitals. However, it has become increasingly clear that efforts to improve the physical environment alone are not likely to help an organization achieve its goals without a complementary shift in work culture and work practices.

Proper design of healthcare settings, along with a culture that prioritizes the health and safety of the care team through its policies and values, can reduce the risk of disease and injury to hospital staff and provide the necessary support needed to perform critical tasks. Also, it is important to identify core systemic and facility design factors that lead to failures and wastage in healthcare, and then develop new solutions (e.g. acuity adaptability, standardized rooms) that address these problems within the context of culture changes and evolving models of care.

Conclusions: The physical environment along with social support, organizational culture, and technology can play an important role in improving health, safety, effectiveness and satisfaction of the healthcare team.
Introduction

Traditionally, healthcare environments have been organized to support the individual work efforts of practitioners in various roles and disciplines (doctors, nurses, therapists, dieticians, and many others) who work primarily in their areas of expertise and attempt to coordinate with others by orders, notes, phone calls, pages, and other methods of individual communication. Patients and families have traditionally been viewed as passive recipients of care rather than as active experts in their life and health conditions.

In contrast, a growing body of evidence demonstrates that healthcare work happens most effectively when practitioners work highly interdependently in well-functioning teams, with active participation by patients and families (McCarthy and Blumenthal 2006; Uhlig et al. 2002). As care moves from simply treating disease to healing the individual in a holistic sense—physically, emotionally, and psychologically—healthcare teams must increasingly work seamlessly together and include the patient and family as integral team members. A disconnect has arisen between the traditional, individual-centric organizational and physical infrastructure of the healthcare workplace and the way that healthcare practitioners, patients, and families optimally must work together. This manifests itself in the form of inefficiencies, communication breakdowns, occupational stress, medical errors, and other operational failures that are alarmingly common in healthcare today.

Further, the physical environment of the healthcare workplace, along with other factors such as culture and work processes, also impacts the health and safety of the healthcare workforce. According to the Peter D. Hart Research Associates’ (2001) survey of registered nurses, the primary reason why nurses leave healthcare—other than for retirement—is to find a job that is less stressful and physically demanding. In a survey of nurses conducted by the American Nurses Association (2001), 76 percent of the nurses stated that unsafe working conditions interfered with their ability to provide quality care.

To understand and address these problems, it is necessary to consider the healthcare workplace as an interdependent system comprised of the physical environment, work processes, organizational culture (e.g., formal and informal values, norms, expectations, and policies, etc.), workforce demographics, and information technology (Becker 2006). Thus, it becomes important to consider the interdependencies and patterns of interaction between these elements, rather than focusing on individual elements alone. While several studies indicate that the physical environment impacts staff outcomes in healthcare settings, it is clear that a well-designed environment alone is unlikely to achieve its intent without a supportive work culture and the technology in place. Likewise, a supportive work culture such as one that promotes family and patient participation in care processes is unlikely to function successfully without the presence of design features (such as space for families in patient rooms) that make this possible. Hospital redesign and renovation projects provide the opportunity to consider how these different elements might interact. The challenge is to create settings where the physical environment, technology, and organizational culture together support ways of working that ensure health, safety, and effectiveness for all in healthcare.

The focus of this paper is on understanding how the physical environment interacts with other factors to impact the health, safety, and effectiveness of the care team in healthcare settings. The three sections in this paper examine how the physical environment, along with other factors such as culture and social support, impact (a) the health and safety of the care team, (b) effectiveness of the healthcare team in providing care and preventing medical errors, and (c) patient and practitioner satisfaction with the experience of giving and receiving care.
Improve health and safety of the care team through environmental measures

Properly designed physical environments impact the health and safety of staff by:

- Reducing infections.
- Decreasing back pain and work-related injuries.
- Reducing injuries from medical equipment.
- Improving adjustment to night-shift work.
- Lessening noise stress.

The healthcare workforce is exposed to various occupational hazards on a daily basis. They are exposed to airborne infections in the hospital as well as those acquired through direct contact with patients. Taking care of patients in the hospital is often back-breaking work with nurses required to manually lift heavy patient loads. For night-shift nurses, poorly entrained circadian rhythms and lack of sleep contribute to stress, fatigue, and health deterioration. In addition, other environmental stressors such as high noise levels, inadequate light, and poorly designed workspaces impact staff health and safety. Proper design of healthcare settings, along with a culture that prioritizes the health and safety of the care team through its policies and values, can reduce the risk of disease and injury to hospital staff and provide the necessary support needed to perform critical tasks.

Reducing infections among healthcare staff

Healthcare employees are at serious risk of contracting infectious diseases from patients due to airborne and surface contamination (Clarke, Sloane, and Aiken 2002; Jiang et al. 2003; Kromhout et al. 2000; Kumari et al. 1998; Smedbold et al. 2002). Factors such as poor ventilation and fungal contamination of the ventilation system that have been linked to the spread of nosocomial infections among patients may also impact staff. For example, one study that examined the relationship between indoor environmental factors and nasal inflammation among nursing personnel found the contamination of air ducts with Aspergillus fumigatus to be the source of infection (Smedbold et al. 2002). A recent study conducted in the wake of the severe acute respiratory syndrome (SARS) epidemic in China found that isolating SARS cases in wards with good ventilation could reduce the viral load of the ward and might be the key to preventing outbreaks of SARS among healthcare workers, along with strict personal protection measures in isolation units (Jiang et al. 2003).

While ventilation-system design and maintenance are critical to controlling the spread of airborne infections, infections are often spread through direct and indirect contact with patients. Ulrich and colleagues (2004), in their extensive literature review, concluded that poor handwashing compliance among staff is the primary cause of contact transmission of infections. They suggest that providing environmental supports to increase handwashing—including visible, conveniently placed sinks; handwashing liquid dispensers; and alcohol rubs—might be more successful in improving and sustaining handwashing compliance than education programs alone (Ulrich et al. 2004). They also document several studies that clearly show that nosocomial infection rates are lower in single patient rooms as compared to semiprivate rooms (Ulrich et al. 2004). These environmental measures that are linked to increased patient safety are also likely to protect staff from infection.

Reducing back pain and work-related injuries among hospital staff

Nursing work has become increasingly complex with changing technology, evolving work practices, and increasing documentation requirements. Further, nurses are growing older and the patient demographics are changing as well (Joint Commission on Accreditation of Healthcare Organizations, 2002). There is a need to redesign workplaces using ergonomic principles to reduce the physical demands on nursing staff.
Moreover, these efforts to redesign the physical workplace need to be augmented by staff education about healthcare occupational hazards and the development of a culture where staff health and safety are a top priority.

Lower back pain is a pervasive problem among nursing staff and is a result of poor fitness, long periods of standing, and efforts far exceeding workers’ strengths (Brophy, Achimore, and Moore-Dawson 2001; Camerino et al. 2001; Miller et al. 2006). Patient lifting in particular is a major cause of injury to healthcare workers. According to Fragala and Bailey (2003), 44 percent of injuries to nursing staff in hospitals that result in lost workdays are strains and sprains (mostly of the back), and 10.5 percent of back injuries in the United States are associated with moving and assisting patients. Reducing injuries that result from patient-lifting tasks can not only result in significant economic benefit (reduced cost of claims, staff lost workdays), but also reduce pain and suffering among workers. Ergonomic programs, staff education, a no-manual lift policy, and use of mechanical lifts have been successful in reducing back injuries that result from patient-handling tasks (Engstand et al. 2005; Garg and Owen 1992; Gargand et al. 1991; Joseph and Fritz 2006; Millerand et al. 2006).

For example, when PeaceHealth in Oregon installed ceiling lifts in most patient rooms in their intensive-care unit and neurology unit, they found that the number of staff injuries related to patient handling came down from ten in the two years preceding lift installation to two in the three years after lift installation (Joseph and Fritz 2006). The annual cost of patient-handling injuries in these units reduced by 83 percent after the lifts were installed (Joseph and Fritz 2006). This study, as well as others, has emphasized the importance of instituting a no-manual lift policy (along with the installation of mechanical lifts) in hospitals to prevent such injuries from occurring. Another environmental design feature that has been linked to reduced discomfort (particularly for the lower extremities and lower back) for workers who spend large amounts of time on their feet, is using softer floors (such as rubber floors) (Redfern and Cham 2000).

Ergonomic evaluations of the work area of different types of nursing staff might provide solutions to problems that are specific to different groups. For example, based on an ergonomic evaluation of the work area of scrub nurses in the operating room, Gerbrands and colleagues (2004) provided short-term solutions for reducing the neck and back problems experienced by this group as well as suggested guidelines for operating-room design. Some suggestions included height-adjustable footstools, better monitor placement, and ergonomically designed instrument tables to help reduce neck and back tension experienced by these nurses as they attempted to obtain an unobstructed view of the operating field and reached for instruments on instrument tables in the operating room. Another area where additional ergonomics research is needed is in the design of computer workstations for nurses, since, with increasing documentation requirements, nurses are likely to spend more time at these workstations. The design of nursing workstations as they impact posture, readability, and visual fatigue need to be addressed in new designs.

**Decreasing staff injuries from medical equipment**

The nursing staff in hospitals is exposed to injuries from medical equipment and sharp instruments. Estimates from the University of Virginia’s Exposure Prevention Information Network surveillance system in 1996 placed the number of injuries among healthcare workers in the United States from exposure to sharps at 600,000 (Clarke, Sloane, and Aiken 2002). While previous guidelines emphasized the use of pro-
tective devices and universal precautions, studies show that other factors such as organizational climate and nurse staffing also impact the likelihood of needlestick injuries (Clarke, Sloane, and Aiken 2002; Grosch et al. 1999). For example, nurses from units with low staffing and poor organizational climates were generally twice as likely as nurses on well-staffed and better-organized units to report risk factors, needlestick injuries, and near misses (Clarke, Sloane, and Aiken 2002). Nursing staff members are also open to risk of injury from medical equipment such as high-intensity surgical-light sources. One study found that a light source used during surgery could potentially cause retinal damage in surgical staff (Fox and Henson 1996). Identifying and removing environmental hazards are steps that can be taken to prevent injuries among nursing staff from medical equipment. The contribution of the physical environment to needlestick injuries has not been studied, but it is plausible that injury rates are higher in chaotic environments as compared to more organized environments. This is an area where additional research is needed.

**Improving adjustment to night-shift work among nurses**

The timing of the sleep–wake schedule and work schedule of night-shift nurses remains permanently out of phase with the natural light–dark cycle, and this causes health problems. Night-shift nurses not only experience loss of sleep and misalignment of circadian rhythms (biological events that repeat themselves at regular hours), they also suffer greater risk of gastric and duodenal ulcers and cardiovascular diseases (Horowitz et al. 2001). Further, their decreased alertness, performance, and vigilance may be responsible for more errors on the job (Smith-Coggins et al. 1997).

Several studies show that exposure to intermittent bright light during the night shift is effective in adapting circadian rhythms of night-shift workers (Baehr, Fogg, and Eastman 1999; Boivin and James 2002; Crowley et al. 2003; Horowitz et al. 2001; Ivata, Ichii, and Egashira 1997; Leppamaki et al. 2003). Exposure to bright light during the night shift may also improve mood and sleep (Leppamaki et al. 2003). In addition to bright-light exposure during the night, studies have shown that additional measures such as using dark sunglasses during the commute home and a regular early daytime sleep schedule ensure complete circadian adaptation to night-shift work (Boivin and James 2002; Crowley et al. 2003; Horowitz et al. 2001).

**Lessening noise stress among staff**

The effects of noise on patients are well-known. However, few studies have examined the impact of noise on healthcare staff. Ulrich and colleagues (2004) analyzed several studies that measured noise levels in hospitals and found that background noise levels in hospitals were typically in the range of 45 dB to 68 dB, with peaks frequently exceeding 85 dB to 90 dB. This is well above the values (35 dB) recommended by the World Health Organization guidelines (Berglund, Lindvall, and Schwela 1999). Staff perceive higher sound levels as interfering with their work (Bayo, Garcia, and Garcia 1995), and higher sound levels are also related to greater stress and annoyance among nursing staff (Morrison et al. 2003). Importantly, noise-induced stress in nurses correlates with reported emotional exhaustion or burnout (Topf and Dillon 1988). Blomkvist and colleagues (2005) examined the effects of changing the acoustic conditions on a coronary intensive-care unit (using sound-absorbing versus sound-reflecting ceiling tiles) on the same group of nurses over a period of months. During the periods of lower noise, many positive outcomes were observed among staff including improved speech intelligibility, reduced perceived work demands, and lessened perceived pressure and strain (Blomkvist et al. 2005).
Hospital personnel are frequently exposed to infectious pathogens and environmental hazards that compromise their health and safety. Through ergonomic interventions, as well as careful consideration of other issues such as air quality, noise, and light, it is possible to significantly impact the health of staff in hospitals.

**Increase effectiveness of the healthcare team and reduce errors by designing better workplaces**

The tasks performed by the healthcare team involve a complex choreography of multiple activities including direct patient care; indirect care, such as filling meds; coordination with care team members; accessing and communicating information; documentation of patient records; and other housekeeping tasks (Lundgren and Segesten 2001; Tucker and Spear 2006). Studies have shown that increased nursing time per patient results in better patient outcomes (Institute for Healthcare Improvement 2004; Tucker and Spear 2006). However, the fact remains that nurses spend less than half their time delivering direct patient care (Institute for Healthcare Improvement 2004). Nurses spend a lot of their time searching for other staff, materials, missing meds, and supplies and also are frequently interrupted during their work to address these problems (Tucker and Spear 2006). In one study, a hospital nurse was interrupted forty-three times during a ten-hour period, including ten instances when necessary materials, equipment, and personnel were unavailable (Potter et al. 2004).

**Staff effectiveness is undermined by poorly designed work systems resulting in:**
- Multiple patient transfers within the hospital.
- Time wasted hunting and gathering people and supplies.
- Frequent communication breakdowns.
- Medical errors.

At the root of the inefficiencies in healthcare is a physical and organizational infrastructure that is completely out of sync with the optimal practice of healthcare. It is becoming increasingly clear that poorly designed physical environments, along with other factors such as lack of social support and an unsupportive work culture, reduces the effectiveness of staff in providing care and potentially leads to medical errors.

Architects, healthcare administrators, and clinicians are increasingly working together to address the root causes of errors and wastage and to use that information while designing care environments (Reiling et al. 2004). Here, we describe some of the inefficiencies and breakdowns that typically undermine staff effectiveness in healthcare settings and the role the physical environment can potentially play in conjunction with a supportive work culture and technology infrastructure in increasing staff effectiveness and reducing errors. Architectural design responses to these problems are presented within the context of emerging operational models and technologies. It must be noted that the benefits of some of these design innovations have not yet been validated and need to be tested through rigorous research.

**Patient transfers**

Patients are transferred from one room to another as often as three to six times during their short stay (national average length of stay in US hospitals is 4.8 days [DeFrances, Hall, and Podgornik 2005]) in the hospital to receive the care that matches their level of acuity (Hendrich, Fay, and Sorrells 2004; Hendrich and Lee 2005). According to Hendrich et al. (2004), a typical nursing unit might transfer or discharge 40 percent to 70 percent of its patients every day. This process is extremely inefficient and leads to increased costs, reduced quality of care, and reduced satisfaction among patients (Hendrich, Fay, and Sorrells, 2004; Hendrich and Lee 2005). The delays, communication discontinuities among staff, loss of information, and changes in computers and systems that occur in the patient transfer process also contribute to increased
medical errors, loss of staff time, and productivity (Cook, Render, and Woods 2000; Hendrich, Fay, and Sorrells 2004).

To improve staff productivity and satisfaction, reduce resource waste (caregiver and fiscal), decrease errors, and improve the overall patient experience, the team at Clarian Methodist Hospital in Indianapolis, Indiana, under the leadership of Ann Hendrich, developed a novel demonstration project, the Cardiac Comprehensive Critical Care. The focus of this project was on providing different levels of care in a single room so as to minimize the need to transfer patients as their acuity level changed (Hendrich, Fay, and Sorrells 2004). These were single patient rooms with acuity adaptable headwalls—which were equipped with the gases and equipment needed to provide care as patient acuity changed. Further, nurses’ stations on this unit were decentralized with additional workstations outside each patient’s room. For the success of the initiative, it was also critical to change the operational model such that all nurses on the unit were trained to respond to patients with varying acuity levels. The impact of this fifty-six-bed acuity adaptable unit (twenty-eight rooms on two floors) on different outcomes was measured by comparing two years of baseline data (before the move) and three years of data after the move. Hendrich and colleagues (2004) found significant improvement postmove in many key areas: patient transfers decreased by 90 percent, medication errors by 70 percent, and there was also a drastic reduction in the number of falls.

This was a path-breaking project that demonstrated the potential impact of acuity-adaptable care in dealing with patient flow and patient safety issues while at the same time improving the model of care. Since then, new hospital projects across the country have adopted this concept to differing extents. Challenges to incorporating acuity-adaptable rooms are often cultural (staffing model is dramatically different) and regulatory. There is a critical need to study the impact of acuity-adaptable rooms in other facilities to better understand how the physical and operational models work in different organizations and also to ascertain the safety advantages of acuity-adaptable rooms for other types of units and patient categories.

Hunting and gathering

Nurses spend a lot of time walking. According to an unpublished time and motion study by Hendrich and colleagues (cited in the 2004 Institute of Medicine report, Keeping patients safe: Transforming the work environment of nurses, pp. 251), most of nurses’ time is spent walking between patient rooms, the nursing unit core, and the nurses’ station. Often, this walking takes place to locate and gather supplies and equipment and find other staff members (Tucker and Spear 2006). Most older existing hospital units have centralized nursing stations with different configurations such as radial, racetrack, or single or double corridor where the nursing station is located centrally and patient rooms are located around the perimeter. This kind of arrangement necessitates frequent trips between patient rooms and the nurses’ station to look for supplies, charting, filling meds, and so on. According to one study, almost 28.9 percent of nursing staff time was spent walking (Burgio et al. 1990). This came second only to patient-care activities, which accounted for 56.9 percent of observed behavior.

A few studies have examined the impact of unit layout on the amount of time spent walking (Shepley 2002; Shepley and Davies 2003; Sturdavant 1960; Trites et al. 1970), and two studies showed that time
saved walking was translated into more time spent on patient-care activities and interaction with family members. Shepley and colleagues (2003) found that nursing staff in a radial unit walked significantly less than staff in a rectangular unit (4.7 steps per minute versus 7.9 steps per minute). Two other studies also found that time spent walking was lower in radial units as compared to rectangular units (Sturdavant 1960; Trites et al. 1970). It must be noted that, in the units examined in these studies, the nursing station was centralized with rooms arrayed around it.

These studies seem to suggest that bringing staff and supplies physically and visually closer to the patients helps in reducing the time spent walking. To take this idea further, new designs are incorporating decentralized nurses’ stations and alcoves outside patient rooms so that staff is distributed around the unit (as opposed to being in a single central location), closer to the patient. In the Clarian demonstration project described earlier, nursing stations with computer access and servers for supplies were decentralized. Further, additional workspace was provided outside each patient room. Also, to reduce time spent walking back and forth to the nursing station, necessary supplies were provided in each room. Hendrich and colleagues (2004) assert that the efficient unit design helped in reducing walking and supply trips, such that nursing time significantly increased allowing for a reduction in budgeted staffing care hours, while at the same time increasing time spent in direct patient-care activities.

Centralized location of supplies, however, could double staff walking and substantially reduce care time irrespective of whether nurses’ stations were decentralized (Hendrich 2003). There is also anecdotal evidence that staff members who move from a centralized nursing unit to a decentralized unit often feel isolated and miss the camaraderie and support of the centralized unit. The social interactions that occur within the care team are critical for information sharing and effective communication. While the decentralized unit potentially has many benefits, it is worthwhile to consider how the design might impact staff interactions. It might be important to incorporate spaces on the unit (such as break rooms, coffee machine, etc.) where spontaneous encounters and social interaction might take place. With decentralized nursing care becoming increasingly common, there is a great opportunity to study the impact of this model on staff time spent walking, in direct patient care, as well as the nature of the interactions between patient and staff and between staff members so as to understand how these changes impact patient and staff satisfaction, communication within the care team, and staff effectiveness.

**Nurses & Walking**

- Nurses spend close to one-third of their time walking on the unit between patient rooms, the nursing unit core, and the nurses’ station.
- This results in fatigue.
- Bringing staff and supplies closer to patients is likely to reduce time spent walking and increase time spent in direct patient-care activities.
- It is also important to consider the impact of decentralized care on staff socialization and communication.

**Teamwork and communication**

Healthcare practitioners are required to process different types of information and react quickly to the continuously changing conditions of their patients. Further, it is critical that practitioners from different disciplines—nurses, physicians, anesthetists, and so on—communicate vital patient information with each other to prevent replication of efforts, errors, and other operational failures (McCarthy and Blumenthal 2006; Uhlig et al. 2002). However, culturally, the practice of healthcare continues to be very individualistic, with independent practitioners gathering information and making decisions independently, noting actions in the medical record, and calling upon other practitioners only when needed (Uhlig et al. 2002). This creates an environment where communication breaks down frequently, something that is not lost on patients and their families. (Frustrated patients and families often ask caregivers “Don’t you people ever
talk to each other?” [Uhlig et al. 2002]). Further, patients and families are rarely included in discussions about their health and well-being.

This practice of healthcare in silos discounts the evidence that, in healthcare as well as other work settings, learning and communication happens most effectively through frequent human contact and social interaction. Such interaction allows for the exchange of explicit knowledge (e.g., through the patient record) but also allows for team members to pick up on cues and triggers from their team members that allow them to perform their work.

Based on a conviction that better teamwork and communication were critical to improving patient safety, Paul Uhlig, MD, and colleagues have been conducting multidisciplinary collaborative rounds at the patient bedside in a cardiac surgery program in Concord, New Hampshire since 1999 (McCarthy and Blumenthal 2006). This involved the entire care team (including the patient and his/her family, bedside nurse, surgeon, nurse practitioner or physician assistant, social worker, spiritual-care counselor, clinical and home-care coordinators, a pharmacist, therapists, dietitian, and rehabilitation specialists) participating in ten-minute briefings at the patient’s bedside at the start of the day. The team reviews the patient’s care plan, discusses medication, and addresses anything that has gone wrong in the process in an open, blame-free environment (McCarthy and Blumenthal 2006). Following these changes, mortality rates declined, and both provider and patient satisfaction increased significantly (Uhlig et al. 2002). Also, according to Uhlig, the rounds have become a way to reorient the care team to a ‘collaborative culture of interaction’ (McCarthy and Blumenthal 2006).

This example, as well as others, points to the importance of providing opportunities for individuals to interact with each other in the workplace for effective communication and knowledge sharing. Becker (2006) suggests that, for a culture of teamwork and communication to thrive, it may be important to provide the physical setting (as well as the technology infrastructure) that supports such behavior. Based on his research on different types of workplace settings, Becker (2006) puts forward five propositions for creating environments that support a culture of communication and collaboration (the cornerstone of a safer and more effective practice of healthcare).

1. **Eco-diversity**: Becker (2006) suggests that learning and collaboration are facilitated by providing many different types of settings within the workplace where spontaneous and planned face-to-face interactions might occur. Depending on the work style of the organization, these spaces might include staff lounges, nursing alcoves, break rooms, nursing stations, and so on.

2. **Spatial transparency**: When employees are able to see and hear what others are doing from their own workspace as well as when they move around their team, unit, or department’s workspace during their daily work, they get more opportunities to model behavior, share information, and ask for and give critical feedback to team members.

3. **Functional inconvenience**: According to Becker (2006), opportunities for learning and interaction might be higher in organizations where employees do not have designated work spaces. Rather, they utilize
any available workspace to perform their work. Opportunities for chance encounters with a wider circle of people will potentially increase under such conditions.

4. **Human scale**: Opportunities for informal learning and interaction between team members might be higher when departments and teams are organized into smaller sections spatially, rather than the same-sized departments and teams occupying a larger space. This might have implications for the sizing of the nursing unit.

5. **Neutral zones**: Environmental cues such as those that convey the status of different individuals create barriers to the free flow of information and interaction (e.g., the traditional nurses’ station with high counters creates a spatial and symbolic distinction between those providing and receiving care, thus potentially deterring patients and families from being active participants in the care process). Similarly, environmental cues that accentuate the hierarchies between doctors and nurses, between care provider and patient are detrimental to a culture of collaboration. Spaces that are neutral, in that they do not belong to any one group but to everyone, are more likely to facilitate open communication and interaction.

These propositions remain to be validated through empirical research. However, they provide a useful framework for understanding the role that the physical environment might play in promoting teamwork and communication in healthcare settings.

**Errors**

According to the Institute of Medicine report, *To Err Is Human: Building a Safer Healthcare System*, more than 98,000 people die each year in US hospitals due to medical errors (Kohn, Corrigan, and Donaldson 1999). According to Reiling and colleagues (2004), while some errors (active failures) occur at the point of service (for example, a nurse administering the wrong drug), most occur due to flaws in the healthcare system or facility design—such as due to high noise levels or inadequate communication systems.

Inadequate lighting and a disorganized chaotic environment are likely to compound the burden of stress for nurses and lead to errors. A few studies have shown that lighting levels and workplace design can impact errors in dispensing medication in pharmacies. One study examined the effect of different illumination levels on pharmacists’ prescription-dispensing error rate (Buchanan and et al. 1991). It found that error rates were reduced when work-surface light levels were relatively high (Buchanan et al. 1991). In this study, three different illumination levels were evaluated (450 lux; 1,100 lux; 1,500 lux). Medication-dispensing error rates were significantly lower (2.6 percent) at an illumination level of 1,500 lux (highest level), compared to an error rate of 3.8 percent at 450 lux. This is consistent with findings from other settings that show that task performance improves with increased light levels (Boyce, Hunter, and Howlett 2003). Two investigations of medication-dispensing errors by hospital pharmacists found that error rates increased sharply for prescriptions when an interruption or distraction occurred, such as a telephone call (Flynn et al. 1999; Kistner et al. 1994). Thus, lighting levels, frequent interruptions or distractions during work, and inadequate private space for performing work can be expected to worsen medication errors.

The design process for St. Joseph’s hospital in West Bend, Wisconsin, exemplifies how design innovation can be fos-

**Most errors in healthcare occur due to healthcare system or facility design contributing to errors:**

- Low light levels.
- Inadequate private space for work.
- Frequent distractions and interruptions.
- Noisy chaotic environments.

Identifying the root cause of errors helps in developing design solutions to maximize patient safety.
tered through a careful examination of latent conditions and active failures in the health system. The design process for this nonprofit eighty-bed acute-care facility was completely driven by safety principles—to reduce errors and maximize patient safety by designing against latent conditions and active failures (Reiling et al. 2004). A multidisciplinary team of experts from systems engineering, human factors, healthcare administration, medicine, pharmacy, healthcare architecture, and quality improvement participated in a learning lab where safety-driven design recommendations were developed. The design team then used Failure Modes Effects Analysis (a tool commonly used in the aviation and manufacturing industry to identify and prevent problems with product and process design) to test any latent problems with departmental adjacencies in the new design under the lens of patient safety. Further, new technology ideas were juxtaposed with equipment and potential design features to maximize the safety-driven design principles (Reiling et al. 2004).

The design that evolved as a result of this process included all single patient rooms allowing for more space for staff and families, a small alcove outside the patient room to allow visibility to patients, and a dedicated space for patient supplies and medication. Further, rooms are all standardized in layout, including furniture placement and location of supplies and equipment (Reiling et al. 2004). The purpose of these design features was to reduce the cognitive burden on the staff (from having to deal with variations from room to room) and also fatigue by reducing the need to walk long distances. St. Joseph’s is currently evaluating the impact of its design on different types of outcomes including error rate, number of falls, and infection rate in the new facility. This project and others that follow this provide a model for redesigning systems to address factors that impact staff effectiveness. There is a need to carefully research whether these efforts are successful and to identify lessons learned for future design projects.

Clearly, there is now recognition that staff effectiveness and productivity cannot be improved through a piecemeal approach. Rather, it is critical to identify core systemic and facility design factors that lead to failures, and then develop new solutions that address these problems within the context of culture changes and evolving models of care.

**Improve staff and patient satisfaction and morale through integrated environmental design**

There is evidence that a supportive physical work environment, along with other factors such as high autonomy, low work pressure, and supervisor support, positively impacts job satisfaction and burnout among nurses (Constable and Russell 1986; Mroczek et al. 2005; Tumulty, Jernigan, and Kohut 1994; Tyson, Lambert, and Beattie 2002). Further, studies show that environments (i.e., physical environment, culture, and work processes) that include patients and families as active participants in the care process (as opposed to passive recipients of care) result in higher levels of satisfaction among patients and families (Sallstrom, Sandman, and Norberg 1987; Uhlig et al. 2002).

For example, the collaborative rounds at Concord Hospital were perceived very positively by patients and families who felt empowered by being part of the care team and comforted by the fact that the team members were all talking to each other (McCarthy and Blumenthal 2006; Uhlig et al. 2002). However, to include families in the care process, it is important to provide spaces for families in the patient room and on the unit where they can spend extended periods of time. Single rooms have clear advantage over multibed rooms in this regard due to increased privacy for patient-family interactions and more space and furniture to accommodate family presence (Chaudhury, Mahmood, and Valente 2006; Ulrich et al. 2004). A survey of nurses in four hospitals found that nurses gave high ratings to single rooms for accommodating family members, but accorded double rooms low scores (Chaudhury, Mahmood, and Valente 2006). In addition to these factors, organizational policies such as those that limit family visitation hours might influence family involvement and satisfaction with care.
Studies show that physical design changes in long-term care settings such as interior design modifications, natural elements, furniture repositioning to support social interaction, design supports for resident independence (such as large clocks, handrails, additional mirrors), orientation (large, clear signposts, and reality orientation boards), and artwork were related to improved morale and satisfaction among staff (Christenfeld et al. 1989; Cohen-Mansfield and Werner 1999; Jones 1988; Loeb et al. 1995; Parker et al. 2004). Tumulty and colleagues (1994) suggest that, if staff were allowed to make small design modifications to their existing environments, their satisfaction with their jobs might increase.

Other studies, primarily conducted in long-term care settings, suggest that smaller units contribute to reduced stress and increased staff satisfaction. A cross-sectional survey of 1,194 employees and 1,079 relatives of residents in 107 residential-home units and health-center bed wards found that large unit size was related to increased time pressure among employees and reduced quality of life for residents (Pekkarinen et al. 2004). Other studies found that small unit sizes were positively associated with increased supervision and interaction between staff and residents in a special-care unit for residents with dementia (McCracken and Fitzwater 1989). However, no consistent numbers are offered on what makes a unit large or small (Day, Carreon, and Stump 2000), and it is also not clear how these findings translate to acute-care settings. Further, even in small units, it is important to consider how the design impacts staff ability to monitor residents. Morgan and Stewart (and1998) found that, in a newly designed, low-density special-care unit with private rooms, enclosed charting spaces, and secluded outdoor areas and activity areas, staff spent increased time monitoring and locating residents.

An important point that is emphasized in many of these studies is that design changes alone are not likely to impact staff behavior, satisfaction, and stress. They must be accompanied by a supportive culture and progressive work practices to result in overall beneficial outcomes for patients and staff.

**Increase staff and patient satisfaction and morale through workplace design by:**

- Incorporating patient and family spaces to support family participation in the care process.
- Design of pleasant, attractive environments.
- Smaller units with good visual access between staff and patients.

**Summary**

There is an urgent need to address the inherent problems in the healthcare workplace that lead to staff injuries, medical errors, and wastage. The physical environment plays an important role in improving the health and safety for staff, increasing effectiveness in providing care, reducing errors, and increasing job satisfaction. These improved outcomes may, in turn, help in reducing staff turnover and increase retention, two key factors related to providing quality care in hospitals.

However, it has become increasingly clear that efforts to improve the physical environment alone are not likely to help an organization achieve its goals without a complementary shift in work culture and work practices. To summarize this discussion, some key steps that could be considered while designing supportive healthcare workplaces include:

- Identify operational and system problems that impact staff effectiveness and productivity (such as interruptions, transfers, lack of information) and develop design and care models (e.g., acuity-adaptable rooms) that effectively address these problems.
- Identify steps to promote culture change parallel to design changes to ensure effectiveness and acceptance for new innovations.
• Through the design of the environment, provide opportunities for spontaneous and planned interactions within the healthcare team.

• Provide spaces for families such that patients and families can be effectively included in the healthcare team.

• Consider installing ceiling lifts in patient rooms to reduce staff back injuries along with instituting a no-manual lift policy.

• Conduct ergonomic evaluation of staff work areas to design spaces that are supportive of staff work practices and reduce pain and injury.

• Carefully consider sources of infection and injury to staff (air, contact, and bloodborne) during design.

• Institute measures to reduce noise stress among nurses (e.g., by improving acoustic conditions on the nursing unit, education, and awareness programs).

• Consider work flows in relation to location of key spaces (patient room, nurse work space, location of equipment and supplies) with the goal of minimizing walking distances and number of trips.

• Consider locating frequently used supplies in patient rooms to minimize walking trips for staff.

While the studies described in this paper demonstrate that well-designed physical workplaces can support staff in their work and increase health and safety, there is a definite need for more research examining the effectiveness of new design innovations such as acuity adaptability, standardized patient rooms, and decentralized nursing station within the larger context of an organization’s culture, technology changes, and work practices.

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Sound Control for Improved Outcomes in Healthcare Settings

Anjali Joseph, Ph.D., Director of Research, The Center for Health Design

Roger Ulrich, Ph.D., Professor, Center for Health Systems and Design, Texas A&M University

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The Center for Health Design is a nonprofit research and advocacy organization whose mission is to transform healthcare settings into healing environments that improve outcomes through the creative use of evidence-based design. We envision a future where healing environments are recognized as a vital part of therapeutic treatment and where the design of healthcare settings contributes to health and does not add to the burden of stress.

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Abstract

**Objective:** The purpose of this paper is to examine how different aspects of sound—noise, speech privacy, speech intelligibility, and music—impact patient and staff outcomes in healthcare settings and the specific environmental design strategies that can be used to improve the acoustical environment of healthcare settings.

**Methods:** This paper provides a literature review of peer-reviewed journal articles, research reports, and books published in medicine, psychology, architecture, and acoustics publications. Keywords used to search for articles included noise in hospitals, reverberation, sleep, patient privacy, HIPAA, speech intelligibility, speech security, and music.

**Key findings:** Hospitals are extremely noisy, and noise levels in most hospitals far exceed recommended guidelines. The high ambient noise levels, as well as peak noise levels in hospitals, have serious impacts on patient and staff outcomes ranging from sleep loss and elevated blood pressure among patients to emotional exhaustion and burnout among staff. Poorly designed acoustical environments can pose a serious threat to patient confidentiality if private conversations between patients and staff or between staff members can be overheard by unintended listeners. At the same time, a poor acoustical environment impedes effective communication between patients and staff and between staff members by rendering speech and auditory signals less intelligible or detectable. This has serious implications for patient safety. A well-designed acoustical environment is critical in addressing these problems related to noise and communication of information. Noise levels can be effectively reduced by providing single-patient bedrooms, installing high-performance sound-absorbing acoustical ceiling tiles, and removing or reducing loud noise sources on hospital units. Also, acoustical ceiling tiles improve speech intelligibility by reducing sound reverberation and increase speech privacy by reducing sound propagation into adjoining areas. Another measure for increasing patient confidentiality is providing private rooms enclosed with walls that go up to the ceiling, thereby preventing voice travel through ceilings in spaces where private patient information is likely to be shared. A large body of research also shows that music therapy is effective in reducing anxiety and distress among patients in many different types of healthcare settings.

**Conclusions:** Sound control is critically important in healthcare settings, and different environmental design strategies have proven successful in mitigating negative effects of noise while allowing effective yet private verbal communication.
Introduction

Sound, in its different manifestations, can have profound impacts on patients, staff, and visitors in hospitals—ranging from soothing and therapeutic to stressful and disturbing. It is well-established that most hospitals are extremely noisy, well-exceeding recommended guidelines for noise levels (Busch-Vishniac et al. 2005). Noise, which is widely defined in the research literature as “unwanted sound,” can be detrimental to patient and staff health. Another aspect of sound—speech intelligibility and audibility—is essential to communication between patients and staff and between staff members in hospitals. On the other hand, if confidential patient information being discussed between patient and staff members or between staff members is overheard by others, it can pose a serious breach of patient confidentiality, and issues of speech security and speech privacy come to the fore. These different aspects of sound, ranging from stressful noise to pleasant music and speech intelligibility to speech privacy, suggest the importance of designing and controlling the environment to prevent the transmission of unwanted sound yet maximize speech intelligibility between persons who need to communicate with each other.

These issues associated with sound control and transmission are interrelated, and different environmental design strategies have proven successful in mitigating negative effects of noise while allowing effective verbal communication. The purpose of this paper is to examine how these different aspects of sound—noise, speech privacy, speech intelligibility, and music—impact patients and staff in healthcare settings and the specific environmental design strategies that can be used to improve the acoustical environment of healthcare settings.

Different aspects of sound that impact patients, staff, and visitors in hospitals:

- Noise
- Speech privacy
- Speech intelligibility
- Music

Noise in healthcare settings

There is a large body of literature that clearly spells out the problem that is pervasive in hospitals the world over—hospitals are extremely noisy. The World Health Organization (WHO) guideline values for continuous background noise in hospital patient rooms are 35 dB(A) during the day and 30 dB(A) at night, with nighttime peaks in wards not to exceed 40 dB(A) (Berglund et al. 1999). Busch-Vishniac and colleagues (2005) examined hospital noise levels reported in thirty-five published research studies over the last forty-five years. They found that not one published study reported noise levels that complied with the WHO guidelines for noise levels in hospitals.

Further, hospital noise levels have been rising consistently since the 1960s. The background noise levels in hospitals rose from 57 dB(A) in 1960 to 72 dB(A) today during daytime hours, and from 42 dB(A) in 1960 to 60 dB(A) today during nighttime hours (Busch-Vishniac et al. 2005). (Note that the decibel is a unit for quantifying sound pressure intensities or loudness levels based on a logarithmic scale. Therefore, a doubling of sound intensity would result in a 3 dB(A) increase in sound-pressure levels for diffuse sound fields. However, with respect to human hearing, a 10 dB(A) increase would be perceived as an approximate doubling of loudness. Accordingly, a 60 dB(A) sound is perceived as roughly four times as loud as a 40 dB(A) sound, despite having a pressure level 100 times higher.)

Further, many studies indicate that peak hospital noise levels often exceed 85 dB(A) to 90 dB(A) (Aaron et al. 1996; Balogh et al. 1993; Blomkvist et al. 2005; Cureton-Lane and Fontaine 1997; Guimaraes et al. 1996; Holmberg and Coon 1999; Kent et al. 2002; Tijunelis, Fitzsullivan, and Henderson 2005). Noises from alarms and certain equipment that exceed 90 dB(A) (for example, portable X-ray machine) are comparable to walking next to a busy highway when a motorcycle or large truck passes. Federal workplace
safety standards list 85 dB(A) as the safe maximum level of noise exposure for an eight-hour shift without ear protection (National Institute for Occupational Safety and Health 1998). Another way of characterizing the extraordinary loudness of common hospital sounds is to consider that an 85 dB(A) noise is 100,000 times higher in sound pressure than the recommended daytime level of 35 dB(A) for patient spaces. It is not surprising that high noise levels in hospitals have serious implications for staff and patient health and well-being.

**Impacts of noise on patients**

Considerable research has been conducted on the negative impacts of noise on patients and staff in hospitals. In addition to being a source of annoyance, loud noises in hospitals have been linked to sleep disturbance and arousals among patients. Studies conducted among neonatal intensive care (NICU) patients (Strauch, Brandt, and Edwards-Beckett 1993), pediatric and adult patients (Schnelle et al. 1993; Aaron et al. 1996; Parthasarathy and Tobin 2004; Freedman et al. 2001) have identified noise as the source of awakenings and sleep disruptions among patients. However, along with noise, other factors such as patient-care routines also contribute to sleep disturbance among patients and must be addressed as part of a comprehensive intervention to improve sleep (Freedman et al. 2001; Gabor et al. 2003).

Quiet time is especially important in NICU environments where loud noise levels decrease oxygen saturation (increasing need for oxygen support therapy), elevate blood pressure, increase heart and respiration rate, and worsen sleep (Slevin et al. 2000; Johnson 2001; Zahr and de Traversay 1995). There is some evidence that noise negatively impacts wound healing. In one study, patients stayed longer in the hospital after a cataract surgery during a period when noise levels were higher due to construction (Fife and Rappaport 1976). Also, Minckley (1968) found that when noise levels were high (more than 60 dB(A)), more medications were required by surgery patients post recovery.

A recent study in Sweden assessed the impact of modifying room acoustics (by switching between sound-absorbing ceiling tiles and sound-reflecting ceiling tiles) of an intensive coronary-care unit (CCU) on patient and staff outcomes (Hagerman et al. 2005; Blomkvist et al. 2005). During the good acoustical conditions (when sound-absorbing ceiling tiles were installed), pulse amplitudes were lower among patients in the acute myocardial infarction groups and unstable angina pectoris groups as compared to the bad acoustical conditions (when sound-reflecting ceiling tiles were installed). Patients were also more satisfied with the care provided by the staff during the good acoustic condition (Hagerman et al. 2005). Importantly, the incidence of rehospitalization was higher among patients treated during the bad acoustic conditions.

**Impacts of noise on staff**

Noise can be a source of stress for hospital staff and may interfere with their ability to work effectively. In the Swedish study on the impact of room acoustics, the researchers found that, during better acoustical conditions, staff experienced less work demands and reported less pressure and strain (Blomkvist et
Topf and Dillon (1988) found that noise-induced stress was related to emotional exhaustion and burnout among critical-care nurses. Morrison et al. (2003) found that noise was strongly related to stress and annoyance among nurses. In another study, healthcare staff perceived that the excessively high noise levels in the workplace interfered with their work and also impacted patient comfort and recovery (Bayo, Garcia, and Garcia 1995).

Little research has examined the impact of noise on healthcare staff performance, and the results are conflicting. Laboratory studies of non-healthcare groups have found that noise often does not impair task performance when there is incentive to increase effort or pressure to maintain exacting standards. The laboratory findings suggest that adequate performance during noise is maintained by increasing effort, as evidenced by heightened cardiovascular responding and other physiological mobilization (Parsons and Hartig 2000). The research implies the possibility that healthcare staff may be able to maintain exacting performance during some noisy situations, but at the cost of exerting greater effort and becoming more fatigued.

A few studies have examined work performance by anaesthetists and surgeons under different sound conditions (e.g., quiet versus simulated noisy conditions) and found that noise did not significantly worsen performance (Moorthy et al. 2004; Hawksworth, Sivalingam, and Asbury 1998). However, one study found that short-term memory and mental efficiency declined among anaesthetists working under typical operating room noise conditions (noise levels over 77 dB(A)) (Murthy et al. 1995). The investigators found that, under these conditions, the threshold level for speech reception increased by 25 percent suggesting that speech communication was possible only by raising one’s voice and, at the same time, speech discrimination reduced by 23 percent (Murthy et al. 1995). Clearly, such conditions may impact errors by hospital staff and have serious implications for patient safety.

**Impacts of high noise levels on staff:**
- Increased perceived work pressure, stress, and annoyance
- Increased fatigue
- Emotional exhaustion and burnout
- Difficulty in communication possibly leading to errors

**Why are hospitals noisy?**

There are two main reasons why hospitals are noisy. First, there are many noise sources present, and, second, environmental surfaces in hospitals—walls, floor, and ceiling—tend to be sound-reflecting rather than sound-absorbing (Ulrich et al. 2004; Ulrich 2003). Sounds contributing to the loud noise levels in hospitals come from mechanical equipment in use—alarms, paging systems, telephones, computer printers, ice machines, staff conversations, and noises generated by roommates and visitors. Many studies have found that staff conversation in particular is a major source of loud noises on the hospital unit (Allaouchiche et al. 2002; Bentley, Murphy, and Dudley 1977; Bayo, Garcia, and Garcia 1995).

The presence of hard sound-reflecting surfaces in the hospital tends to aggravate the noise problem in hospitals. Sound-reflecting surfaces cause noise to propagate considerable distances, traveling down corridors and into patient rooms, and adversely affecting patients and staff over larger areas (Ulrich 2003). Sound-reflecting surfaces typical of hospitals cause sounds to echo, overlap, and linger or have long reverberation times (Cole, Blomkvist, and Ulrich 2005; Blomkvist et al. 2005). Reverberation is the persistence of sound in an enclosed space, resulting from multiple reflections after a sound source has stopped. The reverberation time of a room is the time it takes for

**Why are hospitals noisy?**
- There are many loud noise sources present in hospitals.
- Sound-reflecting rather than sound-absorbing environmental surfaces cause sounds to have long reverberation times.
sound to decay by 60 dB(A) once the source of sound has stopped and is largely determined by the presence of sound-absorbing materials in the room (Joint Subcommittee on Speech Privacy of the Acoustical Society of America, Technical Committees for Architectural Acoustics and Noise; Institute of Noise Control Engineering; and National Council of Acoustical Consultants 2006). Extensive use of sound-absorbing material will mean that the sound is absorbed and, thus, prevented from “building up” (Cole, Blomkvist, and Ulrich 2005). When acoustic conditions are characterized by long reverberation times, echoes will cause blending and overlapping of sounds, resulting in reduced speech intelligibility. To make themselves heard, staff members then need to raise their voices, thereby compounding the noise problem even further.

Environmental strategies to reduce noise in hospitals

A combination of environmental interventions might be effective in reducing noise levels on hospital units:

- Install sound-absorbing ceiling tiles.
- Design all single-bed rooms.
- Eliminate or reduce noise sources such as overhead paging systems and staff conversations.

Research suggests that environmental interventions may be effective in reducing the noise levels in hospitals and improving the acoustical environment. Key interventions include installing high-performance sound-absorbing ceiling tiles, eliminating or reducing noise sources (for example, adopting a noiseless paging system), and providing single-bed rather than multibed rooms (Ulrich 2003).

Sound-absorbing ceiling tiles

At least three studies have shown that installing high-performance sound-absorbing ceiling tiles and panels results in reduced noise levels and perceptions of noise and impacts other outcomes such as improved speech intelligibility and reduced perceived work pressure among staff (Berens and Weigle 1996; Blomkvist et al. 2005; MacLeod et al. 2006; Hagerman et al. 2005). Though decibel levels were not greatly reduced as a result of the ceiling-tile intervention in these studies (reduction of 3 to 6 dB(A)), reverberation times and sound propagation were significantly reduced. This impacted the perception of the unit being less noisy and also improved speech intelligibility, which has implications for staff communication (Blomkvist et al. 2005; MacLeod et al. 2006).

Single-bed rooms

Single-bed rooms are probably the single most-effective strategy for reducing noise levels in patient rooms. Studies of multibed rooms in acute-care and intensive-care units have shown that most noises stem from the presence of another patient (staff talking, staff caring for other patients, equipment, visitors, patient sounds such as coughing, crying out, rattling bed rails) (Yinnon et al. 1992; Southwell and Wistow 1995; Baker 1984; Bailey and Timmons 2005). Bailey and Timmons (2005) found that noise levels increased significantly on a seven-bedded pediatric intensive-care unit when there were more people present on the unit (patients and staff). A study of multibed bays in a children’s hospital concluded that noise levels were so high that consideration should be given to abolishing open bay rooms (Couper et al. 1994).

Further, patient satisfaction data provided for this report by Press Ganey (2006) unequivocally shows that patients in single-bed rooms, compared to those with a roommate, are vastly more satisfied with the “noise levels in and around your room.” The satisfaction data were received from 577,787 patients in 1,363 healthcare facilities across the United States (Press Ganey 2006). Satisfaction with noise level was 15.1 percent higher on average nationally in single rooms than doubles. The higher reported satisfaction with single rooms was evident even when other patient characteristics—gender, age, length of stay, and whether it was the patient’s first stay or not—were considered (Press Ganey 2006).
Eliminating or reducing noise sources

Several studies identify overhead paging systems, equipment, and loud staff conversations to be the source of loud noises on hospital units (Buelow 2001; Baker 1984; Johnson and Thornhill 2006; Kahn et al. 1998). Recommendations for reducing noise levels often include replacing overhead paging with cell phones or wireless communication devices carried by staff, removing the sources of loud noises such as ice machines from the unit, turning off equipment when not in use, conducting group conversations in an enclosed space, and educating staff about the importance of talking quietly and maintaining a quiet environment (Bailey and Timmons 2005; Buelow 2001; Baevsky, Lu, and Smithline 2000).

More healthcare facilities are incorporating wireless systems for communication. However, it is not clear whether this intervention is successful in reducing noise levels. In an emergency department, a shift from overhead paging to a personal wireless communication network was not effective in reducing noise levels (Baevsky, Lu, and Smithline 2000). However, another facility was successful in reducing the number of overhead pages (a source of noise) by more than 50 percent within two years after shifting from an interdepartmental paging system to a wireless communication network (Johnson and Thornhill 2006). Staff education programs and quiet hours (nondisturbance periods) have been somewhat successful in reducing noise levels and improving patient outcomes such as sleep, though it is not clear whether the results are sustained in the long run. (Strauch, Brandt, and Edwards-Beckett 1993; Kahn et al. 1998; Elander and Hellstrom 1995; Monsen and Edell-Gustafsson 2005).

A combination of environmental interventions (such as private rooms, sound-absorbing ceiling tiles and soft flooring) and education programs are likely to be most effective in reducing noise levels and creating better acoustic conditions for patients and staff in healthcare settings.

Speech privacy and patient confidentiality

In many hospitals and outpatient physicians’ offices, patients are frequently exposed to situations where they overhear conversations with or about other patients, or worse, have their private information communicated in an open environment where it can be heard by themselves and others. Clearly, such experiences are likely to impact patient trust and their ability to discuss their health problems freely with their physicians (Barlas et al. 2001). The seriousness of the problem is underscored, for example, by a study of an emergency department where 5 percent of the patients examined in curtained spaces reported withholding portions of their private history and refused parts of their physical examination because of lack of privacy (Barlas et al. 2001). This can have serious implications for patient safety. In the last decade, concerns regarding protecting patient confidentiality have come to the fore and the Health Information Portability and Accountability Act (HIPAA) of 1996 has further elevated the importance of providing reasonable safeguards to protect the confidentiality of patient information (United States Department of Health and Human Services, Office for Civil Rights, 2003). The HIPAA law mandates that all individually identifiable patient health information be kept private and...
this includes privacy of information communicated orally. Thus, it is critical that private conversations with or about a patient are not overheard.

Speech privacy refers to how well a private conversation can be overheard by an unintended listener, and the level of speech privacy achieved in a space is indicated by a privacy index (PI) (Armstrong Ceiling Systems 2003). This is expressed as a percentage and takes into account the acoustical performance of all finishes—ceiling, floors, partitions, and furniture—in the space. The commonly recognized levels of speech privacy are:

- Confidential (PI rating of 95 percent to 100 percent, conversations conducted within the space may be partially overheard but not understood outside the confines of the space)
- Normal (PI rating of 80 percent to 95 percent, conversations may be overheard but are only partially intelligible)
- Marginal or poor (PI rating of 60 percent to 80 percent, most conversations will be overheard and intelligible to unintended listeners)
- No privacy (PI rating less than 60 percent, all conversations can be fully overheard and understood) (Armstrong Ceiling Systems, 2003)

The new *Interim Sound and Vibration Guidelines for Hospitals and Healthcare Facilities* (Joint Subcommittee on Speech Privacy of the Acoustical Society of America, Technical Committees for Architectural Acoustics and Noise; Institute of Noise Control Engineering; and National Council of Acoustical Consultants 2006) recommends that normal speech privacy be provided between enclosed rooms and confidential speech privacy in admitting areas, areas where patients discuss their personal health, psychiatric and psychological testing rooms, hematology labs, exam rooms, etc.

The design of the physical environment clearly impacts patient confidentiality and speech privacy in healthcare settings, though few studies have focused on the role of unit design or architecture. Two studies compared visual and auditory privacy of emergency department patients assigned to either multibed spaces with curtain partitions or rooms with solid walls (Mlinek and Pierce 1997; Barlas et al. 2001). The studies showed that more breaches of patient confidentiality and privacy occurred in the multibed spaces with curtain partitions (Mlinek and Pierce 1997), and patients examined in such spaces were more likely to withhold information because they experienced a lack of auditory and visual privacy as compared to patients in rooms with walls (Barlas et al. 2001). While the unit design and layout often pose obvious difficulties in maintaining privacy, the carelessness of staff in communicating with patients and other staff members compounds the problem. In one study, researchers found that physicians and other hospital staff made inappropriate comments during 14 percent of public elevator trips, of which a large proportion represented patient confidentiality breaches (Ubel, Zell, and Miller 1995).

There are many spaces in healthcare settings where private conversations or information is exchanged and often easily overheard by others. Some examples of the typical difficulties posed by unit design and layout to ensuring patient confidentiality in healthcare settings include:

- Inadequate private discussion spaces in public areas such as admission areas, reception areas, and waiting rooms where private information may be discussed.
- Physical proximity between staff and visitors in admission areas and poorly designed reception areas such that telephone conversations and discussions may be overheard.
- Multioccupancy rooms where discussions with one patient can easily be overheard by other patients and their families.
• Open-plan examination areas with curtained cubicles (instead of walls), which offer little visual or auditory privacy.

• Walls in enclosed offices stop at the ceiling and do not go up all the way up to the deck allowing for sound leaks through the ceiling to adjoining enclosed spaces.

• Nonabsorbing ceilings that cause sound to reflect from one space to another as well as allows sound from one room to pass into the plenum and get transmitted down into another room.

• Inadequate private discussion rooms on patient units for physicians to conduct meetings with families.

Clearly, architectural design solutions could begin to address some of the obvious failings of healthcare settings in terms of preserving patient confidentiality. One design solution that is strongly supported by research is to provide single-patient rooms or rooms enclosed with walls in examination and treatment areas where patients would be required to disclose confidential health information (Barlas et al. 2001; Mlinek and Pierce 1997; Ulrich et al. 2004). Ulrich and colleagues (2004) reported patient satisfaction data from Press Ganey (2003) that clearly showed that patients in single-bed rooms, compared to those with a roommate, were consistently more satisfied with “concern for your privacy.” The satisfaction data were obtained from 2,122,439 patients who received care during 2003 in 1,462 healthcare facilities (Press Ganey 2003). Satisfaction with privacy was 4.5 percent higher on average nationally in single rooms than doubles—a substantial difference considering that it can be difficult for hospitals to increase satisfaction scores by even 1 percent to 2 percent (Ulrich et al. 2004). A survey study of staff in four West Coast hospitals found that nurses overwhelmingly judged single rooms to be superior to double rooms for examining a patient (85 percent) and for collecting a patient’s history (82 percent) (Chaudhury, Mahmood, and Valente 2006).

A third strategy that is sometimes recommended by ceiling systems manufacturers and others to improve speech privacy is to use sound masking, which is “the precise application of electronic background sound that blends into the environment to cover up or mask unwanted noise” (Armstrong Ceiling Systems 2003). This strategy has proven effective in open-plan commercial office environments in providing speech privacy. However, there is a lack of research demonstrating the effects and appropriateness of this intervention in healthcare settings. Given the fact that effective healthcare work requires being able to comprehend and respond to many different types of auditory stimuli—alarms, dictation, spoken communication—overhead sound systems that render speech less intelligible over short distances conceivably might negatively impact the quality and accuracy of communication.

Other key recommendations for increasing speech privacy in healthcare settings include (Armstrong Ceiling Systems 2003):

• Use a high-performance acoustical ceiling to absorb sounds that would otherwise bounce off the ceiling into nearby spaces or cubicles.

• Block sound transmission between spaces by a combination of high-performance ceilings and effective wall and furniture design and layout.
that are essential in healthcare settings. The effects of sound masking on intelligibility and speech recognition errors between staff, and between staff and patient, should be carefully researched and clarified before widely incorporating such systems.

The environment clearly plays an important role in promoting patient privacy and confidentiality. There is a definite need for additional studies to examine the impact of different types of room and unit layout and finishes on privacy and confidentiality breaches in patient rooms, unit hallways, nursing stations, reception areas, and waiting rooms in healthcare settings.

**Speech intelligibility**

Speech intelligibility and speech privacy are very much related, though the goal is often to maximize speech intelligibility between people who need to communicate with each other (e.g., hospital staff, hospital staff and patients) and to minimize the audibility and intelligibility of their conversation (i.e., achieve speech privacy) to unintended listeners. As mentioned earlier, the issue of speech intelligibility assumes great importance in healthcare settings, more so than in other settings such as offices, because nurses and physicians are required to constantly comprehend and act on many types of auditory information in a high-paced stressful environment.

Further, the move toward a digital hospital requires the automation of many hospital operations, and this requires use of speech-recognition systems. While normal-hearing individuals are well-adapted to detecting speech signals embedded in noise (even when signal-to-noise ratios are as low as -6 dB(A)), automated speech recognition systems require a signal-to-noise ratio of +15 dB(A) to ensure correct interpretation of the signal (Busch-Vishniac et al. 2005). A poor acoustic environment may well lead to many errors in automatic transcription of doctors’ spoken notes, automatic dispensing of pharmaceuticals, etc. (Busch-Vishniac et al. 2005).

Ceiling sound-masking systems (mentioned earlier) that are effective in commercial open-plan office environments for increasing speech privacy have not been subjected to thorough research evaluation in healthcare settings such as nurses’ stations where staff are constantly on the move and not likely to stay within a limited physical boundary.

Research is needed to rule out the possibility that masking sounds and speech may erode intelligibility and increase risk for errors in certain healthcare situations.

As described earlier, hard reflecting surfaces cause sounds to echo and linger in spaces and have long reverberation time. This is an important factor that is linked with speech intelligibility. Research shows that installing high-performance sound-absorbing ceiling tiles is highly effective in reducing reverberation times. In the Swedish study by Blomkvist and colleagues (2005), during the period of longer reverberation time (when sound-reflecting ceiling tiles were installed on the CCU), speech intelligibility was thought to be below what was needed on the CCU. When sound-absorbing ceiling tiles were installed, reverberation times decreased and speech intelligibility improved (Blomkvist et al. 2005). Also, patients treated in the unit during the good acoustics period rated the staff attitude higher as compared to patients treated during the poor acoustics period (Hagerman et al. 2005).

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**Why is speech intelligibility critical in healthcare settings?**

- Staff needs to comprehend and act upon many types of auditory information.
- Speech recognition systems, which are critical for the functioning of a digital hospital, cannot interpret sound signals in a poor acoustic environments.
- Poor acoustical environments make it difficult to understand healthcare staff and patients with different languages, accents, and speech patterns.

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- Poor acoustical environments make it difficult to understand healthcare staff and patients with different languages, accents, and speech patterns.
Installing sound-absorbing ceiling tiles and other finishes is critical to reducing reverberation times and improving speech intelligibility in healthcare settings. In addition, single rooms with walls that go up to the ceiling should be provided in areas where private communication between patients and staff is intended to occur (such as inpatient, examination, and treatment rooms) to minimize noise intrusion from outside the room and to enhance speech privacy.

**Impact of music**

Music is defined as a complex of expressively organized sounds composed of some key elements: rhythm, pitch, harmony, and melody. Research shows that certain types of music induce relaxation and positive responses, which reduce activity in the neuroendocrine and sympathetic nervous systems, resulting in decreased anxiety, heart rate, respiratory rate, and increased temperature (Lai et al. 2006). Music therapy, or the therapeutic use of music to promote health and well-being in patients, has been used in different settings including oncology, maternity, postoperative, intensive care, coronary care, and pediatric (Cooke, Chaboyer, and Hiratos 2005). The music preferences of individual patients is an important factor in the effect of music on patients, as not all people are likely to prefer the same types of music due to differences in age, culture, and peer group (Lee et al. 2005). Generally, sedative music that is suitable for music intervention tends to have no accented beats, no percussive characteristics, a slow tempo, and smooth melody (Chlan 2000).

**Impact of music on patients:**
- Decreased anxiety and distress
- Decreased heart rate
- Decreased respiratory rate
- Higher level of satisfaction with experience

**Music selection for music therapy:**
- Music should ideally be selected by patients based on their preferences.
- Generally, sedative music used for music therapy tends to have no accented beats, no percussive characteristics, a slow tempo, and smooth melody.

Music therapy is the therapeutic use of music to promote health and well-being in patients. It has proven highly effective in different settings including oncology, maternity, postoperative, intensive care, coronary care, and pediatric. Studies have shown that listening to music is beneficial to patients undergoing painful procedures. For example, studies that examined the effect of listening to music among mechanically ventilated patients in an intensive-care unit found that relaxing music reduces subjective states of anxiety and emotional disturbance as well as physiological outcomes such as heart rate and respiratory rate (Chlan et al. 2001; Chlan 2000; Lee et al. 2005).

In one study, patients were randomly assigned to either listen to thirty minutes of music (patients selected from given music options) through headphones or a rest period with no music (Lee et al. 2005). The heart rate, respiratory rate, systolic blood pressure, and diastolic blood pressure reduced among the patients who underwent the music intervention while there was no difference in physiological measures in patients in the control group (no music) (Lee et al. 2005).

A similar study conducted among women undergoing Caesarean delivery found that the women who listened to music during the delivery had lower anxiety and a higher level of satisfaction regarding the experience (Chang and Chen 2005). Other studies have found that listening to music reduces anxiety among mothers providing care to preterm infants in the NICU (Lai et al. 2006) and reduces acute postoperative confusion and delirium among elderly patients undergoing elective hip and knee surgery (McCaffrey and Locsin 2004).
Research also shows that listening to individualized music (based on personal preferences) is effective in decreasing behavioral problems and agitation among dementia patients (Goodall and Etters 2005). Studies conducted among children have found that recorded lullabies were an effective distraction in reducing overall distress in children receiving routine immunizations (Malone 1996; Megel, Houser, and Gleaves 1998).

Cooke and colleagues (2005) reviewed twelve experimental studies that examined the impact of music on reducing anxiety and other outcomes among patients while waiting in ambulatory-care settings such as in a day surgery. In all studies, patients who listened to music experienced less anxiety. The authors conclude that music as a simple and cost-effective intervention to reduce anxiety experienced in limited time periods has strong positive implications for clinical practices where patients wait before undergoing invasive investigations, procedures, or surgery (Cooke, Chaboyer, and Hiratos 2005).

There is strong support for music therapy as an effective intervention for patients undergoing painful procedures or experiencing anxiety. In the studies examined here, patients either listened to music through headphones or from a nearby cassette player. Few studies were found that examined the effect of ambient music on patient anxiety or other outcomes. Also, no studies were found that examined the impact of music on staff and families. These are areas where future research is needed.

**Summary**

Sounds impacts patients and staff in many different ways. Unwanted sound or noise is a major problem in hospitals the world over. High noise levels negatively impact patient and staff health and well-being and may slow the process of healing among patients. On the other hand, certain types of music help to reduce anxiety and distress among patients. Poorly designed environments can result in private conversations between patients and staff or between staff members being overheard by unintended listeners, resulting in unacceptable breaches of confidentiality. At the same time, a poor acoustical environment impedes effective communication by rendering speech and auditory signals less intelligible. This has serious implications for patient safety.

Much evidence shows that improving the acoustical environment in hospitals by carefully considering design factors can go a long way toward reducing noise, improving speech intelligibility, as well as increasing patient confidentiality. Key design considerations include:

- Providing single-patient rooms— compared to multibed rooms, private rooms are less noisy, are perceived by patients as being more private, and permit more effective and confidential communication between staff and patients.
- Installing high-performance sound-absorbing acoustical ceiling tiles results in shorter reverberation times, reduced sound propagation, and improved speech intelligibility. Also, this design measure increases speech privacy as less sound travels into adjoining spaces.
- Removing or reducing loud noise sources on hospital units and educating staff about the impact of noise on patients as well as themselves is effective in reducing noise levels.
- Providing patient examination rooms and treatment areas with walls that extend fully to the support ceiling will prevent voice and noise carrying through ceilings.
References


Press Ganey Inc. 2006. National satisfaction data for 2006 assessing satisfaction with noise levels in and around room. Provided by Press Ganey Inc. for this research report at the request of the authors.


**Notes**

Noise levels are measured using the A-weighted sound level, which represents the filtering of sound that replicates the human hearing response. This is the most commonly used descriptor to quantify the relative loudness of various types of sounds with similar or differing frequency characteristics.
Health Promotion by Design in Long-Term Care Settings

Anjali Joseph, Ph.D., Director of Research, The Center for Health Design

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The Center for Health Design (CHD) is a nonprofit research and advocacy organization whose mission is to transform healthcare settings into healing environments that improve outcomes through the creative use of evidence-based design. CHD envisions a future where healing environments are recognized as a vital part of therapeutic treatment and where the design of healthcare settings contributes to health and does not add to the burden of stress.
Abstract

Objective: To assess the relationship between physical environmental factors and resident and staff outcomes in different types of long-term-care settings.

Methods: Literature review of more than 250 peer reviewed journal articles published in different fields such as gerontology, architecture, nursing, psychology, and psychiatry. Key words used to access databases included long-term care, physical environment, homelike environment, elderly, falls, sleep, depression, quality of life, dementia, and safety.

Key Findings: The physical environment impacts outcomes among patients, their family, and staff in three main areas: (a) resident quality of life, (b) resident safety, and (c) staff stress. Several studies show that different aspects of the physical environment—such as the unit layout, supportive features and finishes, reduced noise, as well as access to outdoor spaces—may be linked to better outcomes, including improved sleep, better orientation and wayfinding, reduced aggression and disruptive behavior, increased social interaction, and increased overall satisfaction and well-being. Further, a growing body of research suggests that the environment should not only support functional abilities, but also provide opportunities for residents to be physically active and healthy. The environment can increase safety among residents by removing barriers to ambulation and performance of critical tasks and by preventing infections and unsafe behaviors such as exiting. Studies also show that if supports for work (such as ceiling lifts) are incorporated within a long-term care setting, it results in greater satisfaction, morale, and fewer work-related injuries. Design enhancements, such as a homelike ambience, are also linked to higher satisfaction among nurses.

Conclusions: The design of the physical environment impacts resident and staff outcomes in long-term care settings and contributes to a better quality of life for those who live and work in and visit these facilities.
Introduction

The prevalence of chronic conditions is projected to increase dramatically with the aging of the population. In fact, by year 2030, nearly 150 million Americans will have a chronic condition. Consequently, the need for quality long-term care will also increase in the years to come. The physical environment is an integral component of the care provided in long-term care settings. It is critical, therefore, to carefully assess how long-term care environments can be designed to promote health and well-being among this growing population.

Long-term care refers to any personal care or assistance that an individual might receive on a long-term basis because of a disability or chronic illness that limits his or her ability to function (Kane, 2001). Long-term care may be provided in a range of settings such as an individual’s home and residential, assisted-living, nursing-care, or rehabilitation facilities. In some settings, individuals may spend short periods of time (90 days or less) for rehabilitation before returning to the community. In other settings, individuals stay for much longer periods of time, often to their last days. The term resident rather than patient is more commonly used while referring to individuals residing in long-term care settings. Most individuals receiving long-term care suffer from some chronic illness, and the focus of care is usually on supporting and maintaining health status rather than curing. While all different types of individuals (young and old) might use long-term care services, the overall utilization of long-term care services and products is much higher among older adults (Shi & Singh, 2001).

This report assesses the state of the science linking the physical environment with resident and staff outcomes in long-term care settings. As mentioned earlier, older adults are the main recipients of long-term care. This report primarily focuses on the impact of the physical environment on elderly residents, their families, and staff in long-term care settings in three areas: (a) resident quality of life, (b) resident safety, and (c) staff stress.

This report presents findings from more than 250 articles published in peer-reviewed journals that assess the relationship between physical environmental factors and resident and staff outcomes in different types of long-term care settings—skilled-nursing facilities, assisted-living settings, special-care units, and independent-living facilities. Some of the findings are relevant primarily to one type of setting, while others have wider applicability to different types of long-term care settings.

Resident quality of life

The care provided in long-term care facilities has traditionally been based on a medical model. This is characterized by nursing units with centralized nursing stations and long, doubly loaded corridors with shared bedrooms and bathrooms. Often, the finishes and ambiance are institutional and bare, and the setting provides few opportunities for residents to personalize their environments. Residents follow a rigid routine that dictates when they eat and when they sleep. In such situations, residents have few choices, resulting in a loss of dignity and sense of self. The focus is on the treatment or the medical care provided, rather than the individual who is receiving the care. Such environments harm more often than they heal.

Enhancing the quality of life of residents in long-term care settings is as important a goal as improving the quality of care and the safety and health of residents (Kane, 2001). Several stud-
ies show that different aspects of the physical environment—such as the unit layout, supportive features and finishes, reduced noise, as well as access to outdoor spaces—may be linked to better outcomes, including improved sleep, better orientation and wayfinding, reduced aggression and disruptive behavior, increased social interaction and increased overall satisfaction and well-being. Further, a growing body of research suggests that the environment should not only support functional abilities, but also provide opportunities for residents to be physically active and healthy.

**Improve sleep**

Insomnia or disturbed sleep is a common complaint of older people, and studies show that 50% of individuals living in the community and 70% of individuals living in a long-term care setting are affected by it (Johnston, 1994). Further, research shows that daytime sleepiness, nighttime insomnia, and sleep disturbance are associated with increased mortality among institutionalized elderly (Dale, Burns, & Panter, 2001). The causes for sleep disturbance among the elderly include medical and geriatric factors as well as behavioral and environmental factors. Environmental factors that contribute to sleep disturbance among the elderly in nursing home include:

- Limited sunlight exposure (Alessi, Martin, Webber, & Kim, 2005).
- Large amounts of time spent in bed (Alessi, et al., 2005).
- Lack of physical activity (Alessi, et al., 2005).
- Nighttime noise (Alessi, et al., 2005; Cruise, Schnelle, Alessi, Simmons, & Ouslander, 1998; Ersser et al., 1999).
- Light (Cruise, et al., 1998).
- Incontinence care routines (Cruise, et al., 1998).

According to Rahman and Schnelle (2002), simple interventions can address environmental factors that disturb sleep in the nursing home. These include individualizing nighttime incontinence-care routines, implementing a noise-abatement program, and sensitizing and educating staff about the importance of uninterrupted sleep for residents. However, studies assessing the effect of such multicomponent interventions on nighttime sleep on nursing-home residents have had variable and inconsistent results (Ouslander, J. G., Connell, B., Bliwise, D. L., Endeshaw, Y., Griffiths, P., & Schnelle, J. F., 2006). For example, in a randomized controlled trial, sleep-disturbed nursing-home residents from four different nursing homes were exposed to an intervention that included efforts to decrease time spent in bed during the day, 30 minutes or more of daylight exposure, increased physical activity, structured bedtime routine, and efforts to decrease nighttime noise and light (Ouslander et al., 2006). This study did not find any significant effect of the intervention on overall nighttime sleep or number of night awakenings (Ouslander et al., 2006). However, there was a decrease in daytime sleeping and increased participation in social and physical activities and social conversation.

On the other hand, a small number of studies have found that timed exposure to artificial bright light might be helpful in improving sleep and circadian rhythms. In one study, community-dwelling older adults exposed to either bright white light or dim red light on 12 consecutive days experienced substantial changes in sleep quality (Campbell, Dawson, & Anderson, 1993). Waking
time within sleep was reduced by an hour, and sleep efficiency improved from 77.5% to 90%, without altering time spent in bed (Campbell, et al., 1993). Two other studies showed that exposure to evening bright light was related to improved rest activity rhythms among persons with dementia in nursing homes (Satlin, Volicer, Ross, Herz, & Campbell, 1992; Van Someren, Kessler, Mirmiran, & Swaab, 1997).

Support orientation and wayfinding

Spatial skills decline with age, and the average institutional resident has difficulty maintaining spatial orientation within the typical institution (Rule, Milke, & Dobbs, 1992). Herman and Bruce (1981) found that, although elderly nursing-home residents accurately recognized and placed locations along the central corridor, their accuracy decreased substantially with distance from it. Characteristics of residential institutions that contribute to confusion and disorientation include:

- Monotony of architectural composition and lack of reference points (Passini, Pigot, Rainville, & Tetreault, 2000).
- Lack of windows or lack of access to windows (Rule, et al., 1992).

These issues can be easily addressed in the design of institutions. Also, attention should be paid to locating culturally relevant landmarks in key locations to support wayfinding and orientation.

Designing to promote spatial orientation and wayfinding are critical in environments for persons with dementia who commonly suffer from disorientation—confusion regarding place, time, personal identity, and social situation (Calkins, 2001; Cohen & Day, 1991; Day, Carreon, & Stump, 2000). In a review of empirical studies linking environments for persons with dementia and outcomes, Day and colleagues (2000) identified the following factors as being related to higher levels of orientation:

- Quiet environments.
- Use of room numbers and distinguishing colors for resident rooms and doors.
- Large signs or location maps supported by orientation training for residents (McGilton, Rivera, & Dawson, 2003).
- Use of significant memorabilia outside resident rooms (Nolan, Mathews, & Harrison, 2001).
- Simple building configuration aided by explicit environmental information (Residents experienced greater spatial orientation in facilities designed around L-, H-, or square-shaped corridors, compared with facilities with corridor designs).

Wayfinding was less successful among residents in facilities with low lighting in public areas (Netten, 1989). Passini and colleagues (2000) found that elevators were a major anxiety-causing barrier to wayfinding among demented residents. Also, signage was critical in compensating for loss of memory and spatial understanding. Floor patterns and dark lines or surfaces can disorient the person and cause anxiety (Passini, et al., 2000).
Reduce aggression and disruptive behavior

Disruptive behaviors are very prevalent in most long-term care facilities (Morgan & Stewart, 1998a). In most settings, the prevalence of agitated or disruptive behavior was higher among residents with dementia than nondemented residents. Environmental interventions can be effective in reducing agitated behaviors, especially among demented residents.

- **Unit size and ambiance**: Sloane and colleagues (1998) found that higher levels of agitation among residents in dementia special-care units was associated with the following environmental features: large unit size, poor scores on a rating of homeliness, poor scores in cleanliness of halls, poor maintenance of public areas and bathrooms, absence of nonglare nonslip floors, odors or urine in public areas and bathrooms, and absence of a family kitchen for activities and family use. Families of residents in large units perceived staff as being under time pressure and also perceived a reduced quality of life for residents (Pekkarinen, Sinervo, Perala, & Elova, 2004). Other studies have documented the impact of ward interior redesign on reduction in disruptive behaviors (Christenfeld, Wagner, Pastva, & Acrish, 1989; McGonagle & Allan, 2002).

- **Private rooms**: There is limited evidence that persons with dementia are less agitated in private rooms rather than shared rooms. When dementia residents moved from a multiple occupancy unit to a smaller unit with private rooms, residents slept better at night, there were fewer conflicts between residents, and less rummaging and loss of belongings. Also, the number of interventions to control aggressive behavior (medications) reduced during follow-up (Morgan & Stewart, 1998b).

- **Music (white noise)**: Other environmental interventions that have been successful in reducing verbal agitation among dementia residents include use of music (white noise) (Burgio, Scilley, Hardin, Hsu, & Yancey, 1996; Burgio et al., 1994; Goddard & Abraham, 1994). Goddard and Abraham (1994) found a 74.5% reduction in verbally agitated behaviors when relaxing music was played at a level of 65 to 69 dB (A) (over average noise level in dining room during meal time) in two units in two nursing homes with severely cognitively impaired residents. Loud noises, on the other hand, are associated with agitated behavior and disturbed sleep.

- **Light**: Sloane and colleagues (1998) found that residents in facilities with low light levels displayed higher agitation levels. La Garce (2002) studied the impact of environmental lighting interventions (full-spectrum lighting, microslatted glazed windows, and electronic controls to maintain a constant level of light intensity) on agitated behaviors among residents with Alzheimer’s disease. She found a significant drop in disruptive behaviors when residents were in the experimental setting rather than the control setting (LaGarce, 2002). Lovell and colleagues (1995) also found a reduction in agitated behavior among institutionalized elderly subjects when exposed to bright light. Exposure to bright light is also related to decrease in depression among institutionalized older adults (Sumaya, Rienzi, & Moss, 2001).

- **Access to outdoors**: Wandering (defined as extended periods of aimless or disoriented movement without full awareness of one’s behavior) is a major behavioral symptom of Alzheimer’s disease and related dementia. Historically, physical and chemical restraints
were used to deal with wanderers. This is no longer considered appropriate. The environment can be designed to provide positive outlets for residents who wander (Cohen-Mansfield & Werner, 1999; Namazi & Johnson, 1992). For example, providing access to safe outdoor spaces rather than completely blocking access to the outdoors may be an efficient strategy (Namazi, 1993; Namazi & Johnson, 1992). Mooney and Nicell (1992) found that violent episodes among residents decreased over time in facilities with outdoor environments, whereas violent episodes increased during the same time period in facilities without outdoor environments. Agitated behaviors among residents with Alzheimer’s disease reduced when doors to a secure outdoor garden were kept unlocked (Namazi & Johnson, 1992).

**Increase social interaction while providing privacy and control**

Many older adults in institutional settings may voluntarily withdraw from social interaction as an adaptation strategy (substitute for loss of privacy) or other factors may lead to involuntary reduction in social interaction (Rule, et al., 1992). There is a relationship between the degree of privacy and control (ability to control who you interact with and when you choose to do so) and participation in social behavior (Ittelson, Proshansky, & Rivlin, 1970; Pinet, 1999). Ittelson et al. (1970) introduced the concept of privacy/sharing to explain that residents from shared bedrooms lack privacy and feel less at home in their own bedrooms. Thus, residents in shared rooms are more likely to spend more time in social spaces to leave their roommate alone. Firestone and colleagues (1980) found that ward residents viewed their dwelling as less secure and felt less able to control social encounters than did single-room residents.

Pinet (1999) conducted a study among 50 nursing home residents to examine if the use of social spaces in a facility was related to the distance of residents’ bedroom from the space. She looked at the behavior of residents in private and shared rooms. She found that social spaces closest to resident rooms were used more often than spaces that were farther away. Also, residents walked farther to participate in activities than to visit nonactivity-related social spaces. Residents from shared bedrooms tended to traverse longer distances. Forty-four percent of the residents from semiprivate rooms reported going to social spaces when visitors came to visit them. Also, in homes with shared bedrooms, residents observed in social spaces were more withdrawn than in other homes.

These findings suggest the importance of providing single rooms so that residents can control the degree of privacy and social interaction. However, there are insufficient studies on the relative merits of private and shared rooms in long-term care environments.

Other factors that may be important in promoting use of social spaces in long-term care environments include views to activities and interesting focal points that generate conversation (Cohen & Day, 1991; Howell, 1980; Pinet, 1995; Regnier, 2002).

The size of the facility may be related to resident participation in social and other activities in a facility. Lemke and Moos (1989), in a study of 1,428 residents in 42 facilities, found that smaller size and scale of facility supports activity for moderate- to low-functioning residents, while younger independent residents are more active in a larger facility with a more challenging program.
There is strong evidence that placement of furniture in small flexible groupings in public spaces such as lounges and waiting areas can support social interaction. A few studies in psychiatric wards and nursing homes have found that appropriate arrangement of movable seating in dining areas enhances social interaction and also improves eating behaviors, such as increasing the amount of food consumed by geriatric residents (Melin & Gotestam, 1981; Peterson, Knapp, & Rosen, 1977). Much research on day rooms and waiting areas has shown that the widespread practice of arranging seating side by side along room walls inhibits social interaction (Holahan, 1972; Sommer & Ross, 1958). A study by Harris (2000) found that family and friends stayed substantially longer during visits to rehabilitation units when resident rooms were carpeted rather than covered with vinyl flooring.

**Promote quality of life by providing links to the familiar**

Many design guidelines endorse the importance of providing non-institutional or homelike design features to promote well-being among residents in institutional settings. The premise is that being in an environment that is more like the homes they left behind when they transitioned to long-term care would be more comforting for long-term care residents than one that is reminiscent of an institution. This is often interpreted in terms of residential architectural features, domestic furniture and finishes, use of artwork, natural elements, and personalized rooms. However, the concept of home is very subjective and different for every individual. A homelike environment is also one where residents have the opportunity to participate in activities that are familiar from their past lives (as opposed to rigid institutional routines) and in spaces that are similar in scale and form to those found in people’s homes (Day & Cohen, 2000; Lundgren, 2000).

Day and Cohen (2000) reported on studies conducted on the effect of non-institutional environments among residents with dementia. Such environments were related to different aspects of resident well-being such as:

- Improved intellectual and emotional well-being.
- Enhanced social interaction.
- Reduced agitation.
- Reduced trespassing and exit seeking.
- Greater preference and pleasure.
- Improved functionality.

Compared to residents in traditional (institutional) nursing homes and hospitals, those in non-institutional settings were less aggressive, able to preserve better motor functions, required lower dosage of tranquilizing drugs, and had less anxiety. Relatives reported greater satisfaction and less burden associated with non-institutional facilities (Annerstedt, 1997; Cohen-Mansfield & Werner, 1998).

Other studies have shown that a non-institutional dining-room atmosphere was related to increased food intake among dementia residents (Evans & Crogan, 2001; Melin & Gotestam, 1981; Reed, Zimmerman, Sloane, Williams, & Boustani, 2005). Most of these studies emphasize
the importance of staff support and staff culture in promoting a homelike non-institutional environment of care.

**Promote physical activity**

The benefits of physical activity for older people include prevention and treatment of chronic illnesses, a longer disability-free life expectancy, and better physiological and psychological health (Leveille, 1999; Miller, 2000; Shephard, 1997; United States Department of Health and Human Services, 1996). There is evidence from different fields that the environment influences participation in physical activity among older adults.

Factors such as perceived aesthetics of the neighborhood (Brownson et al., 2000), perceived safety of walking paths in the neighborhood (Carnegie et al., 2002), and convenient location and access to recreational facilities and shops (Brownson et al., 2000; Carnegie et al., 2002) were found to be associated with higher levels of walking among older adults. There are fewer studies that examine how the design of long-term care environments may support participation in physical activity among residents.

A survey of 800 not-for-profit continuing-care retirement communities (CCRC) looked at the relationship between building and site-level features on CCRC campuses and participation in different types of physical activity among residents. The findings from this study suggest that communities with more indoor and outdoor physical-activity facilities and amenities tend to have more residents participating in physical activity (Joseph, Zimring, Harris-Kojetin, & Kiefer, 2006 (in press)). Modest but significant associations were found between the presence of outdoor features such as courtyard gardens and covered outdoor paths and resident participation in walking clubs (Joseph, et al., 2006 (in press)). Also, more independent-living residents walked to meals on campuses that had covered connections between buildings.

In a recent study of path use for walking on CCRC campuses, Joseph (2006) found that independent active residents walked extensively both indoors and outdoors for recreation. Key aspects of the paths that were chosen by residents for recreation included path length, presence of steps in path, and location of path within the network of paths on campus. Residents used looped routes of different length and difficulty level for walking on campus according to their health and functional abilities (Joseph, 2006).

Many of the studies described in this paper were conducted in the context of the nursing home, which was the primary model of care for older adults until about 20 years ago. The concepts regarding improving the quality of life of residents have been applied in the development of new models of housing and care, such as assisted living, continuing care retirement communities (CCRC), and the Eden Alternative. These evolved in response to the need to improve the quality of life of residents and to provide care in a homelike residential environment where the patterns of living would more closely resemble those of a home than an institution.

Assisted living is defined as “a long term care alternative which involves the delivery of professionally managed personal and health care services in a group setting that is residential in character and appearance in ways that optimizes the physical and psychological independence of residents” (Regnier, 1994). Although the main component of assisted living involves personal care
help with ADLs, the overall philosophy is one of personal self-management. These facilities do not provide skilled nursing care. They are known by different names in different parts of the United States: Board and Care, Residential Care Facilities, Community Based Retirement Care Facilities, Personal Care, Adult Living Facilities, Adult Foster Care, etc. Therapeutic goals aimed at improving quality of life for residents require active support by physical and organizational aspects of the facility.

CCRCs are residential campuses that provide a continuum of care — from private units to assisted living and skilled nursing care — all in one location. CCRCs are designed to offer active seniors an independent lifestyle from the privacy of their homes, but also include the availability of services in an assisted living environment and onsite intermediate or skilled nursing care if necessary.

The Eden Alternative focuses on improving the quality of life of nursing home residents and creating a homelike setting by enabling residents to interact with pets, plants, and children and by empowering staff in bringing about these changes (Coleman, et al., 2002). The Green House Project is an offshoot of Eden Alternative (Thomas & Johansson, 2003). According to William Thomas, the founder of Eden Alternative, the Green House Project is “an attempt to design, build and test a radically new approach to residential long-term-care for the elderly” (Thomas & Johansson, 2003). The Green House is designed to be a home for eight to ten elders, which blends architecturally with its surroundings, is aesthetically appealing, and includes many outdoor spaces. Thus, it alters the facility size (much smaller scale than typical nursing facility), interior design (more homelike and residential), staffing patterns, and methods of delivering skilled professional services.

According to the founders, one of the key differences is that in the Green House, residents are not dictated by an institutional schedule, rather they perform daily activities (sleeping, eating, participating in activities) as they choose. Studies are planned to test the effectiveness of the Green House in improving resident outcomes as well as staff outcomes such as retention, turnover and satisfaction (Kane, 2003).

The design of the physical environment of long-term care settings can play a very important role in increasing quality of life of residents by improving sleep, supporting orientation, reducing agitation, and increasing social interaction and providing control and choice. Different aspects of the environment, such as unit size and layout, provision of private rooms, noise levels, and supportive design features, contribute to better outcomes among residents.

**Resident safety**

Residents in long-term care settings usually suffer from one or more chronic conditions. Due to illness and aging processes, their functional abilities are reduced and they experience problems in navigating the environment in which they live. Due to poor vision, frailty, and balance and gait problems, many elderly residents fall and get injured. Residents in nursing homes and other long-term care settings are also exposed to nosocomial infections. Cognitively impaired residents run the risk of hurting themselves in an unsafe environment. A supportive, well-designed environment can increase resident safety.
Reduce falls

More than one-third of older persons fall each year, and, in most cases, falls are recurrent (Tinetti, 2003). Falls are the costliest category of injury among older persons, accounting for nearly 71% of the total costs of injury among persons 60 years of age and older (Rizzo, Friedkin, Williams, Acampora, & Tinetti, 1998). Connell and Wolf (1997) identify three main categories of causal factors for falls among the elderly: personal factors (e.g., chronic disorders and neurological deficits), environmental factors (e.g., obstacles), and behavioral factors (activities and choices that can destabilize balance such as improper shoes). Situations in which falls or near-falls occurred in a sample of healthy elderly subjects included (Connell & Wolf, 1997):

- Collisions in the dark while walking to and from bedrooms in the night.
- Failing to avoid temporarily hazardous conditions.
- Frictional variations between shoe and floor coverings.
- Environmental demands that exceeded physiological abilities (e.g., a doorway threshold that was higher than a regular step).
- Habitual environmental use (when ways of doing habitual activities do not change despite changes in a person’s abilities).
- Inappropriate environmental use.

In addition to events such as the above that are likely to occur in institutional settings as well as at home, use of bedrails and physical restraints have been associated with falls among the elderly in institutional settings. Staff may use bedrails and restraints to prevent residents, especially those with cognitive impairments, from getting out of bed independently and potentially harming themselves (Hofmann, Bankes, Javed, & Selhat, 2003). However, studies indicate that rails may contribute to serious injury and even death by falls over, under, between, and around bedrails (Capezuti, Maislin, Strumpf, & Evans, 2002).

Several studies have documented the effect of multifaceted interventions on reducing falls among nursing-home residents (Becker et al., 2003; Hofmann, et al., 2003; Jensen, Nyberg, Gustafson, & Lundin-Olsson, 2003). These interventions included different components such as attempts to reduce bedrail use, education, restorative therapy, or exercise programs and environmental modifications. Environmental modifications were usually undertaken on an individualized basis in response to specific environmental conditions. This may include repositioning furniture (Hoffman, Powell-Cope, MacClellan, & Bero, 2003; Hofmann, Bankes, Javed & Selhat, 2003), adding floor mats to cushion falls and antislip mats to improve footing and traction (Hoffman, Powell-Cope, MacClellan, & Bero, 2003), providing nightlights and stair rails (Tinetti, 2003), and improving lighting levels (McMurdo, Millar, & Daly, 2000). In these studies, while the combined interventions were effective, it is difficult to isolate the effect of the environment on reduction in falls.

Two studies have specifically assessed the impact of flooring type on incidence of falls, though the results are not consistent. Donald and colleagues (2000) found that elderly residents in a rehabilitation ward in a community hospital incurred fewer falls on vinyl surfaces as compared to carpet. On the other hand, elderly residents exhibited higher gait speed and step length on
a carpeted surface as compared to vinyl (Willmott, 1986). There is insufficient evidence to support the use of one type of surface over the other to reduce falls among the elderly.

Reduce infection

The confined living arrangements and group activities of nursing homes, combined with understaffing and failure of staff to comply with infection-control measures, are associated with high infection rates in nursing homes (Zimmerman, Gruber-Baldini, Hebel, Sloane, & Magaziner, 2002). Nursing-home residents contract more than 1.5 million infections per year, and each resident faces a 5% to 10% risk per year of acquiring infections (Ernst & Ernst, 1999). While different medical conditions increase susceptibility to infection among elderly in long-term care settings, environmental factors are also related to infection rates. A large body of evidence shows clearly that infections are spread in acute-care settings through airborne and contact pathways (Ulrich, Zimring, Joseph, Quan, & Choudhary, 2004).

However, there are relatively fewer studies conducted in long-term care settings examining how infections are transmitted in such settings and how design may address environmental sources of infection. Some of the studies that link environmental factors with infection found the following.

High rates of hospitalization among nursing-home residents was associated with poor rating of environmental quality (cleanliness, odors, noises, homeliness, cues, and environmental quality) (Zimmerman, et al., 2002).

Nosocomial pneumonia among long-term-care residents may be related to colonization of potable water with *Legionella* (Seenivasan, Yu, & Muder, 2005).

Methicillin-resistant *Staphylococcus aureus* (MRSA) positive residents were identified in nursing homes contaminated with MRSA strains, while nursing homes without detectable environmental contamination had either no detectable positive contamination or just one positive resident (Fraise, Mitchell, O’Brien, Oldfield, & Wise, 1997).

Rates of cross infection were higher when residents with indwelling urinary catheters (IUC) were nursed in the same room (Fryklund, Haeggman, & Burman, 1997). This study supported nursing IUC residents in separate rooms.

There are few studies that have specifically examined the pathways by which infection is acquired and spread in long-term care settings. If findings from acute-care settings are directly applied to long-term care, these settings might be overdesigned to prevent risk of infection since long-term care residents are not as severely ill or immunocompromised as patients in acute-care settings. However, the importance of containing and preventing spread of infection through proper handwashing practices, good air quality, and provision of private rooms for residents with infections are applicable in long-term care environments as well.

Reduce wandering and unsafe exiting for cognitively impaired residents

Cognitively impaired residents’ attempts to leave facilities or homes are a source of concern for staff and caregivers (Cohen & Day, 1991; Day, et al., 2000). Wandering and unsafe exiting from buildings increases the risk of injury among cognitively impaired residents. Several studies show that environmental approaches may be adopted to prevent unsafe exiting and may eliminate the...
need for chemical and physical restraints for cognitively impaired residents. Design strategies that are effective in reducing exiting behavior among dementia residents include the following.

**Two-dimensional grid patterns on the floor:** In a quasi experiment with eight residents, two-dimensional grid patterns eliminated most attempts to exit the building (Hussian & Brown, 1987). This strategy may have been effective because persons with dementia perceive two-dimensional patterns on the floor as three dimensional barriers due to problems with depth perception. However, in other studies, two-dimensional floor patterns were not successful in reducing exiting behavior (Chafetz, 1990; Namazi, Rosner, & Calkins, 1989). The lack of success in reducing exiting was attributed to the presence of glass panes in exit doors and windows that provided views to the outdoors that enabled residents to overcome the barrier imposed by the grid pattern (Day, et al., 2000).

**Disguised exit panels and restricted light and views through exit-door windows:** Findings from several studies support the effectiveness of disguising exit doors in different ways, including:

- Placing cloth panels over door knobs eliminated exit attempts by most residents (Dickinson, McLain-Kark, & Marshall-Baker, 1995; Namazi, et al., 1989), though both these studies assessed behavior of a small number of residents.
- Installation of closed, matching miniblinds that restricted light, and views through exit-door windows reduced exiting attempts by half (Dickinson, et al., 1995).
- A wall mural painted over an exit significantly reduced resident attempts to leave the unit (Kincaid & Peacock, 2003).

**Access to safe outdoor areas:** A few studies showed that an alternative to prevent exiting—providing access to safe outdoor spaces—generated positive outcomes such as reduced agitation among dementia residents (Mooney & Nicell, 1992; Namazi & Johnson, 1992).

The environment can increase safety among residents by removing barriers to ambulation and performance of critical tasks and preventing infections and unsafe behaviors such as exiting.

**Staff stress**

Nursing staff in long-term care settings work under challenging conditions and experience both physical and emotional stress. The residents they work with are often seriously ill and cognitively impaired. The high level of stress experienced by staff members is also likely to affect the quality of care they provide. A few studies have examined how work stressors affect employee job performance in long-term care facilities (Pekkarinen, et al., 2004). Some of these have examined the impact of the environment on staff outcomes in long-term care settings. The key findings that are relevant in this regard include the following.

**Smaller units contribute to reduced stress and increased staff satisfaction.** A cross-sectional survey of 1,194 employees and 1,079 relatives of residents in 107 residential-home units and health-center bed wards found that large unit size was related to increased time pressure among employees and reduced quality of life for residents (Pekkarinen, et al., 2004). Other studies found that small unit sizes were positively associated with increased supervision and interaction between staff and residents in a special-care unit for residents with dementia (McC racken &
Fitzwater, 1989). Annerstedt (1993) found that staff members in group-living units reported greater competence, more knowledge in dealing with dementia, and greater satisfaction than their counterparts in nursing homes. However, no consistent numbers are offered on what makes a unit large or small (Day, et al., 2000). Further, even in small units, especially those designed for persons with dementia, it is important to consider how the design impacts staff ability to monitor residents. Morgan and Stewart (1998a) found that in a newly designed, low-density special-care unit with private rooms, enclosed charting spaces, and secluded outdoor areas and activity areas, staff spent increased time monitoring and locating residents.

**Presence of amenities and environmental supports reduces staff turnover.** In a study of staff turnover in 117 community nursing homes and 57 long-term care veteran’s facilities, Brennan and Moos (1990) found that, in the veteran’s facilities, turnover was greater where there were fewer physical amenities, social-recreational aids, prosthetic aids, and less environmental diversity. The authors suggest that the physical design features in these facilities supported the staff’s work efforts and thereby reduced turnover (Brennan & Moos, 1990).

**Physical design enhancements improve morale and satisfaction.** Studies show that physical design changes in long-term care settings such as interior design modifications, natural elements, furniture repositioning to support social interaction, design supports for resident independence (such as large clocks, handrails, additional mirrors) and orientation (large, clear signposts and reality orientation boards), and artwork were related to improved morale and satisfaction among staff (Christenfeld, et al., 1989; Cohen-Mansfield & Werner, 1998; Cox, Burns, & Savage, 2004; Jones, 1988; Parker et al., 2004).

**Back injuries among nursing staff are reduced by using patient lifts.** Patient lifting is the primary occupational back stressor for nursing personnel (Brophy, Achimore, & Moore-Dawson, 2001; Miller, Engst, Tate, & Yassi, 2006). Reducing injuries that result from resident-lifting tasks can not only result in significant economic benefit (reduced cost of claims, staff lost workdays), but also reduce pain and suffering among workers. Ergonomic programs, staff education, a no-manual lift policy, and use of mechanical lifts have been successful in reducing back injuries that result from patient-handling tasks (Engst, Chhokar, Miller, Tate, & Yassi, 2005; Garg & Owen, 1992; Garg, Owen, Beller, & Banaag, 1991; Garg, Owen, & Carlson, 1992; Miller, et al., 2006). Miller and colleagues (2006) studied the impact of installing portable ceiling lifts in a long-term care facility (ratio of ceiling lifts to resident beds was one to six) on risk of resident-handling injuries and compensation costs. After the intervention, staff members perceived that they were at less risk for injury when they used the ceiling lifts compared to manual methods. Also, 75% of the staff preferred using ceiling lifts over any other method for lifting and transferring residents. Compensation costs for resident-handling injuries reduced in the intervention facilities (Miller, et al., 2006).

**Conclusions**

The review of the existing literature clearly suggests that design of the physical environment impacts resident and staff outcomes in long-term care settings and contributes to a better quality of life for those who live, work, and visit these facilities. In fact, the environment is being increasingly accepted as an important component in supporting wellness and health among residents in long-term care environments.
Though a large number of studies exist in different areas, the findings are sometimes mixed and many studies utilize small sample sizes that limit the ability to generalize the findings. Additional research is needed using larger sample sizes and rigorous methods to strengthen the findings reported in this report. While there is a growing body of literature examining the impact of the environment on residents with cognitive impairments, there are relatively fewer studies examining outcomes among cognitively intact long-term care residents. Also, there has been much less focus on staff outcomes in long-term care settings. Some areas for future research include:

- Assessment of environmental modifications to reduce resident falls and to identify environmental causes for falls in nursing-home settings.

- Environmental factors such as homeliness that are potentially related to better quality of life for residents and staff.

- The impact of light (natural and artificial) as a cost-effective strategy for improving sleep quality and depression among institutionalized elderly.

- The impact of unit layout and size on resident agitation and well-being, social interaction, and participation in activities.

- Comparison of private and shared bedrooms in long-term care settings to assess impact on social interaction, privacy and control, sleep quality, and staff ability to monitor residents.

- Impact of amenities and environmental supports on staff work stress and job performance.

References Cited


The article provides information on Parrish Medical Center in Titusville, Florida. The center is the winner of Modern Healthcare's Spirit of Excellence Award for Service in 2006. The facility won because of its effort to maximize patient comfort. It offers a 24-7 concierge service for patients, visitors, employees and medical staff, restaurant-style food service, an entertainment system and comfort carts filled with snacks and beverages for patients and their families.
SPIRIT OF EXCELLENCE AWARD FOR SERVICE--WINNER

Parrish aims to maximize patient comfort

'The Hilton' of hospitals

The need for a new hospital provided Parrish Medical Center with an opportunity to brainstorm how best to create a healing environment, and the resulting 210-bed, 375,000-square-foot, $80 million facility in Titusville, Fla., might sound more like a spa or a resort than a hospital.

The center offers a 24-7 concierge service for patients, visitors, employees and medical staff; restaurant-style, cooked-to-order food service; an entertainment system that includes movies, games, Internet access and patient education videos; and "comfort carts" filled with snacks and beverages for patients and their families.

"People jokingly call us 'the Hilton of hospitals,' " says George Mikitarian, president and chief executive officer of the center, which has won the 2006 Spirit of Excellence Award in the Service category. "As we said to ourselves, using the architectural rule form follows function: 'The form is the building. What do we want the function to be?'"

The new building met the center’s goal of achieving the 93rd percentile in patient satisfaction as ranked by Professional Research Consultants, while 92% of employees in a Baptist Healing Trust survey said the organization places a high importance on loving care, well above the surveywide average of 74%.

Inspiration came from visiting the Center for Health Design's Pebble Project, the first national effort to study and measure the effect of hospital design on healthcare.

"We developed collectively a vision (that was) powerful, although short, of healing experiences for everyone all the time, " Mikitarian says.

"Unfortunately, modern science and modern medicine are not always able to cure people, but you are always able to care for people. You can still help someone who may be failing physically heal psychologically and spiritually," he says.

Such innovations are easier to implement in a brand-new building, he says, adding that the technology and services probably added about 5% to the overall cost of the project.

"When you build things from the ground up, it's far more efficient than a remodel job," he says. "Most buildings are designed around the people who work in them--what's more convenient, what's more productive. This hospital was built first and foremost for the people who receive services."

To accommodate the new services, Parrish rewrote some job descriptions and revamped how it hired and trained certain people but has not needed to add new staff, Mikitarian says, adding that he believes the changes have helped employee recruitment and retention.

"You can't even put a dollar to that. It's basically priceless," he says.

"The multifaceted approach they're taking was impressive to me," explains Larry Higgins, judge in the service category and a vice president at 547-bed King's Daughters Medical Center in Ashland, Ky. "It just wasn't a department that was pushing this service-excellence agenda. It seemed to be an organizational effort."

PHOTO (COLOR): Parrish was built around the patients' needs, according to the center's president and CEO, with services including restaurant-style, cooked-to-order food service.

By Ed Finkel

Copyright of Modern Healthcare is the property of Crain Communications Inc. (MI) and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.
An effective solution

The team decided that an integrated comprehensive automated tool that could produce patient information was needed. Designed as a computer-generated work sheet, the tool is printed at the beginning of each shift and carried and referred to by the nurse as he or she provides patient care. It’s also used to communicate to physicians and at change-of-shift reports.

In order to gain data from staff members about what would constitute an effective tool, a survey was administered to all nurses in three medical/surgical units, with the understanding that no changes would be made until the tool was finalized. It was then tested for 3 months in order to gain additional data. In terms of the three areas the tool was designed to address, 66% to 73% of the nurses noted an improvement. In addition to the survey, interviews conducted with the nurses revealed that the tool resulted in more accuracy and less confusion in what they knew about their patients. Nurses also stated that the new tool was highly efficient and saved them time formerly spent manually pulling together information about the patient from a wide variety of sources in the computerized patient record. Moreover, nurses indicated that they were able to communicate more effectively with physicians.

The staff nurses who felt the tool hadn’t been helpful to them noted that there was too much information contained in the tool, making it too long. Another issue was that the desired changes they recommended couldn’t be implemented due to constraints of the hospital information system. Some interviewees also stated that they felt certain information was repetitive. These issues the hospital continues to work on.

The tool is an example of a customized application designed to enhance accessibility of patient information by the nurse. Such tools are essential for the mastery of data and coordination, and can greatly improve patient safety, quality of care, and teamwork. The quality of nursing care, as well as the satisfaction of the nurse, can be significantly enhanced with the development and use of such tools.

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ABOUT THE AUTHORS

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Good communication and patient information (PI) are two facets of nursing that can’t be overemphasized. Despite this, the transfer of patient data has recently been labeled faulty among caregivers. Because the communication of patient information during a hospital stay is constantly changing, it’s important that the proper systems are in place to provide the nurse with complete and relevant information needed to care for the patient and communicate with the patient, family, nurses, physicians, healthcare team members, and others.

Over 2 years ago, the nursing organization at Parrish Medical Center (PMC), Titusville, Fla., embarked on a strategic planning process that involved identifying the core values and desired future for nursing in the organization. Researchers discovered that the patient information available to nurses as they provided care, interacted with physicians, and passed along information to other staff members needed significant improvement. To address this issue, an innovation team was formed to develop and implement solutions.

**Problem areas**

After considerable discussion, the team concluded that nurses lacked consistent, comprehensive, and accurate patient information. This inadequate information created three specific communication problems:

1. Nurses were dissatisfied with the level and type of information they had available to them as they cared for their patients.
2. Nurses felt that the shift handoff reports they were receiving (and giving) were providing an incomplete picture of the patient for the oncoming staff.
3. Physicians felt the reports they received from nursing staff weren’t adequate and complained that the information they provided to nurses wasn’t passed on to nurses on the next shift.

A review of the literature was conducted regarding these problems. Although relevant journal articles weren’t found regarding nurses having comprehensive patient information during their shift, the issue of adequate communication at the change of shift proved to be a universal problem. Information was incomplete, fragmented, and tended to be lost, especially when communicated orally. Inadequate handoffs between clinicians was noted to be one of the most common factors leading to adverse events. Additionally, the content of shift report was often found to be a ritualistic repetition of data available in the patient record. In examining handoffs, it was recommended that verbal and written communication occur together, as this combination provides multiple channels for information to be exchanged.

In terms of physician/nurse communication, several studies were uncovered that pointed to communication problems, lack of coordination, and fragmented care. The use of telephones and pagers has increased the opportunities for communication between the nurse and the physician, but it’s also created many interruptions that may negatively impact quality of care.

To determine why sufficient patient information was deficient on the part of nurses, the team found that PMC’s patient-information system mainly contained administrative data and physician orders and supplied insufficient information to provide nursing care. There was also a considerable amount of information that wasn’t pulled together for the nurses to access, such as separate documents for vital signs, fall risk, intake and output, I.V. therapy, educational needs assessment, and more. The problem was the nurse didn’t have the time to sort through all of the screens to find and record what he or she needed to be well informed about the patient.
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SOFT TOUCH: The lobby at Parrish Medical Center, Titusville, Fla., which opened late last year. Hospital planners found that the soft lines and curves created a more comfortable place for both patients and staff.

Medical Education

Time's Up

New rules limit the number of hours physician residents can work at hospitals

Beginning July 1, executives running the 600 hospitals sponsoring physician residency programs will face a fresh challenge tapping precious physician resources, as new requirements limit the workweek for medicine's traditional workhorses. New rules from the Accreditation Council for Graduate Medical Education will cause these hospitals and 200 other residency program sponsors to cap resident duty hours at 80 hours per week, including in-house call activities.

It may not be easy, considering that long resident hours are the stuff of legend. Surgical subspecialty residents sometimes put in 120-hour workweeks—and take pride in it. But Ingrid Philibert, director of ACGME field activities, says such grueling schedules are a patient safety issue. “That is not safe, that is not advisable and that is not conducive to human life,” Philibert says.

The rules may cause hospitals and other sponsoring institutions to seek new resources, change procedures and change parts of their culture. But stakeholders by and large support the new rules. They “will yield a lot of change and good change,” says Jim Bentley, the American Hospital Association's senior vice president for strategic policy planning.

Institutions that overwork their residents could face strict penalties, including possible loss of their accreditation and their piece of Medicare medical education funds—which total roughly $6 billion, according to the Accreditation Council for Graduate Medical Education. Such institutions risk becoming a program that medical students will not select for training. The new rules also increase institutional oversight requirements and beef up compliance protocol. Other provisions include enhanced supervision of residents, one 24-hour period free of all educational and clinical responsibilities each week, and 10 hours of rest between duty periods and after in-house call.

ACGME acknowledges the transition could “create financial and/or operational hardships.” Hospitals can look to New York state, which adopted similar duty limits in 1989, for guidance. It has taken hospitals time to comply, and additional staffing for local hospitals in 1989 cost about $358 million, according to a study published in the Journal of the American Medical Association. Bentley says this shows that implementing the 80-hour limit can succeed, but cautions: “It takes work, it takes planning and it takes careful monitoring by the hospital.”

—CHRISTOPHER J. GEARON

Design & Construction

A Pebble at a Time

Hospitals spend a little more on design, and discover the payoff for patients and staff

When planners at Parrish Medical Center, Titusville, Fla., began envisioning a $60 million hospital to replace their 50-year-old building, they wanted a soothing environment. They wanted to get away from long hallways that reduced human contact and intimidated patients. So the new hospital, which opened in November 2002, is all curves, from the driveway to the patient areas. Patients and staff enter a large atrium that acts as a hub, with all services a short distance away.

It cost more than a traditional design would have. The board agreed to spend the extra 5 to 10 percent to create surroundings that designers believe improve patient and staff satisfaction by being a more pleasant place. But it was a gamble, says George Mikitarian, president and CEO of the 200-bed hospital. "We knew there were a lot of things we had learned about and heard about and wanted to try, but there wasn't a lot of proven data that there's a benefit," he says.

Mikitarian’s hospital is one of a dozen that comprise the Pebble Project, an effort to bring outcomes data to the design of healing environments. Proponents of the Pebble Project, an endeavor of the Center for...
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In the midst of a three-year project to standardize treatment across a far-flung rural system with 13 small facilities, Jessica Lambert has found her niche. A newly formed rural Canadian health system, Grey-Bruce Health Network is developing multidisciplinary clinical pathways for a host of common treatments. "When I was looking at pursuing my master's degree, I knew I didn't want to go and work in a bank or the stock market," says Lambert, the system's clinical pathways coordinator. "I had an interest in facilitation and project management, so this fit exactly into what I was looking for." Now that she's in the hospital environment, she's sold. "I've always had this interest," Lambert says. "I can't imagine myself getting out of health care."—JOSEPH V. ROBBINS

The Job
My job is to get groups of frontline clinical staff together and create goals that will guide implementation of treatments across all of our sites.

What's a Pathway?
We defined a pathway as the process of care and coordinating that process across the continuum of care, blending patient needs, quality outcomes and controlled costs.

Continuity of Care
We pick things like pneumonia that affect all our sites. As the patient arrives and is diagnosed, the doctor picks up preprinted orders for that type of patient. Then other team members will pick up the pathway package.

Sharing Resources
The pathway concept really started to spread in the 1990s and it was a natural fit for us because a lot of our hospitals operate in comparative isolation. This allows them to share resources.

Contact Lambert at jlambert@bmts.com

Healthcare Design, Pleasant Hill, Calif., believe there are medical and satisfaction improvements to be had, such as fewer patient falls and nosocomial infections, and less employee turnover. "If we can prove some of these amenities have long-term outcomes, we can get hospitals to think about it as they spend the megabucks to do what's coming down the pike," says Rosalyn Cama, a New Haven, Conn.-based health care interior designer and chairwoman of the Center for Healthcare Design's board.

The project is just two years old, but a few results are in. Bronson Methodist Hospital, Kalamazoo, Mich., reports that it has six fewer nosocomial infections per month in its new inpatient pavilion, which features private rooms, better airflow and sinks that are easily accessible to clinicians so they can wash their hands before seeing a patient. That's significant, says Susan Ulshafer, senior vice president of human resources and organizational development for Bronson. "There are huge implications for folks that are planning or thinking about building," she says. There are also lessons about how not to carry out a redesign, as Pebble Project hospitals put their projects under a microscope. For instance, Parrish officials learned that their staff was overwhelmed by change because it was all introduced at the same time.

Mikitarian sees participation in the Pebble Project as a one-time opportunity because the industry needs solid outcomes data on design quickly, given the pace of hospital construction and the increased emphasis on patient safety and quality. "We need to find out whether this stuff works," he says. "In the end, health care in general will benefit from it."—JAN GREENE
In 1986, Bill Smith, a senior engineer and scientist at Motorola, introduced the concept of Six Sigma to standardize the way defects are counted. Six Sigma provided Motorola the key to addressing quality concerns throughout the organization, from manufacturing to support functions. The application of Six Sigma also contributed to Motorola winning the Malcolm Baldrige National Quality award in 1988.

Since then, the impact of the Six Sigma process on improving business performance has been dramatic and well documented by other leading global organizations, such as General Electric, Allied Signal, and Citibank. That’s why investing in Six Sigma programs is increasingly considered a mission-critical best practice, even among mid-sized and smaller firms.

Today, Motorola continues to implement Six Sigma throughout its own enterprise, and extends the benefit of its Six Sigma expertise to other organizations worldwide through Motorola University.
Lean manufacturing

From Wikipedia, the free encyclopedia

This article may require cleanup to meet Wikipedia's quality standards. Please improve this article (http://en.wikipedia.org/w/index.php?title=Lean_manufacturing&action=edit) if you can. (February 2007)

Lean manufacturing is a generic process management philosophy derived mostly from the Toyota Production System (TPS) but also from other sources. It is renowned for its focus on reduction of the original Toyota 'seven wastes' in order to improve overall customer value. Lean is often linked with Six Sigma because of that methodology's emphasis on reduction of process variation (or its converse smoothness) and Toyota's combined usage. Toyota's steady growth from a small player to the most valuable and the biggest car company in the world has focused attention upon how it has achieved this, making "Lean" a hot topic in management science in the first decade of the 21st century.

"Lean" is viewed by many as the latest management fad in the cost-reduction arena. It has for many the advantage of a very descriptive active name and has been, in many cases, used like any other cost-reduction approach. This has meant that the "Lean" word can be found in many places, projects and proposals. This has meant that for many it has hit the same implementation problems as those other approaches which has created a level of cynicism in some quarters about its effectiveness. However, there are enough high-profile high-success implementations (headed by Toyota) that attitudes to it are quite mixed.

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Overview

For many, Lean is the set of TPS 'tools' that assist in the identification and steady elimination of waste (muda), the improvement of quality, and production time and cost reduction. The Japanese terms from Toyota are quite strongly represented in "Lean". To solve the problem of waste, Lean Manufacturing has several 'tools' at its disposal. These include continuous process improvement (kaizen), the "5 Whys" and mistake-proofing (poka-yoke). In this way it can be seen as taking a very similar approach to other improvement methodologies.

There is a second approach to Lean Manufacturing, which is promoted by Toyota, in which the focus is upon improving the 'flow' or smoothness of work (thereby steadily eliminating mura, unevenness) through the system and not upon 'waste reduction' per se. Techniques to improve flow include production levelling, "pull" production (by means of kanban) and the Heijunka box. This is a fundamentally different approach to most improvement methodologies which may partially account for its lack of popularity.

The difference between these two approaches is not the goal but the prime approach to achieving it. The implementation of smooth flow exposes quality problems which already existed and thus waste reduction naturally happens as a consequence. The advantage claimed for this approach is that it naturally takes a system-wide perspective whereas a 'waste' focus has this perspective, sometimes wrongly, assumed. Some Toyota staff have expressed some surprise at the 'tool' based approach as they see the tools as work-arounds made necessary where flow could not be fully implemented and not as aims in themselves.

Both Lean and TPS can be seen as a loosely connected set of potentially competing principles whose goal is cost reduction by the elimination of waste.[2] These principles include: Pull processing, Perfect first-time quality, Waste minimization, Continuous improvement, Flexibility, Building and maintaining a long term relationship with suppliers, Autonomation, Load levelling and Production flow and Visual control. The disconnected nature of some of these principles perhaps springs from the fact that the TPS has grown pragmatically since 1948 as it responded to the problems it saw within its own production facilities. Thus what one sees today is the result of a 'need' driven learning to improve where each step has built on previous ideas and not something based upon a theoretical framework. Toyota's view is that the methodology is not the tools but the method of application of muda, mura, muri to expose problems systematically and to use the tools where the ideal cannot be achieved. Thus the 'tools' are, in their view, 'workarounds' adapted to different situations which explains any apparent incoherence of the 'principles' above.

The TPS has two pillar concepts: JIT (flow) and autonomation (smart automation). [3] Adherents of the Toyota approach would say that the smooth 'flow'ing delivery of 'value' achieves all these improvements as a side-effect. If production 'flows' perfectly then there is no inventory, if customer valued features are the only ones produced then product design is simplified and effort is only expended on features the customer values. The other of the two TPS pillars is the very human aspect of 'autonomation' whereby automation is achieved with a human touch.[4] This aims to give the machines enough 'intelligence' to recognise when they are working abnormally and flag this for human attention. Thus humans do not have to monitor normal production and only have to focus on abnormal, or fault, conditions. A reduction in human workload that is probably much desired by all involved since it removes much routine and repetitive activity that humans often do not enjoy and where they are therefore not at their most effective.

Lean implementation is therefore focused on getting the right things, to the right place, at the right time, in the
right quantity to achieve perfect work flow while minimizing waste and being flexible and able to change. These concepts of flexibility and change are principally required to allow production leveling, using tools like SMED, but have their analogues in other processes such as R&D. The flexibility and ability to change are not open-ended, and therefore often not expensive capability requirements. More importantly, all of these concepts have to be understood, appreciated, and embraced by the actual employees who build the products and therefore own the processes that deliver the value. The cultural and managerial aspects of Lean are just as, and possibly more, important than the actual tools or methodologies of production itself. There are many examples of Lean tool implementation without sustained benefit and these are often blamed on weak understanding of Lean in the organisation.

Lean aims to make the work simple enough to understand, to do and to manage. To achieve these three at once there is a belief held by some that Toyota's mentoring process (loosely called Senpai and Kohai relationship), so strongly supported in Japan, is one of the best ways to foster Lean Thinking up and down the organizational structure. This is the process undertaken by Toyota as it helps its suppliers to improve their own production. The closest equivalent to Toyota's mentoring process is the concept of Lean Sensei, which encourages companies, organizations, and teams to seek out outside, third-party "Sensei" that can provide unbiased advice and coaching, (see Womack et al, Lean Thinking, 1998).

History of waste reduction thinking

Pre-20th Century

Most of the basic goals of lean manufacturing are common sense and documented examples can be seen back to at least Benjamin Franklin. Poor Richard's Almanack says of wasted time, "He that idly loses 5s. [shillings] worth of time, loses 5s., and might as prudently throw 5s. into the river." He added that avoiding unnecessary costs could be more profitable than increasing sales: "A penny saved is two pence clear. A pin a-day is a groat a-year. Save and have."

Again Franklin's The Way to Wealth says the following about carrying unnecessary inventory. "You call them goods; but, if you do not take care, they will prove evils to some of you. You expect they will be sold cheap, and, perhaps, they may [be bought] for less than they cost; but, if you have no occasion for them, they must be dear to you. Remember what Poor Richard says, 'Buy what thou hast no need of, and ere long thou shalt sell thy necessaries.' In another place he says, 'Many have been ruined by buying good penny worths'." Henry Ford cited Franklin as a major influence on his own business practices, which included Just-in-time manufacturing.

The concept of waste being built into jobs and then taken for granted was noticed by motion efficiency expert Frank Gilbreth, who saw that masons bent over to pick up bricks from the ground. The bricklayer was therefore lowering and raising his entire upper body to get a 5 pound (2.3 kg) brick but this inefficiency had been built into the job through long practice. Introduction of a non-stooping scaffold, which delivered the bricks at waist level, allowed masons to work about three times as quickly, and with less effort.

20th Century

Frederick Winslow Taylor, the father of scientific management, introduced what are now called standardization and best practice deployment: "And whenever a workman proposes an improvement, it should be the policy of the management to make a careful analysis of the new method, and if necessary conduct a series of experiments to determine accurately the relative merit of the new suggestion and of the old standard. And whenever the new method is found to be markedly superior to the old, it should be adopted as the standard for the whole establishment" (Principles of Scientific Management, 1911).
Taylor also warned explicitly against cutting piece rates (or, by implication, cutting wages or discharging workers) when efficiency improvements reduce the need for raw labor: "...after a workman has had the price per piece of the work he is doing lowered two or three times as a result of his having worked harder and increased his output, he is likely entirely to lose sight of his employer's side of the case and become imbued with a grim determination to have no more cuts if soldiering [marking time, just doing what he is told] can prevent it." This is now a foundation of lean manufacturing, because it is obvious that workers will not drive improvements they think will put them out of work. Shigeo Shingo, the best-known exponent of single-minute exchange of die (SMED) and error-proofing or poka-yoke, cites Principles of Scientific Management as his inspiration (Andrew Dillon, translator, 1987. The Sayings of Shigeo Shingo: Key Strategies for Plant Improvement).

American industrialists recognized the threat of cheap offshore labor to American workers during the 1910s, and explicitly stated the goal of what is now called lean manufacturing as a countermeasure. Henry Towne, past President of the American Society of Mechanical Engineers, wrote in the Foreword to Frederick Winslow Taylor's Shop Management (1911), "We are justly proud of the high wage rates which prevail throughout our country, and jealous of any interference with them by the products of the cheaper labor of other countries. To maintain this condition, to strengthen our control of home markets, and, above all, to broaden our opportunities in foreign markets where we must compete with the products of other industrial nations, we should welcome and encourage every influence tending to increase the efficiency of our productive processes."

**Ford starts the ball rolling**

Henry Ford continued this focus on waste while developing his mass assembly manufacturing system. "Ford's success has startled the country, almost the world, financially, industrially, mechanically. It exhibits in higher degree than most persons would have thought possible the seemingly contradictory requirements of true efficiency, which are: constant increase of quality, great increase of pay to the workers, repeated reduction in cost to the consumer. And with these appears, as at once cause and effect, an absolutely incredible enlargement of output reaching something like one hundredfold in less than ten years, and an enormous profit to the manufacturer".\[5\]

Ford (1922, My Life and Work) provided a single-paragraph description that encompasses the entire concept of waste. "I believe that the average farmer puts to a really useful purpose only about 5% of the energy he expends. ... Not only is everything done by hand, but seldom is a thought given to a logical arrangement. A farmer doing his chores will walk up and down a rickety ladder a dozen times. He will carry water for years instead of putting in a few lengths of pipe. His whole idea, when there is extra work to do, is to hire extra men. He thinks of putting money into improvements as an expense. ... It is waste motion— waste effort— that makes farm prices high and profits low." Poor arrangement of the workplace-- a major focus of the modern kaizen-- and doing a job inefficiently out of habit-- are major forms of waste even in modern workplaces.

Ford also pointed out how easy it was to overlook material waste. As described by Harry Bennett[6], "One day when Mr. Ford and I were together he spotted some rust in the slag that ballasted the right of way of the D. T. & I [railroad]. This slag had been dumped there from our own furnaces. 'You know,' Mr. Ford said to me, 'there's iron in that slag. You make the crane crews who put it out there sort it over, and take it back to the plant.'" In other words, Ford saw the rust and realized that the steel plant was not recovering all of the iron.

Design for Manufacture (DFM) also is a Ford concept. Per My Life and Work, "Start with an article that suits and then study to find some way of eliminating the entirely useless parts. This applies to everything—a shoe, a dress, a house, a piece of machinery, a railroad, a steamship, an airplane. As we cut out useless parts and simplify necessary ones, we also cut down the cost of making. ...But also it is to be remembered that all the parts are designed so that they can be most easily made." The same reference describes Just in time manufacturing very
explicitly.

Whilst Ford is renowned for his production line it is often not recognised how much effort he put into removing the 'fitters' work in order to make the production line possible. Until Ford a car's components always had to be 'fitted' or reshaped by a skilled engineer at the point of use so that they would connect properly. By enforcing very strict specification and quality criteria on component manufacture he eliminated this work almost entirely, this reduced manufacturing effort by between 60-90%[7]. However Ford's mass production system failed to incorporate the notion of Pull and thus often suffered from over production.

**Toyota develops Lean thinking**

Toyota's development of ideas that later became Lean may have started at the turn of the 20th century with Sakichi Toyoda in their textile business with looms that stopped themselves when a thread broke, this became the seed of "Autonomation" and "Jidoka". Toyota's journey with JIT may have started back in 1934 when it moved from textiles to produce its first car. Kiichiro Toyoda, founder of Toyota Motor Corp., directed the engine casting work and discovered many problems in their manufacture. He decided he must stop the repairing of poor quality by intense study of each stage of the process. In 1936 Toyota won its first truck contract with the Japanese government his processes hit new problems and developed the "Kaizen" improvement teams.

Levels of demand in the Post War economy of Japan were low and the focus of mass production on lowest cost per item via economies of scale therefore had little application. Having visited and seen supermarkets in the US Taiichi Ohno recognised the scheduling of work should not be driven by sales or production targets but by actual sales. Given the financial situation during this period over-production was not an option and thus the notion of Pull (build to order rather than target driven Push) came to underpin production scheduling.

It was with Taiichi Ohno at Toyota that these themes came together. He built on the already existing internal schools of thought and spread its breadth and use into what has now become the Toyota Production System (TPS). It is principally from the TPS, but now including many other sources, that Lean production is developing. Norman Bodek wrote the following in his foreword to a reprint of Ford's (1926) *Today and Tomorrow:* "I was first introduced to the concepts of just-in-time (JIT) and the Toyota production system in 1980. Subsequently I had the opportunity to witness its actual application at Toyota on one of our numerous Japanese study missions. There I met Mr. Taiichi Ohno, the system's creator. When bombarded with questions from our group on what inspired his thinking, he just laughed and said he learned it all from Henry Ford's book." It is the scale, rigour and continuous learning aspects of the TPS which have made it a core of Lean.

**Types of waste**

Whilst the elimination of waste may seem like a simple and clear subject it is noticeable that waste is often very conservatively identified. This then hugely reduces the potential of such an aim. The elimination of waste is the goal of Lean, Toyota defined three types of waste: muda or nonvalue-added work, muri or overburden and mura or unevenness.

- To illustrate the state of this thinking Shigeo Shingo observed that it's only the last turn of a bolt that tightens it - the rest is just movement. This ever finer clarification of waste is key to establishing distinctions between value-adding activity, waste and non-value adding work.[8] Non-value adding work is waste that must be done under the present work conditions. It is key to measure, or estimate, the size of these wastes in order to demonstrate the effect of the changes achieved and therefore the movement towards the goal.
The 'flow' (or smoothness) based approach aims to achieve JIT by removing the variation caused by work scheduling and thereby provide a driver, rationale or target and priorities for implementation, using a variety of techniques. The effort to achieve JIT exposes many quality problems that had been hidden by buffer stocks, by forcing smooth flow of only value-adding steps these problems become visible and must be dealt with explicitly.

Muri is all the unreasonable work that management imposes on workers and machines because of poor organisation, such as carrying heavy weights, moving things around, dangerous tasks, even working significantly faster than usual, etc. It is pushing a person or a machine beyond its natural limits. This may simply be asking a greater level of performance from a process than it can handle without taking shortcuts and informally modifying decision criteria. Unreasonable work is almost always a cause of multiple variations.

To link these three concepts is straightforward. Firstly, Muri focuses on the preparation and planning of the process, or what work can be avoided proactively by design. Next, Mura then focuses on implementation and the elimination of fluctuation at the scheduling or operations level, such as quality and volume. The third — Muda — is discovered after the process is in place and is dealt with reactively. It is seen through variation in output. It is the role of management to examine the Muda, or waste, in the processes and eliminate the deeper causes by considering the connections to the Muri and Mura of the system. The Muda — waste — and Mura — inconsistencies — must be fed back to the Muri, or planning, stage for the next project.

A typical example of the interplay of these wastes is the corporate behaviour of "making the numbers" as the end of a reporting period approaches. Demand is raised, increasing (mura), when the "numbers" are low which causes production to try to squeeze extra capacity from the process which causes routines and standards to be modified or stretched. This stretch and improvisation leads to muri style waste which leads to downtime, mistakes and backflows and waiting, thus the muda of waiting, correction and movement.

Observers who have toured Toyota plants have described their aim as 'learning to see' these wastes in order to carry back a new vision of 'ideal' to their parent companies.

The original seven muda 'deadly wastes' are:

- Overproduction (production ahead of demand)
- Transportation (moving products that is not actually required to perform the processing)
- Waiting (waiting for the next production step)
- Inventory (all components, work-in-progress and finished product not being processed)
- Motion (people or equipment moving or walking more than is required to perform the processing)
- Over Processing (due to poor tool or product design creating activity)
- Defects (the effort involved in inspecting for and fixing defects)[9]

for other candidate wastes see muda

Some of these definitions may seem rather 'idealist' but this tough definition is seen as important. The clear identification of 'non-value adding work', as distinct from waste or work, is critical to identifying the assumptions behind the current work process and to challenging them in due course. In the words of Taiichi Ohno "eliminate muda, mura, muri completely".[10] Breakthroughs in SMED and other process changing techniques rely upon clear identification of where untapped opportunities may lie if the processing assumptions are challenged.

Lean implementation
Lean manufacturing - Wikipedia, the free encyclopedia

**System engineering**

Lean is about more than just cutting costs in the factory. One crucial insight is that most costs are assigned when a product is designed, (see Genichi Taguchi). Often an engineer will specify familiar, safe materials and processes rather than inexpensive, efficient ones. This reduces project risk, that is, the cost to the engineer, while increasing financial risks, and decreasing profits. Good organizations develop and review checklists to review product designs.

Companies must often look beyond the shop-floor to find opportunities for improving overall company cost and performance. At the system engineering level, requirements are reviewed with marketing and customer representatives to eliminate costly requirements. Shared modules may be developed, such as multipurpose power-supplies or shared mechanical components or fasteners. Requirements are assigned to the cheapest discipline. For example, adjustments may be moved into software, and measurements away from a mechanical solution to an electronic solution. Another approach is to choose connection or power-transport methods that are cheap or that used standardized components that become available in a competitive market.

**An example program**

In summary, an example of a lean implementation program could be:-

<table>
<thead>
<tr>
<th>With a tools based approach</th>
<th>With a muri or flow based approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ Senior management to agree and discuss their lean vision</td>
<td>■ Sort out as many of the visible quality problems as you can, as well as downtime and other instability problems, and get the internal scrap acknowledged and its management started.</td>
</tr>
<tr>
<td>■ Management brainstorm to identify project leader and set objectives</td>
<td>■ make the flow of parts through the system/process as continuous as possible using workcells and market locations where necessary and avoiding variations in the operators work cycle</td>
</tr>
<tr>
<td>■ Communicate plan and vision to the workforce</td>
<td>■ introduce standard work and stabilise the work pace through the system</td>
</tr>
<tr>
<td>■ Ask for volunteers to form the Lean Implementation team (5-7 works best, all from different departments)</td>
<td>■ start pulling work through the system, look at the production scheduling and move towards daily orders with kanban cards</td>
</tr>
<tr>
<td>■ Appoint members of the Lean Manufacturing Implementation Team</td>
<td>■ even out the production flow by reducing batch sizes, increase delivery frequency internally and if possible externally, level internal demand</td>
</tr>
<tr>
<td>■ Train the Implementation Team in the various lean tools - make a point of trying to visit other non competing businesses which have implemented lean</td>
<td>■ improve exposed quality issues using the tools</td>
</tr>
<tr>
<td>■ Select a Pilot Project – 5S is a good place to start</td>
<td>■ remove some people and go through this work again</td>
</tr>
<tr>
<td>■ Run the pilot for 2-3 months - evaluate, review and learn from your mistakes</td>
<td></td>
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</table>
the next lean tool. Select the one which will give you the biggest return for your business.

Lean Leadership

The role of the leaders within the organisation is the fundamental element of sustaining the progress of lean thinking. Experienced kaizen members at Toyota, for example, often bring up the concept of "Senpai, Kohai," and "Sensei," because they strongly feel that transferring of Toyota culture down and across the Toyota can only happen when more experienced Toyota Sensei continuously coach and guide the less experienced lean champions. Unfortunately, most lean practitioners in North America focus on the tools and methodologies of lean, versus the philosophy and culture of lean. Some exceptions include Shingijitsu Consulting out of Japan, which is made up of ex-Toyota managers, and Lean Sensei International based in North America, which coaches lean through Toyota-style cultural experience.

One of the dislocative effects of Lean is in the area of KPIs (Key Process Indicators). The KPIs by which a plant/facility are judged will often be driving behaviour by leadership within it, e.g. Production against forecast, because the KPIs themselves assume a particular approach to the work being done. This can be an issue where for example a truly Lean, FRS and JIT approach is planned to be adopted because these KPIs will no longer reflect performance since the assumptions on which they are based become invalid. It is a key leadership challenge to manage the impact of this KPI chaos within the organisation.

Key focus areas for leaders are
- PDCA thinking
- 'go and see' philosophy (or "Genchi Genbutsu")
- Process confirmation

Lean services

Lean, as a concept or brand, has captured the imagination of many in different spheres of activity. Examples of these from many sectors are listed below.

A study (http://www.scotland.gov.uk/Publications/2006/06/13162106/0) conducted on behalf of the Scottish Executive, by Warwick University, in 2005/06 found that Lean methods were applicable to the public sector, but that most results had been achieved using a much more restricted range of techniques than Lean provides.

The challenge in moving Lean to services is the lack of widely available reference implementations to allow people to see how it can work and the impact it does have. This makes it more difficult to build the level of belief seen as necessary for strong implementation. It is also the case that the manufacturing examples of 'techniques' or 'tools' need to be 'translated' into a service context which has not yet received the level of work or publicity that would give starting points for implementors. The upshot of this is that each implementation often 'feels its way' along as must the early industrial engineers of Toyota. This places huge importance upon sponsorship to encourage and protect these experimental developments. On the positive side there are many examples in service industries accessible through the Lean Enterprise Academy (http://www.leanuk.org/) (car servicing, hospital admissions, administrative processes etc) of Lean delivering important results. At this time, however, they are not well publicised.
References

3. ^ Taichi Ohno (1988), p 4
5. ^ (Charles Buxton Going, preface to Arnold and Faurote, Ford Methods and the Ford Shops (1915))
6. ^ 1951, Ford: We Never Called Him Henry

See also

Those areas below are linked to this subject:

Lean Software Engineering

- Agile manufacturing
- Agile software development
- Scrum
- Extreme Programming

Closely related methodologies

- Toyota Production System
- Value Network
- Theory of Constraints
- Six Sigma
- Statistical Process Control

Terminology

- Just In Time or JIT
- Fixed Repeating Schedule or FRS
- Kaizen
- SMED
- Poka-Yoke
- Autonomation and Jidoka
- 5S
- Production levelling
- muda, mura, muri
- workcell
- Takt time
- Andon
- Genchi Genbutsu
- Gemba
- 5 Whys

Areas of implementation outside Production

- Lean Construction
- Lean software development
- Lean office processes

Other

- Cellular manufacturing
- Industrial engineering
- Manufacturing
- Preorder Economy
- Process Reengineering
- Training Within Industry
- Value Stream Mapping

Books on lean production

- Carlino, Andy and Flinchbaugh, Jamie (2005), The Hitchhiker's Guide to Lean, Society of Manufacturing
Engineers, ISBN 0-87263-831-6
- Rother, Mike and Shook, John (2003), *Learning to See*, Lean Enterprise Institute, ISBN 0-9667843-0-8

### External links

- Links to Value-adding Lean Resources NOT Available on Wikipedia ([http://www.tpslean.com/LeanResources.htm](http://www.tpslean.com/LeanResources.htm))

Retrieved from "http://en.wikipedia.org/wiki/Lean_manufacturing"

Categories: Cleanup from February 2007 | All pages needing cleanup | Quality control | Management | Value | Business terms | Production and manufacturing | Lean concepts
The Role of the Physical Environment in the Hospital of the 21st Century: A Once-in-a-Lifetime Opportunity

Roger Ulrich*, Xiaobo Quan, Center for Health Systems and Design, College of Architecture, Texas A&M University
Craig Zimring*, Anjali Joseph, Ruchi Choudhary, College of Architecture, Georgia Institute of Technology

* Co-principal investigators and corresponding authors: Roger Ulrich, Ph.D.: ulrich@archone.tamu.edu;
Craig Zimring, Ph.D.: craig.zimring@arch.gatech.edu.

Report to The Center for Health Design for the Designing the 21st Century Hospital Project. This project is funded by the Robert Wood Johnson Foundation.

September 2004
The Role of the Physical Environment in the Hospital of the 21st Century: A Once-in-a-Lifetime Opportunity

A visit to a U.S. hospital is dangerous and stressful for patients, families and staff members. Medical errors and hospital-acquired infections are among the leading causes of death in the United States, each killing more Americans than AIDS, breast cancer, or automobile accidents (Institute of Medicine, 2000; 2001). According to the Institute of Medicine in its landmark *Quality Chasm* report: “The frustration levels of both patients and clinicians have probably never been higher. Yet the problems remain. Health care today harms too frequently and routinely fails to deliver its potential benefits” (IOM, 2001). Problems with U.S. health care not only influence patients; they impact staff. Registered nurses have a turnover rate averaging 20 percent (Joint Commission on Accreditation of Healthcare Organizations, 2002).

At the same time, the United States is facing one of the largest hospital building booms in US history. As a result of a confluence of the need to replace aging 1970s hospitals, population shifts in the United States, the graying of the baby boom generation, and the introduction of new technologies, the United States will spend more than $16 billion for hospital construction in 2004, and this will rise to more than $20 billion per year by the end of the decade (Babwin, 2002). These hospitals will remain in place for decades.

This once-in-a-lifetime construction program provides an opportunity to rethink hospital design, and especially to consider how improved hospital design can help reduce staff stress and fatigue and increase effectiveness in delivering care, improve patient safety, reduce patient and family stress and improve outcomes and improve overall healthcare quality.

Just as medicine has increasingly moved toward “evidence-based medicine,” where clinical choices are informed by research, healthcare design is increasingly guided by rigorous research linking the physical environment of hospitals to patients and staff outcomes and is moving toward “evidence-based design” (Hamilton, 2003). This report assesses the state of the science that links characteristics of the physical setting to patient and staff outcomes:

- What can research tell us about “good” and “bad” hospital design?
- Is there compelling scientifically credible evidence that design genuinely impacts staff and clinical outcomes?
- Can improved design make hospitals less risky and stressful for patients, their families, and for staff?

In this project, research teams from Texas A&M University and Georgia Tech combed through several thousand scientific articles and identified more than 600 studies—most in top peer-reviewed journals—that establish how hospital design can impact clinical
outcomes. The team found scientific studies that document the impact of a range of design characteristics, such as single-rooms versus multi-bed rooms, reduced noise, improved lighting, better ventilation, better ergonomic designs, supportive workplaces and improved layout that can help reduce errors, reduce stress, improve sleep, reduce pain and drugs, and improve other outcomes. The team discovered that, not only is there a very large body of evidence to guide hospital design, but a very strong one. A growing scientific literature is confirming that the conventional ways that hospitals are designed contributes to stress and danger, or more positively, that this level of risk and stress is unnecessary: improved physical settings can be an important tool in making hospitals safer, more healing, and better places to work.

**RESEARCH PROCESS**

The research teams searched through scores of databases and in libraries at Texas A&M, Georgia Institute of Technology, University of Michigan, and elsewhere. The team was looking for studies that are:

- Rigorous, in that they use appropriate research methods that allow reasonable comparisons, and discarding of alternative hypotheses. The research studies were assessed on their rigor, quality of research design, sample sizes, and degree of control.

- High impact, in that the outcomes they explore are of importance to healthcare decision-makers, patients, clinicians, and society.

In 1998, Haya Rubin and her colleagues Amanda Owens and Greta Golden found 84 studies produced since 1968 that met similar criteria (Rubin, Owens, & Golden, 1998). Reviewing the research literature six years later, the team estimated that they would find around 125 rigorous studies. We found more than 600.

**RESULTS**

The research team found rigorous studies that link the physical environment to patient and staff outcomes in four areas:

1. Reduce staff stress and fatigue and increase effectiveness in delivering care
2. Improve patient safety
3. Reduce stress and improve outcomes
4. Improve overall healthcare quality

**I. Reduce Staff Stress and Fatigue and Increase Effectiveness in Delivering Care**

There is a growing nurse shortage, and this directly threatens patient safety. And the existing hospital-based nursing force is aging. Registered nurses in the United States average more than 43 years old and will average 50 by 2010 and have a turnover rate
The Joint Commission on Accreditation of Healthcare Organizations (JCAHO), in their 2002 report, *Health Care at the Crossroads: Strategies for Addressing the Evolving Nursing Crisis*, noted that a shortage of nurses in America's hospitals is putting patient lives in danger. JCAHO examined 1,609 hospital reports of patient deaths and injuries since 1996 and found that low nursing staff levels were a contributing factor in 24 percent of the cases. The JCAHO report and surveys of nursing found that physical working conditions, along with support and compensation, are key contributors to turnover and burnout. Environmental support for work has become more critical as the typical patient is more seriously ill, patient loads increase, technology changes, and documentation requirements increase.

While reducing staff stress and fatigue through a healing and supportive environment seems like an obvious goal, there are relatively few studies that have dealt with this issue in any detail. More attention has been given to patient outcomes. However, the following sections review several studies that do document (a) effects of healthcare environments on staff health and safety and (b) improving workplaces to increase staff effectiveness, reduce errors, and increase staff satisfaction. Each section also suggests directions for further research.

**Improve Staff Health and Safety through Environmental Measures**

Nurses, physicians, and other healthcare employees work under extremely stressful physical conditions. Several studies deal with healthcare employees’ risk of contracting infectious diseases from patients due to airborne and surface contamination (Jiang et al., 2003; Kromhout et al., 2000; Kumari et al., 1998; Smedbold et al., 2002). A recent study conducted in the wake of the SARS epidemic in China found that isolating SARS cases in wards with good ventilation could reduce the viral load of the ward and might be the key to preventing outbreaks of SARS among healthcare workers, along with strict personal protection measures in isolation units (Jiang et al., 2003). Another study in Norway found correlations between environmental factors and nasal symptoms of 115 females who worked at 36 geriatric nursing departments. They found significant decrease in nasal inflammation in relation to presence of *Aspergillus fumigatus* in ventilation supply and elevated room temperatures (Smedbold et al., 2002). An evaluation of 17 acute-care or university hospitals in Canada shows that tuberculosis (TB) infection among healthcare workers was associated with ventilation of general or nonisolation patient rooms of less than two air exchanges per hour. The evaluation included all personnel who worked at least two days per week in the respiratory and physiotherapy departments (Menzies, Fanning, Yuan, & Fitzgerald, 2000). This study, like the others, supports the importance of adequate ventilation with good maintenance for ensuring both staff and patient safety in hospitals. Several good studies demonstrating the risk of the sick building syndrome in hospitals also have been compiled within the 2003 *Guidelines for Environmental Infection Control in Healthcare Facilities* by the US Centers for Disease Control and Prevention (CDC) and the Healthcare Infection Control Practices Advisory Committee (HICPAC) (Sehulster & Chinn, 2003).
Nursing staff members are also open to risk of injury from medical equipment such as high-intensity surgical-light sources. One study found that a light source used during surgery could potentially cause retinal damage in surgical staff (Fox & Henson, 1996). Much research has examined the effects of noise on patients, but comparatively few studies are available for healthcare staff. There is evidence that staff perceive higher sound levels as stressful (Bayo, Garcia, & Garcia, 1995; Norbeck, 1985). Importantly, noise-induced stress in nurses correlates with reported emotional exhaustion or burnout (Topf & Dillon, 1988). A recent study by Blomkvist et al. (in press, 2004) examined the effects of higher versus lower noise levels on the same group of coronary intensive-care nurses over a period of months. Lower noise levels were linked with a number of positive effects on staff, including reduced perceived work demands, increased workplace social support, improved quality of care for patients, and better speech intelligibility.

Poor ergonomic design of patient beds and nurses’ stations leads to back stress, fatigue, and other injuries among nursing staff. In one nursing home study, Garg and Owen evaluated manual tasks deemed stressful by nursing staff and used the information to select patient-transferring devices and to modify toilets and shower rooms. This nursing intervention resulted in a reduction of back injuries of almost 50 percent, from 83 per 200,000 work hours to 47 per 200,000 work hours. Also, in the four months after the intervention, there were no injuries resulting in lost or restricted workdays (Garg & Owen, 1992).

Thus, reducing staff stress by ergonomic interventions, as well as careful consideration of other issues such as air quality, noise, and light, can have significant impact on staff health. In addition, it is also likely to send a message that maintaining health and safety of staff members is an important goal for the organization.

Increase Staff Effectiveness, Reduce Errors, and Increase Staff Satisfaction by Designing Better Workplaces

Jobs by nurses, physicians, and others often require a complex choreography of direct patient care, critical communications, charting, filling meds, access to technology and information, and other tasks. Many hospital settings have not been rethought as jobs have changed, and, as a result, the design of hospitals often increases staff stress and reduces their effectiveness in delivering care. While much research in the hospital setting has been aimed at patients, there is a growing and convincing body of evidence suggesting that improved designs can make the jobs of staff much easier.

Nurses spend a lot of time walking. According to one study, almost 28.9 percent of nursing staff time was spent walking (Burgio, Engel, Hawkins, McCorick, & Scheve, 1990). This came second only to patient-care activities, which accounted for 56.9 percent of observed behavior. At least four studies have shown that the type of unit layout (e.g. radial, single corridor, double corridor) influences amount of walking among nursing staff (Shepley, 2002; Shepley & Davies, 2003; Sturdavant, 1960; Trites, Galbraith, Sturdavant, & Leckwart, 1970), and two studies showed that time saved walking was translated into more time spent on patient-care activities and interaction with family
members. Sturdavant (1960) found that fewer trips were made to patient rooms in radial units as nurses were able to better supervise patients visually from the nursing station, though the average time spent with patients was the same in radial as well as single-corridor designs. Shepley and colleagues (2003) found that nursing staff in the radial unit walked significantly less than staff in the rectangular unit (4.7 steps per minute versus 7.9 steps per minute). However, Shepley and her colleagues noted that radial designs might provide less flexibility in managing patient loads. Trites and colleagues (1970) found that a decrease in the percentage of time spent walking by staff in radial units was correlated to an increase in the percentage of time spent in patient-care activities. Also, the majority of the staff surveyed preferred to work in the radial units. Hendrich’s research showed that decentralized nurses stations reduced staff walking and increased patient-care time, especially when supplies also were decentralized and placed near the nurses’ station (Hendrich, 2003; IOM, 2004). Centralized location of supplies, however, could double staff walking and substantially reduce care time irrespective of whether nurses stations were decentralized (Hendrich, 2003).

Workplace design that reflects a closer alignment of work patterns and the physical setting, such as redesign of a pharmacy layout, has been shown to improve work flow and reduce waiting times, as well as increase patient satisfaction with the service (Pierce, Rogers, Sharp, & Musulin, 1990). Other studies that compared delivery times in decentralized and centralized pharmacy systems found medication delivery times are reduced by more than 50 percent by using decentralized drug-dose distribution systems (Hibbard, Bosso, Sward, & Baum, 1981; Reynolds, Johnson, & Longe, 1978).

Other aspects of the environment, such as lighting levels and auditory or visual distractions, can also affect staff effectiveness while performing critical tasks such as dispensing medical prescriptions. There are relatively few studies that have examined the effect of environmental factors on medication errors, though this is clearly an area of great interest and future research potential. This is discussed in greater detail in the following section.

II. Improve Patient Safety

Hospital-Acquired Infections

One critically important way that evidence-based design improves safety is by reducing risk from hospital-acquired infections. The research team identified more than 120 studies linking infection to the built environment of the hospital. Transmission of infection to patients occurs through two general routes: airborne and contact. The research literature shows that the design of the physical environment strongly impacts hospital-acquired infection rates by affecting both airborne and contact transmission routes. The literature suggests a clear pattern wherein infection rates are lower when there is very good air quality and patients are in single-bed rather than multi-bed rooms. Also, there is some evidence that providing numerous, easily accessible alcohol-based hand-rub
dispensers or hand washing sinks can increase hand washing compliance and thereby reduce contact contamination.

**Reducing Infections Caused by Airborne Pathogens**

Evidence from many studies leaves no doubt that hospital air quality and ventilation play decisive roles in affecting air concentrations of pathogens such as fungal spores (*Aspergillus*) and, in this way, have major effects on infection rates.

**Source of airborne infections:** Well-conducted research has linked all of the following to air quality and infection rates: type of air filter, direction of airflow and air pressure, air changes per hour in room, humidity, and ventilation system cleaning and maintenance (Lutz, 2003; McDonald et al., 1998). For example, in one study where six patients and one nurse were involved with an outbreak of epidemic methicillin-resistant *Staphylococcus aureus* (EMRSA-15), an environmental source was suspected, and the ventilation grilles in two patient bays were found to be harboring EMRSA-15 (Kumari et al., 1998). The ventilation system, at that time, was working on an intermittent cycle from 4:00 p.m. to 8:00 p.m. Daily shutdown of the system created negative pressure, sucking air in from the ward environment into the ventilation system and contaminating the outlet grilles. The contaminated air blew back into the ward when the ventilation system was started. In another case, the source of infection was the exhaust ducting of the adjacent isolation room ventilation system that allowed the contaminants to enter the unit via a partially open window positioned above a particular bed.

Several studies have identified hospital construction and renovation activities as the sources of airborne infection outbreaks due to dust or particulate generation (Humphreys et al., 1991; Iwen, Davis, Reed, Winfield, & Hinrichs, 1994; Loo et al., 1996; Opal et al., 1986; Oren, Haddad, Finkelstein, & Rowe, 2001). In one study, high spore counts were found within and outside construction sites in a hospital. After control measures were instituted, no further cases of disseminated aspergillosis were identified (Opal et al., 1986). In another study, a nosocomial (hospital-induced) outbreak of invasive pulmonary aspergillosis (IPA) occurred in acute leukemia patients treated in a regular ward with natural ventilation during extensive hospital construction and renovation. The observed infection rate was 50 percent. At this point, some of the patients were moved to a new hematology ward with high-efficiency particulate air (HEPA) filters. During the following three years, none of the patients hospitalized exclusively in the hematology ward developed IPA, although 29% of leukemia patients still housed in the regular ward contracted IPA (Oren et al., 2001).

**Controlling and preventing airborne infection:** There is convincing evidence that immunocompromised and other high-acuity patient groups have lower incidence of infection when housed in a HEPA-filtered isolation room (Passweg et al., 1998; Sherertz, et al., 1987; Sherertz & Sullivan, 1985). In one study, bone-marrow transplant recipients were found to have a tenfold greater incidence of nosocomial *Aspergillus* infection, compared to other immunocompromised patient populations, when assigned beds outside of a HEPA-filtered environment (Sherertz, et al., 1987). Air contamination is least in
laminar airflow rooms with HEPA filters, and this approach is recommended for operating-room suites and areas with ultraclean room requirements such as those housing immunocompromised patient populations (Alberti et al., 2001; Arlet, Gluckman, Gerber, Perol, & Hirsch, 1989; Dharan & Pittet, 2002; Friberg, Ardnor, & Lundholm, 2003; Hahn et al., 2002; Sherertz, et al., 1987). (Laminar flows are very even, smooth, low velocity airflows that are used in cleanrooms and other settings where high quality ventilation is critical. But laminar flows are relatively expensive and difficult to achieve because furnishings, vents and other features can create turbulence.) HEPA filters are suggested for healthcare facilities by the CDC and HICPAC, but are either required or strongly recommended in all construction and renovation areas (Sehulster & Chinn, 2003).

Effective prevention or control measures during construction and renovation activities include, for example, portable HEPA filters, installing barriers between the patient care and construction areas, negative air pressure in construction/renovation areas relative to patient-care spaces, and sealing patient windows. There is strong evidence of the impact of using HEPA filters for air intakes near construction and renovation sites (Loo et al., 1996; Mahieu, De Dooy, Van Laer, Jansens, & Ieven, 2000; Opal et al., 1986; Oren et al., 2001). A strong study by Humphreys (1991) demonstrates that HEPA filters are not by themselves an adequate control measure, and must be employed in conjunction with other measures such as enhanced cleaning, the sealing of windows, and barriers. Cornet et al. (1999) concludes that carefully directed airflow (e.g. laminar airflow) is important, however, we were unable to find and document cost-benefit analysis in the literature to justify the expense versus effectiveness of laminar airflow for patient-care areas near construction and renovation sites.

Reducing Infections by Increasing Hand Washing

Although infection caused by airborne transmission poses a major safety problem, most infections are now acquired in the hospital via the contact pathway (Bauer, Ofner, Just, Just, & Daschner, 1990; IOM, 2004). It is well-established that the hands of healthcare staff are the principal cause of contact transmission from patient to patient (Larson, 1988). The importance of assiduous hand washing by healthcare workers, accordingly, cannot be overemphasized for reducing hospital-acquired infections. In this context, the fact that rates of hand washing by healthcare staff are low represents a very serious patient safety challenge. Several studies of hand washing in high-acuity units with vulnerable patients have found that as few as one in seven staff members wash their hands between patients: compliance rates in the range of 15 percent to 35 percent are typical; rates above 40 percent to 50 percent are the exception (Albert & Condie, 1981; Graham, 1990). Hand washing compliance tends to be consistently lower in units that are understaffed and have a high patient census or bed-occupancy rate (Archibald, Manning, Bell, Banerjee, & Jarvis, 1997).

Education programs to increase hand washing adherence have yielded disappointing or, at best, mixed results. Some investigations have found that education interventions generate no increase at all in hand washing. Even intensive education or training
programs (classes, group feedback, for example) produce only transient increases in hand washing (Conly, Hill, Ross, Lertzman, & Louie, 1989; Dorsey, Cydulka, & Emerman, 1996; Dubbert, Dolce, Richter, Miller, & Chapman, 1990). Given the tremendous morbidity and mortality associated with high rates of hospital-acquired infections, there is an urgent need to identify more effective ways for producing sustained increases in hand washing. Is there evidence suggesting improved hospital design can be effective in elevating hand washing?

**Effect of number and location of sinks/dispensers on hand washing:** The research team identified six studies that examined whether hand washing is improved by increasing the ratio of the number of sinks or hand-cleaner dispensers to beds and/or by placing sinks or hand-cleaner dispensers in more accessible locations (Cohen, Saiman, Cimiotti, & Larson, 2003; Graham, 1990; Kaplan & McGuckin, 1986; Muto, Sistrom, & Farr, 2000; Pittet et al., 2000; Vernon, Trick, Welbel, Peterson, & Weinstein, 2003). These studies, on balance, offer support, though limited, for the notion that providing numerous, conveniently located alcohol-rub dispensers or washing sinks can increase compliance. In particular, the evidence suggests that installing alcohol-based hand-cleaner dispensers at bedside usually improves adherence. As an example, a study by Pittet et al. (2000) found that a combination of bedside antiseptic hand-rub dispensers and posters to remind staff to clean their hands substantially increased compliance. Cohen et al. (2003) likewise reported improved adherence in association with the installation of numerous alcohol-gel dispensers. By contrast, Muto et al. (2000) reported that placing alcohol-gel dispensers next to the doors of patient rooms did not increase adherence. Two other investigations focusing on sinks (water/soap) identified a positive relationship between observed frequency of hand washing and a higher ratio of sinks to beds (Kaplan & McGuckin, 1986; Vernon et al., 2003). Providing automated water/soap sinks, however, appears not to increase hand washing rates compared to traditional non-automated sinks (Larson, et al., 1991; Larson, Bryan, Adler, & Blane, 1997).

Further, three studies offer convincing and important evidence that providing single-patient rooms with a conveniently located sink in each room reduces nosocomial infection rates in intensive care units, such as neonatal intensive care (NICU) or burn units, compared to when the same staff and comparable patients are in multibed open units with few sinks (Goldmann, Durbin, & Freeman, 1981; McManus, A. T., Mason, McManus, & Pruitt, 1994; McManus, A. T., McManus, Mason, Aitcheson, & Pruitt, 1985; Mulin et al., 1997). Although hand washing frequency was not measured in these studies, the investigators posited that increased hand washing was an important factor in reducing infections in the units with single rooms and more sinks. A comparison of an ICU converted from an open unit with few sinks to single rooms with one sink per room found a nonsignificant tendency for hand washing to increase (from 16 percent to 30 percent) but no decline in infection incidence (Preston, Larson, & Stamm, 1981). These results are perhaps explainable by the fact that several sinks in the single-bed unit were placed in comparatively inaccessible or inconvenient locations, such as behind doors or away from staff work paths.
Despite the encouraging overall pattern of findings in these studies, it is not clear how much of the effectiveness in terms of increased hand washing or reduced infection rates can be attributed to the installation of more numerous and/or accessible sinks and alcohol-gel dispensers. Future research should include controlled experiments that systematically vary the number and location of hand-cleaning stations or dispensers. There is also a conspicuous need for studies that define accessible locations for hand-cleaning stations in an evidence-based manner—that is, on the basis of empirical analysis of staff movement paths, visual fields, interactions with patients and families, and work processes. In this regard, the neglect of human factors knowledge and research methods is a major weakness of the hand washing research and, more generally, of the infection control literature. Research teams should include a human factors specialist and often an environmental psychologist. The urgent need to increase hand washing frequency underscores the high priority that should be accorded this research direction.

**Reducing Infections with Single-Bed Rooms**

The research team identified at least 16 studies relevant to the question of whether nosocomial infection rates differ between single-bed and multi-bed rooms. The findings collectively provide a strong pattern of evidence indicating that infection rates are usually lower in single-bed rooms. Different mechanisms or factors have been identified or implicated as contributing to lower infection incidence in single rooms. One clear set of advantages relates to reducing airborne transmission through air quality and ventilation measures such as HEPA filters, negative room pressure to prevent a patient with an aerial-spread infection from infecting others, or maintaining positive pressure to protect an immunocompromised patient from airborne pathogens in nearby rooms. A strong study by Passweg et al. (1998) found that the combination of room isolation and HEPA filtration reduced infection and mortality in bone marrow transplant patients and significantly increased their one-year survival rates. Research studying burn patients also has shown that single rooms and good air quality substantially reduce infection incidence and reduce mortality (McManus, A.T. et al., 1994; McManus, A.T., Mason, McManus, & Pruitt, 1992; Shirani et al., 1986; Thompson, Meredith, & Molnar, 2002). Studies of cross-infection for contagious airborne diseases (influenza, measles, TB, for example) have found, as would be expected, that placing patients in single rooms is safer than housing them in multibed spaces (Gardner, Court, Brocklebank, Downham, & Weightman, 1973; McKendrick & Emond, 1976).

Severe Acute Respiratory Syndrome (SARS) outbreaks in Asia and Canada dramatically highlighted the shortcomings of multibed rooms for controlling or preventing infections both for patients and healthcare workers. SARS is transmitted by droplets that can be airborne over limited areas. Approximately 75 percent of SARS cases in Toronto resulted from exposure in hospital settings (Farquharson & Baguley, 2003). The pervasiveness in Canadian and Asian hospitals of multibed spaces in emergency departments and ICUs, together with the scarcity of isolation rooms with negative pressure, severely hindered treatment and control measures. Toronto hospitals were forced to create additional negative-pressure isolation rooms by quickly constructing wall barriers to replace bed curtains and making airflow and pressure adaptations (Farquharson & Baguley, 2003).
In addition to clear advantages in reducing airborne transmission, several studies show that single-bed rooms also lessen risk of infections acquired by contact. As background for understanding how single rooms can lessen contact spread, it should first be mentioned that many environmental surfaces and features become contaminated near infected patients. Examples of surfaces found to be contaminated frequently via contact with patients and staff include: overbed tables, bed privacy curtains, computer keyboards, infusion pump buttons, door handles, bedside rails, blood pressure cuffs, chairs and other furniture, and countertops (Aygun et al., 2002; Boyce, Potter-Bynoe, Chenevert, & King, 1997; Bures, Fishbain, Uyehara, Parker, & Berg, 2000; Devine, Cooke, & Wright, 2001; Neely & Maley, 2001; Noskin, Bednarz, Suriano, Reiner, & Peterson, 2000; Palmer, 1999; Roberts, Findlay, & Lang, 2001; Rountree, Beard, Loewenthal, May, & Renwick, 1967; Sanderson & Weissler, 1992; Williams, Singh, & Romberg, 2003). These and other contaminated surfaces and features act as pathogen reservoirs that increase cross-infection risk. Boyce et al. (1997) found that in the rooms of patients infected with methicillin-resistant *Staphylococcus aureus* (MRSA), 27 percent of all environmental surfaces sampled were contaminated with MRSA.

Compared to single-bed rooms, multi-bed rooms are far more difficult to decontaminate thoroughly after a patient is discharged, and therefore worsen the problem of multiple surfaces acting as pathogen reservoirs. Because different staff members who enter a room can touch the same contaminated surfaces, the risk of a nurse unknowingly becoming contaminated should be greater in multioccupancy rooms. Circumstantial support for this point is provided by research on contamination of nurses in units having patients infected by MRSA. Boyce et al. (1997) found that 42 percent of nurses who had no direct contact with an MRSA patient but had touched contaminated surfaces contaminated their gloves with MRSA.

In a study of MRSA infections in NICUs, Jernigan et al. (1996) reported that risk was lowered by isolation in single-bed rooms; high risk was associated with spatial proximity to an infected patient and shared exposure to caregivers. Ben-Abraham et al. (2002) found that nosocomial infection frequency was much lower in a single-bed pediatric intensive care unit than a unit with multi-bed rooms. The investigators tentatively concluded that single-bed rooms helped to limit person-to-person spread of pathogens between pediatric patients. Having a roommate has been identified as a risk factor for nosocomial diarrhea and gastroenteritis (Chang, V. T. & Nelson, 2000; Pegues & Woernle, 1993).

To summarize briefly, there is a convincing pattern of evidence across many studies indicating that single-bed rooms lower nosocomial infection rates. Singles appear to limit person-to-person and person-surface-person spread of infection in part because they are far easier to decontaminate thoroughly than multibed rooms after patients are discharged. Also, single rooms with a conveniently located sink or alcohol-gel dispenser in each room may heighten hand washing compliance compared to multibed rooms with few sinks. Finally, single rooms are clearly superior to multi-bed rooms with respect to reducing airborne transmission of pathogens.
Reducing Medication Errors

The research team identified three rigorous studies that link environmental factors, such as lighting, distractions, and interruptions, with errors in prescribing or dispensing medications (Booker & Roseman, 1995; Buchanan, Barker, Gibson, Jiang, & Pearson, 1991; Flynn et al., 1999). Although there are relatively few studies in this area, the findings suggest a promising research direction that merits further exploration, considering the vital importance of preventing medical errors in hospitals. Results from a large-scale study of the effects of different illumination levels on pharmacists’ prescription-dispensing error rates strongly suggested that such errors are reduced when work-surface light levels are relatively high (Buchanan et al., 1991). In this study, three different illumination levels were evaluated (450 lux, 1,100 lux, 1,500 lux). Medication-dispensing error rates were significantly lower (2.6 percent) at an illumination level of 1,500 lux (highest level), compared to an error rate of 3.8 percent at 450 lux. Two investigations of medication dispensing errors by hospital pharmacists found that error rates increased sharply for prescriptions when an interruption or distraction occurred, such as a telephone call (Flynn et al., 1999; Kistner, Keith, Sergeant, & Hokanson, 1994). Thus, lighting levels, frequent interruptions or distractions during work, and inadequate private space for performing work can be expected to worsen medication errors. The process of improving systems and processes to reduce medication errors in hospitals should include an assessment of the environment in which staff members perform their activities. Additional research is required to confirm the findings from studies as well as to identify ways to design better working environments that may reduce or prevent the likelihood of such errors occurring.

There is mounting evidence that the transfer of patients between rooms or different units is a source of medication errors (Cook, Render, & Woods, 2000). Reasons why errors plague room transfers include delays, communication discontinuities among staff, loss of information, and changes in computers or systems. The solution implied is to create an acuity-adaptable care process and patient rooms that substantially reduce transfers. When Methodist Hospital in Indianapolis, Indiana, changed from two-bed rooms in coronary intensive care to acuity-adaptable single-bed rooms, transfers declined 90 percent and medication errors were lowered by 67 percent (Hendrich, Fay, & Sorrells, 2002; 2004). Reducing transfers also saves much staff time, shortens patient stays, and reduces costs (IOM, 2004). Further studies and demonstration projects are needed to ascertain the safety advantages of acuity-adaptable rooms for other types of units and patient categories.

Reduce Patient Falls

There is a very large literature that looks at the causes and risk factors involved in patient falls in hospitals. This is an area of great importance because patients who fall incur physical injuries, psychological effects, and have greater lengths of stay in the hospital (Brandis, 1999). It is estimated that the total cost of fall injuries for older people was
around $20.2 billion per year in the United States in 1994, and is projected to reach $32.4 billion (in 1994 U.S. dollars) in 2020 (Chang, 2004). While the role of the environment in causing or preventing patient falls is widely accepted, there is not yet evidence conclusively tying environmental interventions with reduced falls. Available studies usually examine the location of fall incidents retrospectively or discuss environmental-modification programs such as improving lighting, securing carpeting, and so on. However, a meta-analysis and systematic review of randomized controlled trials of fall-prevention interventions found that there was no clear evidence for the independent effectiveness of environmental-modification programs (Chang, 2004).

Nonetheless, several studies have shown that most patient falls occur in the bedroom, followed by the bathroom, and that comprehensive fall-prevention programs can have an effect. Brandis (1999) reported transfers to and from bed as the cause of 42.2 percent of inpatient falls. Design faults identified in the bathroom and bedroom areas included slippery floors, inappropriate door openings, poor placement of rails and accessories, and incorrect toilet and furniture heights. After the fall-prevention program (which included identifying high-risk patients, management strategies, environmental and equipment modification, and standardization) was implemented, there was an overall decrease of 17.3 percent in falls. Thus, fall-prevention strategies that have included environmental modification have worked in the past. However, it is not clear how much of the effectiveness of such strategies can be attributed to environmental factors alone.

An innovative and promising environmental strategy for reducing falls has its origins in evidence suggesting that many falls occur when patients attempt to get out of bed unassisted or unobserved (Uden, 1985; Vassallo, Azeem, Pirwani, Sharma, & Allen, 2000). It should be mentioned that considerable evidence has shown that bedrails are ineffective for reducing the incidence of falls and may increase the severity of fall injuries from beds (Capezuti, Maislin, Strumpf, & Evans, 2002; Hanger, Ball, & Wood, 1999; van Leeuwen, Bennett, West, Wiles, & Grasso, 2001). To increase observation and improve assistance for patients and thereby reduce falls, Methodist Hospital in Indianapolis, Indiana, changed from a coronary critical care unit with centralized nurses stations and two-bed rooms to one having decentralized nurses stations and large single-bed rooms designed to support family presence (Hendrich, et al., 2002). Comparison of data from two years prior and three years after the new unit design showed that falls were cut by 2/3—from six-per-thousand patients to two-per-thousand. Given that falls are a critical safety problem, additional research is needed to understand the effectiveness of this approach for designing patient-care units.

**Improve Patient Confidentiality and Privacy**

Confidentiality has emerged as a priority issue in light of research showing that physicians and nurses very frequently breach patient confidentiality and privacy by talking in spaces where they are overhead by other patients or persons (Ubel, Zell, & Miller, 1995). The seriousness of the problem is underscored, for example, by a study of an emergency department at a university hospital that showed that 100 percent of physicians and other clinical personnel committed confidentiality and privacy breaches...
HIPAA, the Health Insurance Portability and Accountability Act of 1998, has further elevated the importance of providing reasonable safeguards to protect the confidentiality of staff conversations with and about patients.

Although the importance of the built environment for patient confidentiality may seem self-evident, only a few studies have directly examined the role of unit design or architecture. A study by Barlas et al. (2001) compared auditory and visual privacy for emergency department patients assigned to either multibed spaces with curtain partitions or rooms with solid walls. Those with curtains reported having far less auditory and visual privacy than patients with walls. An important finding was that 5 percent of the patients in curtained spaces reported they withheld portions of their medical history and refused parts of their physical examination because of lack of privacy (Barlas et al., 2001). None of the patients in rooms with walls reported withholding information. The fact that some emergency department patients with curtains withheld information suggests that lack of privacy can reduce patient safety. Additional convincing evidence of the importance of the emergency department physical environment comes from a study that documented frequent breaches of auditory and visual privacy and confidentiality in areas with curtains compared to rooms with solid walls (Mlinek & Pierce, 1997). A recent questionnaire study of staff in four West Coast hospitals found that nurses overwhelmingly judged single rooms to be superior to double rooms for examining a patient (85 percent) and for collecting a patient’s history (82 percent) (Chaudhury, Mahmood, & Valente, 2003).

There is a clear need for additional studies that examine privacy and confidentiality breaches associated with the physical environment in single versus double rooms, multibed spaces in ICUs and other types of units, and in spaces such as waiting rooms and nurses’ stations. As well, priority should be accorded to generating more research that investigates how the quality of communication and information from patients to physicians and nurses is affected by the unit architecture.

Analysis of patient satisfaction data made available by Press Ganey (2003) for this report leaves no doubt that patients in single-bed rooms, compared to those with a roommate, are consistently much more satisfied with “concern for your privacy.” The satisfaction data were obtained from 2,122,439 patients who received care during 2003 in 1,462 healthcare facilities (Press Ganey, 2003). Fifty-six percent of the patients were in single rooms; 44 percent had a roommate. Greater satisfaction with privacy in single rooms was evident across all major patient categories and types of unit and across different age and gender groups. Satisfaction with privacy was 4.5 percent higher on average nationally in single rooms than doubles—a substantial difference considering that it can be difficult for hospitals to increase satisfaction scores by even 1 percent to 2 percent.
III. Reduce Stress and Improve Outcomes

Reduce Noise

The research team identified more than 130 references focusing on noise in hospitals in the research literature. Studies tend to fall into three broad categories: those that measure noise levels in hospital spaces but do not assess outcomes, studies of the effectiveness of environmental and/or organizational interventions in reducing noise, and investigations of the effects of noise on outcomes.

World Health Organization guideline values for continuous background noise in hospital patient rooms are 35 dB, with nighttime peaks in wards not to exceed 40 dB (Berglund, Lindvall, & Schwela, 1999). These guidelines notwithstanding, many studies have shown that hospital background noise levels fall in far higher ranges. Background noise levels typically are 45 dB to 68 dB, with peaks frequently exceeding 85 dB to 90 dB (Aaron et al., 1996; Allaouchiche, Duflo, Debon, Bergeret, & Chassard, 2002; Blomkvist et al., in press, 2004; Falk & Woods, 1973; Hilton, 1985; McLaughlin, McLaughlin, Elliott, & Campalani, 1996; Robertson, Cooper-Peel, & Vos, 1998). In judging these noise levels, it is worth noting that the decibel scale is logarithmic; each 10 dB increase represents approximately a doubling in the perceived sound level. A 60 dB sound, accordingly, is perceived as roughly four times as loud as a 40 dB sound. Medical equipment and staff voices often produce 70 dB to 75 dB levels measured at the patient’s head, which approach the noise level in a busy restaurant (Blomkvist et al., in press, 2004). Noises from alarms and certain equipment exceed 90 dB (for example, portable X-ray machine), which is comparable to walking next to a busy highway when a motorcycle or large truck passes. A study in a NICU measured peak levels once per minute and found that 31 percent of peaks exceed 90 dB (Robertson et al., 1998). Noise peaks in hospitals can be extraordinarily loud. A recent study recorded 113 dB during shift changes at a large hospital (Cmiel, Karr, Gasser, Oliphant, & Neveau, 2004). Operating room noises from drills, saws, and other equipment are in the range of 100 dB to 110 dB, presenting a significant risk for noise-induced hearing loss (Hodge & Thompson, 1990; Love, 2003; Nott & West, 2003).

The research reviewed suggests that hospitals are excessively noisy for two general reasons (Ulrich, Lawson, & Martinez, 2003). First, noise sources are numerous, often unnecessarily so, and many are loud. Well-documented examples include paging systems, alarms, bedrails moved up/down, telephones, staff voices, ice machines, pneumatic tubes, trolleys, and noises generated by roommates. Second, environmental surfaces—floors, walls, ceilings—usually are hard and sound-reflecting, not sound-absorbing, creating poor acoustic conditions. Sound-reflecting surfaces cause noise to propagate considerable distances, traveling down corridors and into patient rooms, and adversely affecting patients and staff over larger areas. Sound-reflecting surfaces typical of hospitals cause sounds to echo, overlap, and linger or have long reverberation times (Blomkvist et al., in press, 2004; Ulrich et al., 2003).
Environmental interventions that have proven especially effective for reducing noise and improving acoustics in hospital settings include: installing high-performance sound-absorbing ceiling tiles, eliminating or reducing noise sources (for example, adopting a noiseless paging system), and providing single-bed rather than multibed rooms. In general, studies of the effectiveness of noise-reduction measures suggest that environmental or design interventions are more successful than organizational interventions such as staff education or establishing quiet hours (Gast & Baker, 1989; Moore, 1998; Walder, Francioli, Meyer, Lancon, & Romand, 2000).

A clear-cut finding in the literature is that noise levels are much lower in single-bed than multi-bed rooms. Studies of multi-bed rooms in acute care and intensive care units have shown that most noises stem from the presence of another patient (staff talking, staff caring for other patients, equipment, visitors, patient sounds such as coughing, crying out, rattling bed rails) (Baker, 1984; Southwell & Wistow, 1995; Yinnon, Ilan, Tadmor, Altarescu, & Hershko, 1992). A study of multi-bed bays in a children’s hospital concluded that noise levels were so high that consideration should be given to abolishing open bay rooms (Couper et al., 1994). Further, patient satisfaction data provided for this report by Press Ganey (2003) unequivocally show that patients in single-bed rooms, compared to those with a roommate, are vastly more satisfied with the “noise levels in and around your room.” The satisfaction data, as noted in an earlier section, were obtained from 2,122,439 patients who received care during 2003 in 1,462 healthcare facilities (Press Ganey, 2003). Far higher satisfaction with noise levels in single rooms was evident across all major patient categories and types of unit and across different age and gender groups. Satisfaction with noise level was 11.2 percent higher on average nationally in single rooms than doubles—a huge difference. As was noted above, it can be difficult for hospitals to achieve even 1 percent to 2 percent increases in patient satisfaction scores. The combination of findings from noise-level measurement studies and patient-satisfaction surveys highlight the great advantage of providing single rooms, compared to two-bed rooms, with respect to reducing noise.

A considerable body of research has documented negative effects of noise on patient outcomes. Several studies have focused on infants in NICUs, finding that higher noise levels, for example, decrease oxygen saturation (increasing need for oxygen support therapy), elevate blood pressure, increase heart and respiration rate, and worsen sleep (Johnson, 2001; Slevin, Farrington, Duffy, Daly, & Murphy, 2000; Zahr & de Traversay, 1995). Much research on adults and children has unequivocally shown, as might be expected, that noise is a major cause of awakenings and sleep loss (Blomkvist et al., in press, 2004; Gabor et al., 2003; Meyer et al., 1994; Parthasarathy & Tobin, 2004; Schnelle, Ouslander, Simmons, Alessi, & Gravel, 1993; Topf, 1985; Topf & Davis, 1993; Topf & Thompson, 2001; Yinnon et al., 1992). In multi-bed rooms, noises stemming from the presence of other patients often are the major cause of sleep loss. Berg (2001) found, by monitoring brain activity, that even relatively low decibel levels—38 dB to 40 dB—when coupled with longer reverberation times (sound-reflecting ceiling) significantly fragmented and worsened sleep of volunteers in patient rooms. Berg’s (2001) findings have disturbing implications because most hospitals have nighttime sound peaks exceeding those of the patient rooms in his study.
Apart from worsening sleep, there is strong evidence that noise increases stress in adult patients, for example, heightening blood pressure and heart rate (Baker, 1992; Morrison, Haas, Shaffner, Garrett, & Fackler, 2003; Novaes, Aronovich, Ferraz, & Knobel, 1997; Topf & Thompson, 2001). A recent study by Blomkvist et al. (in press, 2004) examined the effects of poor versus good sound levels and acoustics on coronary intensive-care patients by periodically changing the ceiling tiles from sound-reflecting to sound-absorbing tiles. When the sound-absorbing ceiling tiles were in place, patients slept better, were less stressed (lower sympathetic arousal), and reported that nurses gave them better care. There were also indications in this study that the incidence of re-hospitalization was lower if patients had experienced the sound-absorbing rather than sound-reflecting ceiling during their hospital stay (Hagerman et al., in press, 2004). More studies are needed such as that by Blomkvist et al. (in press, 2004), which use experimental research designs and systematically vary noise conditions. Future research should also investigate the effects of noise on re-hospitalization rates and other outcomes. In sum, the main message from the research review is clear: new hospitals should be much quieter, and effective design strategies for quieting hospitals are available.

**Improve Sleep**

The above section reviewed many studies showing that noise levels are high in hospitals and that noise is a major cause of poorer sleep in patients. Interventions that reduce hospital noise have been found to improve sleep and reduce patient stress. As noted earlier, environmental interventions found to be most effective for reducing noise in hospital settings include: providing single-bed rather than multi-bed rooms, installing high-performance, sound-absorbing ceiling tiles, using sound-absorbing flooring where possible, and eliminating or reducing noise sources (for example, use noiseless paging, locate alarms outside patient rooms).

**Reduce Spatial Disorientation**

Wayfinding problems in hospitals are costly and stressful and have particular impacts on outpatients and visitors, who are often unfamiliar with the hospital and are otherwise stressed and disoriented. In a study conducted at a major regional 604-bed tertiary-care hospital, the annual cost of the wayfinding system was calculated to be more than $220,000 per year in the main hospital or $448 per bed per year in 1990. Much of this cost was the hidden costs of direction giving by people other than information staff, which occupied more than 4,500 staff hours, the equivalent of more than two full-time positions (Zimring, 1990). While almost all hospitals strongly feel the problems associated with a complicated building and poor wayfinding system, it is usually difficult to tackle this problem with a piecemeal approach. A wayfinding system, as the name implies, is not just about better signage or colored lines on floors. Rather, hospitals are seeking to provide integrated systems that include coordinated elements such as visible and easy-to-understand signs and numbers, clear and consistent verbal directions, consistent and clear paper, mail-out and electronic information and a legible physical
A wayfinding system includes four main components that work at different levels: administrative and procedural levels, external building cues, local information and global structure.

**Administrative and procedural information:** Mail-out maps, electronic information available on the Web and at kiosks and verbal directions are organizational strategies aimed at providing key information to patients to prepare them for their hospital visit. This is not dealt with in this review.

**External building cues:** Signs and cues that lead to the hospital, especially the parking lot, need to be considered carefully, as they are the first point of contact of the patient with the hospital (Carpman, Grant, & Simmons, 1985). For example, Carpman, Grant and Simmons conducted a video simulation study to assess the relative role of signs and seeing a destination. The hospital wanted to direct most traffic to a parking structure rather than a drop-off lane. When the researchers showed prospective visitors a simulated video showing a design alternative that allow arriving drivers to see the main pavilion with the drop-off lane, 37 percent of the respondents said that they would turn into the drop circle when they could see the entry to the garage, ignoring the signs. As a consequence, the hospital chose to redesign the entry.

**Local information:** Once patients find their way to the building from the parking lot, they are faced with the prospect of identifying the destination. Informational handouts, information desks, you-are here maps, directories, and signage along the way are critical wayfinding aids (Carpman, Grant, & Simmons, 1983-84; Levine, Marchon, & Hanley, 1984; Nelson-Shulman, 1983-84; Wright, Hull, & Lickorish, 1993). In an experimental study, researchers found that patients who had the benefit of an information system (welcome sign, hospital information booklet, patient letter, orientation aids) upon reaching the admitting area were more self-reliant and made fewer demands on staff. In contrast, uninformed patients rated the hospital less favorably and were found to have elevated heart rates (Nelson-Shulman, 1983-84).

Information provided in you-are-here maps can be useful. However, you-are-here maps should be oriented so that the top signifies the direction of movement for ease of use. When the maps were aligned in directions other than the forward position, people not only took much longer to find their destination, but were significantly less accurate (Levine et al., 1984). Another study found that people who used signs found their destination faster than those who only used maps (Butler, Acquino, Hissong, & Scott, 1993). However, people who were given a combination of handheld maps and wall signs reached their destination more often than those who just used wall signs (Wright et al., 1993).

It is critical to design signage systems with logical room numbering and comprehensible nomenclature for departments (Carpman & Grant, 1993; Carpman, Grant, & Simmons, 1984). For example, inpatients, outpatients, and visitors to a hospital preferred simple terms such as walkway or general hospital over more complex or less-familiar terms such as overhead link, medical pavilion or health-sciences complex.
Contrary to the belief that fewer signs in hospital hallways means less clutter and hence less confusion, an experimental study in a hospital found that patients who had access to more number of signs along the way to the destination were faster, less hesitant, asked for directions a fewer number of times, and reported lower levels of stress (Carpman et al., 1984). Based on this study, the authors suggest that directional signs should be placed at or before every major intersection, at major destinations, and where a single environmental cue or a series of such cues (e.g. change in flooring material) convey the message that the individual is moving from one area into another. If there are no key decision points along a route, signs should be placed approximately every 150 feet to 250 feet.

**Global structure:** In addition to local properties of the spaces that people move through, there are specific characteristics of the overall structure of the system of rooms and corridors that impact the paths people take (Haq & Zimring, 2003; Peponis, Zimring, & Choi, 1990). People tend to move toward spaces and through corridors that are more accessible from a greater number of spaces. Based on observations of search patterns of study participants in a hospital and use of objective measures that quantify spatial characteristics, researchers found that participants tended to move along more “integrated” routes—routes that are, on average, more accessible because they are fewer turns from all other routes in the hospital. This research suggests that it may be important to identify such integrated routes in the plan while placing important facilities and key points such as the entrance (Peponis et al., 1990).

The research supports the value of a systems approach to wayfinding. Wayfinding continues to be a pervasive problem in hospitals because it is not sufficient to consider one or two components separately. Well-designed signs are likely to be quite ineffective in a building that is highly complicated and does not provide simple cues that enable natural movement. While there are more than 17 studies that look at wayfinding in hospitals and other buildings (Brown, Wright, & Brown, 1997; Carpman & Grant, 1993; Carpman et al., 1983-84, 1984; Carpman et al., 1985; Christensen, 1979; Grover, 1971; Haq & Zimring, 2003; Levine et al., 1984; Moeser, 1988; Nelson-Shulman, 1983-84; Ortega-Andeane & Urbina-Soria, 1988; Passini, Rainville, Marchand, & Joanette, 1995; Peponis et al., 1990; Schneider, L. F. & Taylor, 1999; Weisman, 1981; Wright et al., 1993; Zimring & Templer, 1983-84), it is quite difficult to isolate single influences of design on wayfinding performance or of wayfinding on outpatient or visitor stress. The problem is exacerbated by the fact that most hospitals have existing complex buildings upon which they try to superimpose a signage system to make things work. This strategy is ineffective in most cases.

There are some very good studies that deal with designing better signage, optimal spacing and location of signage, types of information that are most effective in way finding, and so on. Similarly, other studies at the global scale have looked at the properties of the building layout that facilitate or impede movement. It is essential that these different pieces of information come together while designing new hospitals where there is opportunity to develop an effective wayfinding system at multiple levels. Additional
studies are needed to ascertain the magnitude of stress that wayfinding problems have on outpatients and family.

Reduce Depression

Several studies strongly support that bright light—both natural and artificial—can improve health outcomes such as depression, agitation, sleep, circadian rest-activity rhythms, as well as length of stay in demented patients and persons with seasonal affective disorders (SAD). At least eleven strong studies suggest that bright light is effective in reducing depression among patients with bipolar disorder or SAD. Further, seven studies show that exposure to morning light is more effective than exposure to evening light in reducing depression (Beauchemin & Hays, 1996; Benedetti, F., Colombo, C., Barbini, B., Campori, E., & Smeraldi, E., 2001; Lewy et al., 1998; Lovell, Ancoli-Israel, & Gevirtz, 1995; Terman, Terman, Lo, & Cooper, 2001; Van Someren, Kessler, Mirmiran, & Swaab, 1997; Wallace-Guy et al., 2002). An experimental study that compared the effect of morning and evening light on patients with winter depression found that morning light was twice as effective as evening light in treating SAD (Lewy et al., 1998). Exposure to bright morning light has been shown to reduce agitation among elderly patients with dementia. When elderly patients with dementia were exposed to 2,500 lux for two hours in the morning for two ten-day periods, their agitation reduced. Patients were significantly more agitated on non-treatment days (Lovell et al., 1995).

There is also strong evidence that exposure to bright light improves sleep and circadian rhythms. When the daytime environmental illumination level was increased in different living spaces of a dementia unit, it was found that, during increased illumination periods, the stability of the rest-activity rhythm increased in patients with intact vision, but not in visually impaired patients (Van Someren et al., 1997).

It has also been shown that patients in brightly lit rooms have a shorter length of stay compared to patients in dull rooms. Beauchemin and Hays (1996) found that patients hospitalized for severe depression reduced their stays by an average of 3.67 days if assigned to a sunny rather than a dull room overlooking spaces in shadow.

A recent randomized prospective study assessed whether the amount of sunlight in a hospital room modifies a patient’s psychosocial health, quantity of analgesic medication used, and pain medication cost (Walch et al., 2004, in press). Patients undergoing elective cervical and lumbar spinal surgeries were admitted to the bright or the dim side of the inpatient surgical ward postoperatively. The outcomes measured included the standard morphine equivalent of all opioid medication used postoperatively by patients and their subsequent pharmacy cost. This strong study found that patients exposed to an increased intensity of sunlight experienced less perceived stress, less pain, took 22 percent less analgesic medication per hour and had 20 percent less pain medication costs.

Using light as an intervention to reduce depression in clinically depressed as well as non-depressed patients is a relatively inexpensive intervention that has been shown to yield consistently positive results. While many studies deal with the effects of artificial light,
natural daylight in patient rooms has also been found effective in reducing depression, reducing length of stay, and reducing intake of pain medication. Thus, an important consideration while designing hospital layouts may be to optimize exposure to morning light in patient rooms by using an east-facing orientation. This research further implies the possibility that depression might be worsened by architectural designs that block or sharply reduce natural daylight in patient rooms. A hypothetical example would be a hospital having patient-room windows looking out into a roofed atrium with few skylights and little natural daylight. In this example, deprivation of natural daylight could be extreme if patient windows were tinted to prevent users of the atrium from looking into patient rooms and violating privacy.

**Provide Nature and Positive Distraction**

Positive distractions refer to a small set of environmental features or conditions that have been found by research to effectively reduce stress. Distractions can include certain types of music, companion animals such as dogs or cats, laughter or comedy, certain art, and especially nature (Ulrich, 1991). The focus here is on the last, nature. (There is an additional large research literature on music, but this is not covered in this review.)

As background relevant to assessing the credibility of nature findings in healthcare environments, it should be mentioned that many studies of populations other than hospital patients have produced strong evidence that even fairly brief encounters with real or simulated nature settings can elicit significant recovery from stress within three minutes to five minutes at most (Parsons & Hartig, 2000; Ulrich, 1999). Investigators have consistently reported that stress-reducing or restorative benefits of simply viewing nature are manifested as a constellation of positive emotional and physiological changes. Stressful or negative emotions such as fear or anger diminish while levels of pleasant feelings increase. Laboratory and clinical studies have shown that viewing nature produces stress recovery quickly evident in physiological changes, for instance, in blood pressure and heart activity (Ulrich, 1991). By comparison, considerable research has demonstrated that looking at built scenes lacking nature (rooms, buildings, parking lots) is significantly less effective in fostering restoration and may worsen stress.

Questionnaire studies have found that bedridden patients assign especially high preference to having a hospital window view of nature (Verderber, 1986). Mounting research is providing convincing evidence that visual exposure to nature improves outcomes such as stress and pain. For example, a study in a Swedish hospital found that heart-surgery patients in ICUs who were assigned a picture with a landscape scene with trees and water reported less anxiety/stress and needed fewer strong doses of pain drugs than a control group assigned no pictures (Ulrich, 1991). Another group of patients assigned an abstract picture, however, had worsened outcomes compared to the control group. Ulrich (1984) found that patients recovering from abdominal surgery recovered faster, had better emotional well-being, and required fewer strong pain medications if they had bedside windows with a nature view (looking out onto trees) than if their windows looked out onto a brick wall.
Recently, strong studies using experimental designs have produced additional convincing evidence that viewing nature reduces patient pain as well as stress. These investigations also support the interpretation that nature serves as a positive distraction (Ulrich, 1991) that reduces stress and diverts patients from focusing on their pain or distress. A randomized prospective investigation found that adult patients undergoing a painful bronchoscopy procedure reported less pain if they were assigned to look at a ceiling-mounted nature scene rather than a control condition consisting of a blank ceiling (Diette, Lechtzin, Haponik, Devrotes, & Rubin, 2003). Another controlled experiment that used volunteers in a hospital assessed the effect on pain of viewing a soundless nature videotape in contrast to a static blank screen (Tse, Ng, Chung, & Wong, 2002). Subjects who watched the nature scenes evidenced a higher threshold for detecting pain and had substantially greater pain tolerance. Two studies of female cancer patients have shown that taking a virtual reality nature walk while in bed or a hospital room (through a forest with bird sounds) reduced anxiety and symptomatic distress (Schneider, S. M., Prince-Paul, Allen, Silverman, & Talaba, 2004). Research on patients suffering intense pain because of severe burns found that exposing patients to a videotape of scenic nature (forest, flowers, ocean, waterfalls) during burn dressing changes significantly reduced both anxiety and pain intensity (Miller, Hickman, & Lemasters, 1992).

The possibility that nature can improve outcomes even in patients with late-stage dementia, including Alzheimer’s disease, has received some support from a quasi-experimental study that found reduced levels of agitated aggressive behavior associated with a shower bath when recorded nature sounds (birds, babbling brook) and color pictures were present (Whall et al., 1997). A well-controlled study of blood donors in a waiting room found that blood pressure and pulse were lower on days when a wall-mounted television displayed a nature videotape, compared to days with continuous daytime television programs (Ulrich, Simons, & Miles, 2003). More research is needed to identify conditions under which television can either be a stress-reducing positive distraction or a stressor in hospitals.

**Gardens in healthcare environments:** Hospital gardens not only provide restorative or calming nature views, but can also reduce stress and improve outcomes through other mechanisms, for instance, fostering access to social support and providing opportunities for positive escape and sense of control with respect to stressful clinical settings (Cooper Marcus & Barnes, 1995; Ulrich, 1999). Based on postoccupancy evaluations of four hospital gardens in California, Cooper-Marcus and Barnes (1995) concluded that many nurses and other healthcare workers used the gardens for achieving pleasant escape and recuperation from stress. Other postoccupancy studies indicate that patients and family who use hospital gardens report positive mood change and reduced stress (Whitehouse et al., 2001). These reports also suggest that gardens and nature in hospitals can heighten patient and family satisfaction with overall quality of care.

**Art in healthcare environments:** A small number of studies on art in hospitals has yielded findings parallel to those from nature research. Results suggest a consistent pattern wherein the great majority of patients respond positively to representational
nature art, but many react negatively to chaotic abstract art (Ulrich & Gilpin, 2003). For example, Carpman & Grant (1993) studied the preferences of 300 randomly selected inpatients and concluded that the patients consistently preferred nature images but disliked abstract art. Although nature pictures and other emotionally appropriate art elicit positive reactions, there is also evidence that inappropriate art styles or image subject matter can increase stress and worsen other outcomes (Ulrich, 1991). It should not be expected that all art is suitable for high-stress healthcare spaces, as art varies enormously in subject matter and style, and much art is emotionally challenging or provocative.

The pitfalls of displaying emotionally challenging art in healthcare environments are revealed by a study of psychiatric patients (Ulrich, 1991). The unit was extensively furnished with a diverse collection of wall-mounted paintings and prints. Interviews with patients indicated strongly negative reactions to artworks that were ambiguous, surreal, or could be interpreted in multiple ways. The same patients, however, reported having positive feelings and associations with respect to nature paintings and prints.

Provide Social Support

Many studies of several different categories of patients have indicated that social support reduces stress and improves, for example, recovery outcomes in myocardial infarction patients. Considering the well-established importance of social support, it is unfortunate that there is only a moderate amount of research concerning how hospital design can facilitate or hinder access to social support. Most studies have focused on psychiatric units and nursing homes. There is strong evidence that levels of social interaction can be increased—and presumably beneficial social support as well—by providing lounges, day rooms, and waiting rooms with comfortable movable furniture arranged in small flexible groupings. A few well-designed studies in psychiatric wards and nursing homes have found that appropriate arrangement of movable seating in dining areas enhances social interaction and also improves eating behaviors, such as increasing the amount of food consumed by geriatric patients (Melin & Gotestam, 1981; Peterson, Knapp, Rosen, & al., 1977). Much research on day rooms and waiting areas has shown that the widespread practice of arranging seating side-by-side along room walls inhibits social interaction (Holahan, 1972; Sommer & Ross, 1958). A novel study by Harris (2000) found that family and friends stayed substantially longer during visits to rehabilitation patients when patient rooms were carpeted rather than covered with vinyl flooring.

Much evidence indicates that single rooms are markedly better than multi-bed rooms for supporting or accommodating the presence of family and friends. Some research suggests that open-plan multibed rooms deter family presence and accordingly reduce social support (Sallstrom, Sandman, & Norberg, 1987). Multibed rooms greatly reduce privacy for patient-family interactions compared to single rooms and are much more likely to have restricted visiting hours. A clear advantage of single rooms in fostering social support stems from the fact they provide more space and furniture than double rooms to accommodate family presence (Chaudhury et al., 2003). A survey of staff in four hospitals that each had a mix of single and double rooms found that nurses gave high
ratings to single rooms for accommodating family members but accorded double rooms low scores (Chaudhury et al., 2003). Further, patient-satisfaction data obtained from 2,122,439 patients who received care during 2003 provide overwhelming evidence that patients in single-bed rooms, compared to those with a roommate, are much more satisfied with “accommodations and comfort for family and visitors” (Press Ganey, 2003).

Do patients sharing the same room provide each other with stress-reducing social support? While some patients find roommates provide comforting social support, findings from several studies indicate that the presence of a roommate usually is a source of stress rather than social support. In most cases, roommates are linked to stressors, for example, loss of privacy or having a roommate who is unfriendly, has too many visitors, or is seriously ill (Van der Ploeg, 1988; Volicer, Isenberg, & Burns, 1977). An earlier section emphasized that noise is a much greater problem in double rooms than singles, and that noises stemming from the presence of other patients are a major cause of sleep loss.

**Improve Communication to Patients**

Good staff communication helps reduce patient and family anxiety, promotes better care at home after discharge, and in other ways can improve outcomes. Good communication also tends to be the single most important factor affecting overall satisfaction with care across different patient categories (Press Ganey, 2003). Data obtained from 2,122,439 patients nationally in 2003 show that patients consistently report significantly higher satisfaction with communication from nurses and physicians when they are in single rooms compared to when they have one or more roommates (Press Ganey, 2003). To explain this clear and important advantage of single rooms, Kaldenburg (1999) has proposed that staff in multibed rooms are reluctant to discuss patient issues or give information within hearing of a roommate, out of respect for privacy. Growing concern for patient confidentiality and HIPAA are certain to increase the already major advantages of single rooms with respect to communication.

**IV. Improve Overall Healthcare Quality**

**Provide Single-Bed Patient Rooms**

Based on an extremely large and varied body of research reviewed in earlier sections, there can be no question that single-bed rooms have several major advantages over double rooms and open bays. To summarize briefly, these advantages include: lower nosocomial infection rates, fewer patient transfers and associated medical errors, far less noise, much better patient privacy and confidentiality, better communication from staff to patients and from patients to staff, superior accommodation of family and consistently higher satisfaction with overall quality of care.
Reduce Length of Stay

Climate and sunlight influence the length of hospital stay as well as sleep-wake patterns among hospitalized patients (Beauchemin & Hays, 1996; Benedetti, Francesco, Colombo, Cristina, Barbini, Barbara, Campori, Euridice, & Smeraldi, Enrico, 2001; Federman, Drebing, Boisvert, Penk, 2000; Hebert, Dumont, & Paquet, 1998; Kecskes et al., 2003; Kinnunen, Saynajakangs, Tuuponen, & Keistinen, 2002). One research group studied the impact of the amount of natural light on the length of hospitalization of patients with unipolar and bipolar disorder. The researchers found that bipolar patients randomly assigned to the brighter, eastern rooms (exposed to direct sunlight in the morning) had a mean 3.67-day shorter hospital stay than patients in west-facing rooms (Benedetti, Francesco et al., 2001). Patients recovering from abdominal surgery had shorter stays if they had a bedside window view of nature rather than if their windows looked out onto a brick wall (Ulrich, 1984).

The large research literature on infection reviewed in an earlier section indicated that the design of the physical environment strongly impacts hospital-acquired infection rates by affecting both airborne and contact transmission routes. Evidence-based design measures, by reducing nosocomial infection rates, play a key role in shortening hospital stays.

Increase Patient Satisfaction with Quality of Care

There is strong evidence that design changes that make the environment more comfortable, aesthetically pleasing, and informative relieve stress among patients and increases satisfaction with the quality of care provided. Renovating a traditional waiting area in a neurology clinic by making small changes to the general layout, color scheme, furniture, floor covering, curtains, and providing informational material and information displays resulted in more positive environmental appraisals, improved mood, altered physiological state, and greater reported satisfaction among waiting patients (Leather, Beale, Santos, Watts, & Lee, 2003).

Patients in well-decorated and well-appointed hotel-like rooms rated their attending physicians, housekeeping, and food-service staff, the food, and the hospital better than patients in standard rooms (typical hospital beds, inexpensive family sitting chairs, and no artwork) in the same hospital. Also, they had stronger intentions to use the hospital again and would recommend the hospital to others (Swan, Richardson, & Hutton, 2003). In another study, it was found that environmental satisfaction was a significant predictor of overall satisfaction, ranking only below perceived quality of nursing and clinical care (Harris, P. B., McBride, Ross, & Curtis, 2002). Several post-occupancy evaluation studies have examined patient and staff satisfaction with the different elements of the healthcare environment such as gardens, individual wards, and patient rooms (Brown, Wright, & Brown, 1997; Heath & Gifford, 2001; Shepley, 1995, 2002; Shepley & Davies, 2003; Shepley & Wilson, 1999; Whitehouse et al., 2001). These studies yield rich context-specific data that describe which aspects of the environment were effective. Some studies show quite clearly that tacit, as well implicit, staff and organizational practices and policies influence how an environment actually functions and is perceived.
by patients and staff members. The qualitative and quantitative data provided by such studies are very important in understanding the nature of the problem (e.g. why are the gardens not being used as intended?) as well in developing solutions to tackle the problem. Future research that looks at satisfaction among hospital patients should consider using these multi-method post-occupancy evaluations that use different methods to obtain objective and subjective evaluations of use and satisfaction.

CONCLUSIONS

The research team found more than 600 rigorous studies linking a range of aspects of the built environment of hospitals to staff stress and effectiveness, patient safety, patient and family stress and healing, and improved overall healthcare quality and cost. This deep and wide base of evidence suggests that, parallel to evidence-based medicine, we can move to evidence-based design (EBD). EBD refers to a process for creating healthcare buildings, informed by the best available evidence, with the goal of improving outcomes and of continuing to monitor the success of designs for subsequent decision-making. While it is difficult to conduct rigorous research on the impacts of the healthcare environment—hospitals are complex systems where it is difficult to isolate the impact of single factors and the building industry conducts little impact-based research—The Center for Health Design and other groups have made considerable progress in developing a knowledge base of evidence.

EBD is not about hospitals that are simply nicer or fancier than traditional hospitals. Rather, the focus of evidence-based design is to create hospitals that actually help patients recover and be safer, and help staff do their jobs better. EBD is a process for creating health care buildings informed by the best available evidence concerning how the physical environment can interfere with or support activities by patients, families, and staff, and how the setting provides experiences that provide a caring, effective, safe, patient-centered environment. Many of the improvements suggested by EBD are only slightly more expensive than traditional solutions, if they are more expensive at all.

The large research literature surveyed in this report point to several actions we can take immediately:

- Provide single-bed rooms in almost all situations. Adaptable-acuity single-bed rooms should be widely adopted. Single rooms have been shown to lower hospital-induced nosocomial infections, reduce room transfers and associated medical errors, greatly lessen noise, improve patient confidentiality and privacy, facilitate social support by families, improve staff communication to patients, and increase patients’ overall satisfaction with health care.
- New hospitals should be much quieter to reduce stress and improve sleep and other outcomes. Noise levels will be substantially lowered by the following combination of environmental interventions: providing single-bed rooms, installing high-performance sound-absorbing ceilings, and eliminating noise sources (for example, using noiseless paging).
• Provide patients stress reducing views of nature and other positive distractions.
• Develop wayfinding systems that allow users, and particularly outpatients and visitors, to find their way efficiently and with little stress.
• Improve ventilation through the use of improved filters, attention to appropriate pressurization, and special vigilance during construction.
• Improve lighting, especially access to natural lighting and full-spectrum lighting.
• Design ward layouts and nurses stations to reduce staff walking and fatigue, increase patient care time, and support staff activities such as medication supply, communication, charting, and respite from stress.
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Reduce Stress and Improve Outcomes


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if anything, does your unit do to reduce noise levels in the ICU? Critical Care Nurse, 14(6), 88-89.


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Topf, M. (1992). Stress effects of personal control over hospital noise. Behavioral Medicine,


unit. *Archives of Internal Medicine, 130*(2), 225-226.


**Improve Overall Health-Care Quality**


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Judkins, S. (2003). Paediatric emergency department design: Does it affect staff, patient and


Press Ganey, Inc. (2003). National patient satisfaction data for 2003. (Provided by Press Ganey, Inc. at the request of the authors of this research review.)


The Role of the Physical Environment in the Hospital of the 21st Century: A Once-in-a-Lifetime Opportunity

Abstracts Table Supplement

Roger Ulrich*, Xiaobo Quan, Center for Health Systems and Design, College of Architecture, Texas A&M University
Craig Zimring*, Anjali Joseph, Ruchi Choudhary, College of Architecture, Georgia Institute of Technology

* Co-principal investigators and corresponding authors: Roger Ulrich, Ph.D.: ulrich@archone.tamu.edu; Craig Zimring, Ph.D.: craig.zimring@arch.gatech.edu.

Abstract supplement to a report to The Center for Health DesignSM for the Designing the 21st Century Hospital Project. This project is funded by the Robert Wood Johnson Foundation.

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# Abstracts Table

**Reduce Staff Stress**

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<tr>
<th>No.</th>
<th>Study</th>
<th>Environmental variable(s) studied</th>
<th>Outcome measure(s)</th>
<th>Research design</th>
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<th>Major findings</th>
<th>Grade</th>
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<tr>
<td>1</td>
<td>Alexandre, N. M., de Moraes, M. A., Corrêa Filho, H. R., &amp; Jorge, S. A. (2001). Evaluation of a program to reduce back pain in nursing personnel. <em>Revista de Saúde Pública, 35</em>(4), 356-361.</td>
<td>Intervention program: set of exercises and educational component stressing ergonomic aspect (included ergonomic orientation about workplace: work surface height, workspace, and height of reach)</td>
<td>Intensity of pain before and after ergonomic intervention program using a visual analog scale</td>
<td>Before-after study; intervention administered twice a week for four months</td>
<td>Nonprobabilistic sample of nursing aides less than 50 years: control group ($n = 29$) and intervention group ($n = 27$)</td>
<td>There was a statistically significant decrease in the frequency of cervical pain in the last two months and in the last seven days in the intervention group. There was also a reduction in cervical pain intensity in the two periods (two months, seven days) and lumbar pain intensity in the last seven days.</td>
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<td>2</td>
<td>Annis, J. F., Case, H. W., Clauser, C. E., &amp; Bradtmiller, B. (1991). Anthropometry of an aging work force. <em>Experimental Aging Research, 17</em>(3), 157-176.</td>
<td>Changes in weight and body dimensions from third to eighth decade of life</td>
<td>Age-associated changes in workspace dimensions</td>
<td>Literature review</td>
<td>Longitudinal and cross-sectional studies</td>
<td>Several body characteristics such as weight, volume, stature, depths, breadths, and circumferences change with age. While acknowledging the need for flexibility in future workplace designs, the authors conclude that age-related changes in body size are insufficient in themselves to justify the resizing of existing ergonomically designed workplaces.</td>
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<td><strong>Authors</strong></td>
<td><strong>Description</strong></td>
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<td>Daraiseh, N., Genaidy, A. M., Karwowski, W., Davis, L. S., Stambough, J., &amp; Huston, R. L. (2003). Musculoskeletal outcomes in multiple body regions and work effects among nurses: The effects of stressful and stimulating working conditions. <em>Ergonomics, 46</em>(12), 1178-1199.</td>
<td>Work demands (six categories: physical-task demands, mental-task demands, sensory demands, physical environmental demands, social demands, organizational demands) and work stimuli</td>
<td>Six general categories: 1) effort extended, 2) perceived risk of injury or illness, 3) work satisfaction and dissatisfaction, 4) energy state at end of workday, 5) psychosomatic outcomes, 6) musculoskeletal outcomes</td>
<td>Questionnaire; prospective study</td>
<td>34 registered female nurses from hospitals in U.S. Midwest</td>
<td>Effort was significantly associated with physical factors and organizational demands. Perceived risk was statistically positively correlated with task as well as physical-organizational environment demands; it was negatively correlated with social stimuli. Psychosomatic outcomes were positively correlated with environmental demands.</td>
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<td>5</td>
<td>Garg, A., &amp; Owen, B. (1992). Reducing back stress to nursing personnel: An ergonomic intervention in a nursing home. <em>Ergonomics</em>, 35(11), 1353-1375.</td>
<td>Ergonomic intervention strategy: training nursing assistants in use of patient transferring devices, modifying toilets and shower rooms, and applying techniques to patient care</td>
<td>Injury rates, intervention acceptability rates; biomechanical stresses; ratings of perceived exertion; mean task performance times</td>
<td>Prospective epidemiologic study; before-after study 57 nursing assistants from two units of nursing home</td>
<td>Biomechanical evaluation showed that the mean compressive force on the L5/S1 disc, the mean hand force required to make a transfer, and the strength requirements all decreased after intervention. Mean rating of perceived exertion was less than “very light” after intervention as compared to “somewhat hard” and “hard” before intervention. Acceptability rates were high (more than 80%) for assistive devices used. Incidence of back injuries decreased.</td>
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<td>7</td>
<td>Petzall, K., &amp; Petzall, J. (2003). Transportation with hospital beds. <em>Applied Ergonomics</em>, 34, 383-392.</td>
<td>Four types of tests beds with principally different wheel arrangements</td>
<td>Perception of effort (Borg’s category ratio scale) and perceived level of difficulty (visual analog scale)</td>
<td>Experimental; four common transport conditions were studied (transporting hospital bed along a 48m straight corridor, transport bed around corner, maneuver the bed into patient room, maneuver the bed) 22 registered nurses and enrolled nurses working at an ear, nose, and throat ward at Sahlgrenska University Hospital at Goteberg</td>
<td>Standard small-diameter castor wheels made the bed easier to maneuver in limited spaces, while larger wheels on fixed axles made the beds more comfortable for long-distance transportation.</td>
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<td><strong>Smedbold, H., Ahlen, C., Unimed, S., Nilsen, A., Norbaeck, D., &amp; Hilt, B. (2002).</strong> Relationships between indoor environments and nasal inflammation in nursing personnel. <em>Archives of Environmental Health, 57</em>(2), 155-161.</td>
<td><strong>Ventilation system</strong></td>
<td><strong>Nasal inflammation in nursing personnel</strong></td>
<td><strong>Retrospective study</strong></td>
<td>Clinical data of 115 females working in 36 geriatric nursing departments in Norway</td>
<td>Nasal patency due to fungal contamination of the air-supply ducts. The findings illustrate the significance of maintaining the ventilation systems and lowering room temperatures.</td>
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<td>8</td>
<td><strong>Smith, H., MacKintosh, P., Sverisdottir A, &amp; Robertson C. (1993).</strong> Improved coordination makes for faster work: Ergonomic analysis of a trauma resuscitation room. <em>Professional Nurse, 8</em>(11): 711-715.</td>
<td><strong>Work environment in trauma resuscitation room: location of equipment and personnel (nodes), links between equipment and work areas</strong></td>
<td><strong>Time spent on individual tasks as percentage of overall workload</strong></td>
<td><strong>Video recordings of activities in trauma resuscitation rooms were analyzed independently by three observers; two aspects examined: tasks of each individual, utilization of space, and staff movement for tasks in relation to room layout</strong></td>
<td><strong>First 15 minutes of resuscitation process on 19 occasions</strong></td>
<td>During 19 resuscitations, 2,760 internodal movements were performed by nursing and medical staff. Nurse moved significantly greater number of times than medical staff. Specific problem areas were identified and strategies developed for more efficient performance.</td>
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## Improve Patient Safety

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<td>1</td>
<td>Adeniran, A., Shakespeare, P., Patrick, S., Fletcher, A. J., &amp; Rossi, L. A. (1995). Influence of a changed care environment on bacterial colonization of burn wounds. <em>Burns, 21</em>(7), 521-525.</td>
<td>Air conditioning in specialized burn unit vs. traditional open ward with no specialized air conditioning</td>
<td>Bacterial colonization of burn wounds</td>
<td>Retrospective study of clinical and laboratory records in two phases; during period 1, patients managed on an 'open ward;' period 2, patients managed on the permanent unit</td>
<td>224 patients admitted to the permanent unit in 1992. 231 patients admitted to the temporary burn unit.</td>
<td>No significant difference in wound colonization rates was found between the two groups. Authors conclude that, a conditioned care environment per se does not influence bacterial colonization rates of burn wounds.</td>
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<td>2</td>
<td>Albert, R. K., &amp; Condie, F. (1981). Hand-washing patterns in medical intensive-care units. <em>New England Journal of Medicine, 304</em>(24), 1465-1466.</td>
<td>Hand washing by staff category</td>
<td>Hand-washing compliance (number of patient contacts followed by hand washing/total number of contacts)</td>
<td>Descriptive; hand-washing behavior observation (disguised)</td>
<td>1,212 direct contacts observed in 10 four-hour periods during morning working rounds in a university hospital; 297 during 20 hours in a private hospital.</td>
<td>The overall hand-washing compliance rates were 41% for the university hospital and 28% for the private hospital. In the university hospital, physicians’ compliance rate was lower than nurses. Compliance rates by physicians were 28% (university) and 14% (private), by nurses were 43% and 28%, by respiratory therapists were 76% and 48%, and by radiology technicians were 44% and 25%. The same pattern appeared in both hospitals.</td>
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<td>3</td>
<td>Alcee, D. A. (2000). The experience of a community hospital in quantifying and reducing patient falls. <em>Journal of Nursing Care Quality, 14</em>(3), 43-54.</td>
<td>Location of patient falls</td>
<td>Patient falls</td>
<td>Retrospective review of patient fall data: data were collected about number of falls, percentage of falls by nursing unit, location of falls, number of repeat</td>
<td>209 falls were documented in an eight-month period</td>
<td>Majority of patients fell during the night shift (8 p.m. to 8 a.m.); greatest percentage of falls occurred on the medical/oncology unit followed by the medical/orthopedic unit. Thirty percent of patients who fell were attempting to use the bathroom. As a result of this study, several organizational, staffing, and physical interventions were implemented.</td>
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<td>Anderson, R. L., Mackel, D. C., Stoler, B. S., &amp; Mallison, G. F. (1982).</td>
<td>Carpet contamination; colonization; infection rate</td>
<td>Six pools of carpet plugs (3 plugs per pool) and 6 samples of bare floor in each sampling period (total 58 periods); 23 patients in carpeted rooms and 36 in noncarpeted rooms.</td>
<td>Higher microorganism counts were found on carpeted floor than on bare vinyl-tile floor. Patients were colonized with the same types of organisms as those initially recovered from the carpet in patient rooms. No difference was found, however, regarding infection rate and disease between carpeted and noncarpeted rooms.</td>
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<td>Archibald, L. K., Manning, M. L., Bell, L. M., Banerjee, S., &amp; Jarvis, W. R. (1997).</td>
<td>Patient density measured as patient days; nurse-to-patient ratio measured as nursing-hours to-patient-day ratio</td>
<td>Nosocomial infection rate (NIR)</td>
<td>Administrative, patient, and microbiology records of 782 admissions to a pediatric cardiac intensive care unit in Philadelphia during the period between December 1994 and December 1995</td>
<td>There was a very strong linear correlation between the monthly NIR and patient days ($r = 0.89$, $P = 0.0001$). There was an inverse correlation between the monthly NIR and nursing-hours-to-patient-day ratio ($r = -0.77$). These factors may influence the infection rate via breaks in healthcare worker aseptic technique or decreased hand washing.</td>
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<td>6</td>
<td>Arlet, G., Gluckman, E., Gerber, F., Perol, Y., &amp; Hirsch, A. (1989).</td>
<td>Measurement of bacterial and fungal air counts in two bone marrow transplant units. <em>Journal of Hospital Infection, 13</em>(1), 63-69.</td>
<td>Laminar airflow rooms, conventional rooms, and ultraclean rooms in new and old units. Bacterial and fungal air counts. Air samples were taken from the different types of rooms in the old and new units.</td>
<td>Bacterial air contamination was least in laminar airflow rooms and reduced in ultraclean rooms in comparison with conventional rooms. Similar results were obtained with culture of air for fungi.</td>
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<td>Aygun, G., Demirkiran, O., Utku, T., Mete, B., Urkmez, S., Yilmaz, M., et al. (2002).</td>
<td>Environmental contamination during a carbapenem-resistant <em>Acinetobacter baumannii</em> outbreak in an intensive care unit. <em>Journal of Hospital Infection, 52</em>(4), 259-262.</td>
<td>Environmental surface contamination with pathogens in a multibed intensive care unit (ICU). Pathogenic bacteria (<em>Acinetobacter baumannii</em>) contamination of environmental surfaces. Epidemiological survey; microbial surveillance.</td>
<td>56 swab samples from a 16-bed ICU in Turkey. <em>Acinetobacter baumannii</em> was found in 22 (39.3%) of 56 environmental samples obtained by swabbing. Environmental contamination is an important reservoir of <em>Acinetobacter baumannii</em> in ICUs. Appropriate antibiotic treatment, isolation precautions, and infection-control education of the staff failed to halt the outbreak of <em>Acinetobacter baumannii</em>.</td>
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<td>8</td>
<td>Babb, J. R., Lynam, P., &amp; Ayliffe, G. A. (1995).</td>
<td>Risk of airborne transmission in an operating theatre containing four ultraclean air units. <em>Journal of Hospital Infection, 31</em>(3), 159-168.</td>
<td>Air quality in a single large operating theatre (barn) containing four ultraclean operating units (cabins). Number of airborne bacteria in the operating fields with and without activity. Prospective study; bacteriological air sampling of air in the cabins using two Casella slit samplers.</td>
<td>Air sampled in four ultraclean units. The airflows and bacterial counts during operations within the cabins met the prevalent standards for ultraclean systems, and there was no evidence for mixing of air between cabins. However, bacterial air counts were found to be high in one of the empty cabins when the ventilation was off indicating that contaminated air had entered from other cabins.</td>
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<td><strong>Barnes, R. A., &amp; Rogers, T. R. (1989).</strong> Control of an outbreak of nosocomial aspergillosis by laminar airflow isolation. <em>Journal of Hospital Infection, 14</em>(2), 89-94.</td>
<td>Normally ventilated bone marrow transplantation (BMT) ward with adjacent laminar airflow (LAF) unit construction vs. BMT ward with LAF system post-construction</td>
<td>Incidence of invasive pulmonary aspergillosis</td>
<td>Before-after study; prospective air sampling: the BMT unit, a control ward on a different floor of the hospital, and outside from a small park approximately 200m from the hospital</td>
<td>Six of the 19 children undergoing BMT in the area adjacent to the construction site for the new LAF unit died of invasive pulmonary aspergillosis (IPA). Ward air samples confirmed that heavy fungal air contamination had occurred. No cases of IPA were detected in patients nursed exclusively in the LAF unit.</td>
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<td>10</td>
<td><strong>Bauer, T. M., Ofner, E., Just, H. M., Just, H., &amp; Daschner, F. D. (1990).</strong> An epidemiological study assessing the relative importance of airborne and direct contact transmission of microorganisms in a medical intensive care unit. <em>Journal of Hospital Infection, 15</em>(4), 301-309.</td>
<td>Pathogen contamination in air and on hands in an intensive care unit (ICU)</td>
<td>Pathogenic bacteria contamination</td>
<td>Epidemiological survey; prospective; microbial surveillance; DNA typing</td>
<td>Specimens from 53 patients; 326 hand-washing samples from 39 staff members; 97 air samples in a seven-bed ICU</td>
<td>The spectrum of bacteria recovered from patients and air was generally different, whereas strains recovered from patients and their attendants' hands were indistinguishable on multiple occasions. The results confirm that direct contact by hand is the principal pathway of microbial transmission.</td>
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<td>11</td>
<td><strong>Ben-Abraham, R., Keller, N., Szold, O., Vardi, A., Weinberg, M., Barzilay, Z., et al. (2002).</strong> Do isolation rooms reduce the rate of nosocomial infections in the pediatric intensive care unit? <em>Journal of Critical Care, 17</em>(3), 176-180.</td>
<td>Conversion of open-bay pediatric intensive care unit (PICU) to single rooms with separate sinks</td>
<td>Nosocomial infection rates</td>
<td>Quasi-experimental; before-after comparison; retrospective and prospective hypotheses; chart records</td>
<td>78 children hospitalized for more than 48 hours in 1992 and 115 children hospitalized for more than 48 hours in 1995 in a six-bed PICU</td>
<td>The average number of nosocomial infections per patient was significantly higher in 1992 in the open-space unit (3.62) than 1995 with single rooms with separate sinks (1.87). Similarly, the average length of stay was significantly longer in 1992 than 1995 (25 +/- 6 and 11 +/- 6 days, respectively). There was a significant reduction of respiratory, urinary tract, and catheter-related infections in the separate-room arrangement.</td>
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<td>Human exhalation, respiration, and movement</td>
<td>Contaminant distribution</td>
<td>Experimental and numerical investigation</td>
<td>Three typical situations are modeled</td>
<td>A moving person significantly alters the ambient air within a space. A very good and unique study on the relationship between the ventilation system and &quot;activity&quot; within the room.</td>
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<td>Length of daylight</td>
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<td>Methicillin-resistant <em>Staphylococcus aureus (MRSA)</em> contamination of environmental surfaces</td>
<td>Occurrence of MRSA contamination of environmental surfaces, and types of surfaces contaminated in rooms of patients with MRSA</td>
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<td>15</td>
<td><strong>Brandis, S. (1999).</strong> A collaborative occupational therapy and nursing approach to falls prevention in hospital inpatients. <em>Journal of Quality in Clinical Practice, 19</em>(4), 215-221.</td>
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<td>16</td>
<td><strong>Buchanan, T. L., Barker, K. N., Gibson, J. T., Jiang, B. C., &amp; Pearson, R. E. (1991).</strong> Illumination and errors in dispensing. <em>American Journal of Hospital Pharmacy, 48</em>(10), 2137-2145.</td>
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<td>Computer keyboards and faucet handles in an intensive care unit (ICU)</td>
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<td>Physical proximity of patients</td>
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<td>Location of airborne particle source, ventilation rate, air inlet size, supply-air velocity, air-outlet location, and heat source</td>
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<td>Algorithms used for computing air quality and distribution have been derived from earlier studies.</td>
<td>Seems to be better for avoiding recirculation within the operating area. No significant influence of heat source.</td>
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| Bacterial air counts | Incidence of peritonitis in intermittent peritoneal dialysis patients | Outbreak investigation and retrospective case-control study | 10 episodes of peritonitis were documented in eight patients |


Dispensers with alcohol-based hand rub vs. sinks with antimicrobial soap in two neonatal intensive care units. *Pediatric Infectious Disease Journal, 22*(6), 494-499.

1,472 hand touches in two NICUs in New York (44 and 50 beds)

Only 22.8% of all touches were with cleaned and/or newly gloved hands. The mean ratio of direct touches by staff members with cleaned hands was significantly greater in the NICU using an alcohol-based hand rub than in the NICU using antimicrobial soap and sinks.

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<th>Methods</th>
<th>Data</th>
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<tr>
<td>22</td>
<td>Conly, J. M., Hill, S., Ross, J., Lertzman, J., &amp; Louie, T. J. (1989)</td>
<td>Hand-washing practices in an intensive care unit: The effects of an educational program and its relationship to infection rates.</td>
<td>American Journal of Infection Control, 17(6), 330-339.</td>
<td>Educational programs (feedback, posters, policy changes) in an intensive care unit (ICU)</td>
<td>Hand-washing compliance rate; nosocomial infection rate</td>
<td>Quasi-experimental; sequential before-after comparison; prospective; hypotheses; observation in clinical setting</td>
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<td>23</td>
<td>Cotterill, S., Evans, R., &amp; Fraise, A. P. (1996)</td>
<td>An unusual source for an outbreak of methicillin-resistant Staphylococcus aureus on an intensive therapy unit.</td>
<td>Journal of Hospital Infection, 32(3), 207-216.</td>
<td>Air quality</td>
<td>Incidence of methicillin-resistant Staphylococcus aureus (MRSA)</td>
<td>All cases of MRSA were identified from hospital records; investigation of the environment included microbiological sampling and assessment of the ventilation system for the side room (adjacent to ward)</td>
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<td>24</td>
<td>Davidson, A. I., Smylie, H. G., Macdonald, A., &amp; Smith, G. (1971).</td>
<td>Ward design in relation to postoperative wound infection. <em>British Medical Journal</em>, 1(740), 72-75.</td>
<td>Quasi-experimental; before-after comparison of two units; hypotheses; microorganism surveillance; observation; chart records</td>
<td>1,000 general surgical operations in two surgical wards in a UK hospital (493 surgery patients in Nightingale unit, 507 in newer racetrack unit)</td>
<td>The cross-infection was significantly lower after the Nightingale open ward was changed to a racetrack unit with 40% single rooms and controlled ventilation.</td>
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<td>25</td>
<td>Dettenkofer, M., Scherrer, M., Hoch, V., Glaser, H., Schwarzer, G., Zentner, J., et al. (2003).</td>
<td>Shutting down operating theater ventilation when the theater is not in use: Infection control and environmental aspects. <em>Infection Control and Hospital Epidemiology</em>, 24(8), 596-600.</td>
<td>Experimental; the ventilation system was switched off and restarted after 10 hours. Particles suspended in the air near the operating table were counted, operating-room (OR) temperature was measured and settle plates were exposed and incubated</td>
<td>13 investigations were conducted in operating theater of neurological OR of a German university hospital</td>
<td>Shutting down OR ventilation during off-duty periods does not appear to result in an unacceptably high particle count of microbial contamination of the OR air shortly after the system is restarted.</td>
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<td>26</td>
<td>Devine, J., Cooke, R. P., &amp; Wright, E. P. (2001).</td>
<td>Is methicillin-resistant Staphylococcus aureus (MRSA) contamination of ward-based computer terminals a surrogate marker for nosocomial MRSA transmission and handwashing compliance? <em>Journal</em></td>
<td>Quasi-experimental; comparison of two hospitals; hypotheses; chart records; microorganism surveillance</td>
<td>25 computer terminals and 66,065 admissions (during 1999) in wards in two acute general hospitals (456 and 526 beds)</td>
<td>Five of 12 computer terminals in hospital A and 1 of 13 computer terminals in hospital B were contaminated with MRSA. The nosocomial MRSA transmission rate was significantly greater in A. The rate of hand-hygiene towel use in hospital B was 44% higher. Computer terminals pose a low risk of MRSA cross-infection. This risk can be reduced if all staff washes their hands before and after patient contact.</td>
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<td>No.</td>
<td>Author(s)</td>
<td>Study Description</td>
<td>Hand-washing Compliance</td>
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<td>27</td>
<td>Dorsey, S. T., Cydulka, R. K., &amp; Emerman, C. L. (1996).</td>
<td>Is handwashing teachable? Failure to improve handwashing behavior in an urban emergency department. <em>Academy of Emergency Medicine, 3</em>(4), 360-365.</td>
<td>Hand washing compliance rate</td>
<td>Quasi-experimental; before-after comparison; prospective; hypotheses; observation in natural setting</td>
<td>252 situations requiring hand washing observed in ED in a 742-bed urban hospital</td>
<td>Hand-washing compliance showed tendencies toward improvement after the signs and publications were placed in the ED, but the increase was not significant.</td>
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<td>28</td>
<td>Dubbert, P. M., Dolce, J., Richter, W., Miller, M., &amp; Chapman, S. W. (1990).</td>
<td>Increasing ICU staff handwashing: Effects of education and group feedback. <em>Infection Control and Hospital Epidemiology, 11</em>(4), 191-193.</td>
<td>Hand-washing compliance rate</td>
<td>Quasi-experimental; repeated measurements; prospective; hypotheses; observation in natural setting; descriptive statistical analyses</td>
<td>591 patient contacts by 12 nurses in a 12-bed intensive care unit during a 14-week period (six baseline, four with education, followed by four weeks with feedback)</td>
<td>The average hand-washing compliance rates were 81%, 86%, and 92% for the three consecutive periods. During baseline, the hand-washing compliance rate increased by the end of the period. During the education period, it increased at the beginning then declined to the baseline level. During the feedback period, it increased to 97% by the second week and was maintained to the end of the period.</td>
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<td>Authors</td>
<td>Title</td>
<td>Environmental measures implemented to control infection and spread of SARS</td>
<td>Retrospective report; case study of one hospital</td>
<td>Nineteen probable cases were reported in this emergency department during the SARS outbreak. 77% percent of SARS cases in the Toronto area were the result of exposure within hospitals. Direct contact and airborne transmission were potential modes of transmission. Strategies of SARS control in the hospital included: a triage screening tool, restricting visitation, eliminating beds in hallways and beds separated by curtains, replacing curtains with wall barriers, one bed to each room, and a strict infection-control protocol that included hand washing and masks.</td>
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<td>29</td>
<td>Farquharson, C., &amp; Baguley, K. (2003). Responding to the severe acute respiratory syndrome (SARS) outbreak: Lessons learned in a Toronto emergency department. <em>Journal of Emergency Nursing</em>, 29(3), 222-228.</td>
<td>Changes made to an emergency department environment during a SARS outbreak</td>
<td>Environmental measures implemented to control infection and spread of SARS</td>
<td>A Toronto emergency department with 26 beds in open-bay rooms before SARS outbreak, converted to 16 single rooms and seven negative-pressure isolation rooms during the outbreak</td>
<td>Nineteen probable cases were reported in this emergency department during the SARS outbreak. 77% percent of SARS cases in the Toronto area were the result of exposure within hospitals. Direct contact and airborne transmission were potential modes of transmission. Strategies of SARS control in the hospital included: a triage screening tool, restricting visitation, eliminating beds in hallways and beds separated by curtains, replacing curtains with wall barriers, one bed to each room, and a strict infection-control protocol that included hand washing and masks.</td>
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<td>30</td>
<td>Friberg, B., Friberg, S., &amp; Burman, L. G. (1999). Correlation between surface and air counts of particles carrying aerobic bacteria in operating rooms with turbulent ventilation: an experimental study. <em>Journal of Hospital Infection</em>, 42(1), 61-68.</td>
<td>Operating room (OR) turbulent ventilation systems (either upward air displacement system or a conventional plenum pressure system)</td>
<td>Bacterial air and surface contamination rates (measured by sedimentation rates)</td>
<td>Experimental: the relationship between bacterial air and surface contamination rates at different sampling sites was studied during rigidly standardized sham operations performed by the same six-member team wearing either disposable or cotton clothing in an OR ventilated by two different turbulent systems</td>
<td>During one week, 10 sham operations (five disposable clothing, five cotton clothing) were studied in the displacement ventilation system in the conventional system</td>
<td>Airborne contamination in the wound and instrument areas was related to the surface contamination rate in the same areas, and, in addition, on the patient chest and in the periphery of the OR. With the exception of the periphery of the OR, the surface and air contamination rates were highly correlated in both ventilation systems.</td>
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<td>Study Reference</td>
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<td>Gardner, P. S., Court, S. D., Brocklebank, J. T., Downham, M. A., &amp; Weightman, D. (1973).</td>
<td>Quasi-experimental; concurrent comparison; hypotheses; chart records; epidemiological survey; swab sampling</td>
<td>Single cubicles vs. open ward with some cubicles</td>
<td>219 children hospitalized for respiratory syncytial infection, 61 hospitalized for influenza A, 134 hospitalized for parainfluenza in eight pediatric wards (four open wards, four wards with single cubicles)</td>
<td>There was a clear pattern for cross-infection rates to be lower in wards with single cubicles than wards combining an open area with some cubicles. Among sampled children, 16 were due to nosocomial cross-infection of respiratory syncytial, 15 were due to cross-infection of influenza A, and 19 were due to cross-infection of parainfluenza.</td>
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<td>Goldmann, D. A., Durbin, W. A., Jr., &amp; Freeman, J. (1981).</td>
<td>Quasi-experimental; before-after comparison; hypotheses; microbial surveillance; chart records</td>
<td>Old neonatal intensive care unit (NICU) vs. new NICU with more nurses, increased space per infant, convenient sinks, and isolation facilities</td>
<td>642 discharges in the old NICU (January 1974 to February 1977) and 542 in the new NICU (February 1977 to December 1978) in a hospital in Boston</td>
<td>In the old unit, 5.2% of infants had at least one major nosocomial infection. By contrast, in the new unit, 0.9% of infants had a major nosocomial infection (relative risk [old nursery/new nursery] = 5.06; p &lt; 0.00001).</td>
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<td>Graham, M. (1990).</td>
<td>Quasi-experimental; interrupted time series (before-after comparison); prospective; hypotheses; observation</td>
<td>Intensive care unit with vs. without an antiseptic hand-rub dispenser positioned near each bed</td>
<td>884 patient contacts by staff members observed during two (before) and eight (after) weeks in an 18-bed intensive care unit in Australia</td>
<td>A total of 440 contacts and 140 hand washes (32% compliance) were observed in stage one (without antiseptic hand-rub dispensers), and 444 contacts and 201 hand washes (45% compliance) in stage two with hand-rub dispensers. There were significant differences in hand-washing compliance rate and hand-washing duration among the staff groups. Compared to physicians, nurses had a higher hand-washing rate but with shorter duration.</td>
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<td>35</td>
<td>Hanger, H. C., Ball, M. C., &amp; Wood, L. A. (1999). An analysis of falls in the hospital: Can we do without bedrails? <em>Journal of the American Geriatrics Society</em>, 47(5), 529-531.</td>
<td>Bedrails on hospital beds</td>
<td>Total number of falls, falls around the bed, and minor and serious injuries before and after policy change</td>
<td>Fall and injury rates were quantified before and after the implementation of a policy introduced to discourage overuse of bed rails; the presence of bed rails physically attached to beds was checked throughout the year and both major and minor falls were counted; nonrandom assignment of patients to beds with or without bed rails</td>
<td>All patients admitted during 1994 calendar year to any of the five assessment, treatment, or rehabilitation wards of a New Zealand hospital</td>
<td>B</td>
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<td>36</td>
<td>Hopkins, C. C., Weber, D. J., &amp; Rubin, R. H. (1989). Invasive aspergillus infection: possible non-ward common source within the hospital environment. <em>Journal of Hospital Infection</em>, 13(1), 19-25.</td>
<td>Air quality (measured by air sampling)</td>
<td>Incidence of invasive Aspergillosis</td>
<td>Epidemiological investigation: investigation of hospital records to identify cases and trends; air sampling (though exact methods and location of air samples is not described)</td>
<td>Six immuno-compromised patients housed in widely separated portions of a hospital campus</td>
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<td>Journal of Hospital Infection, 13(1), 19-25.</td>
<td>Contamination of air during construction</td>
<td>Incidence of invasive aspergillosis (IA)</td>
<td>Prospective air sampling for molds was done using the gravity air-settling plate method</td>
<td>Five neutropenic patients developed IA</td>
<td>Four of the five patients with IA were housed in rooms adjacent to a construction staging area. Aerobiological monitoring detected an increase in the number of airborne fungal spores including <em>Aspergillus</em> species in these rooms.</td>
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<td>Iwen, P. C., Davis, J. C., Reed, E. C., Winfield, B. A., &amp; Hinrichs, S. H. (1994). Airborne fungal spore monitoring in a protective environment during hospital construction, and correlation with an outbreak of invasive aspergillosis. <em>Infection Control and Hospital Epidemiology, 15</em>(5), 303-306.</td>
<td>Contact isolation room vs. open bay in a neonatal intensive care unit</td>
<td>Methicillin-resistant <em>Staphylococcus aureus</em> (MRSA) transmission rate</td>
<td>Quasi-experimental; comparison between patients; hypotheses; microbial surveillance; chart records</td>
<td>331 neonates in a 33-bed neonatal intensive care unit (NICU) in Virginia (one two-bed isolation room, one open bay)</td>
<td>The rate of transmission of MRSA among patients in the contact isolation room was substantially lower than the rate for patients not in isolation.</td>
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<td>Kaplan, L. M., &amp; McGuckin, M. (1986). Increasing handwashing compliance with more accessible sinks. <em>Infection Control</em>, 7(8), 408-410.</td>
<td>Quasi-experimental; concurrent comparison; prospective; hypotheses; observation</td>
<td>The nurses in the unit with one sink per bed had significantly higher hand-washing compliance (76%) rate than those in the unit with fewer sinks (51%). Physicians had a lower hand-washing compliance rate than nurses.</td>
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<td>Kim, M. H., Mindorff, C., Patrick, M. L., Gold, R., &amp; Ford-Jones, E. L. (1987). Isolation usage in a pediatric hospital. <em>Infection Control</em>, 8(5), 195-199.</td>
<td>Descriptive; survey; hypotheses; observation; chart records</td>
<td>The mean number of isolation days was 153 per 1,000 pediatric patient days or 15.3% of all bed days. During one-third of the 365-day year, the hospital was unable to provide an adequate number of single rooms. The shortage of single rooms ranged from 1 to 20 per day. Hospitals with multibed rooms and an inadequate number of single rooms may be unable to meet current isolation guidelines.</td>
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<td>Kumari, D. N., Haji, T. C., Keer, V., Hawkey, P. M., Duncanson, V., &amp; Flower, E. (1998). Ventilation grilles as a potential source of methicillin-resistant <em>Staphylococcus aureus</em> causing an outbreak in an orthopaedic ward at a district general hospital. <em>Journal of Hospital Infection</em>, 39(2), 127-133.</td>
<td>Screening of patients and staff for MRSA; environmental sampling</td>
<td>The ventilation grilles in bays 1 and 2 were found to be harboring EMRSA-15. The ventilation system at that time was working on an intermittent cycle from 4 p.m. to 8 a.m. Daily shutdown of the system temporarily created a negative pressure, sucking air in from the ward environment into the ventilation system and probably contaminating the outlet grilles. It is likely that contaminated air was blown back into the ward when the ventilation system was started.</td>
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Number and availability of single-bed rooms  
Demand and usage of single-bed rooms  
Survey; repeated measurements; prospective; questionnaire; chart records  
1,634 patients in 89 rooms in six units in a 218-bed Canadian pediatric hospital (point prevalence survey); also, questionnaire survey of 10 Canadian pediatric hospitals  
Use of isolation rooms in the 218-bed hospital varied seasonally, with 71% between November and April. Demand for single-bed isolation exceeded supply by 2 to 22 beds throughout the year. Children younger than 24 months comprised 28% of admissions and 57% of the isolation bed use. Respiratory and enteric infections requiring contact isolation accounted for 80% of isolation-room use. Among 10 questionnaire-surveyed hospitals, those built after 1965 had more single rooms. Hospitals with less than 33% single-bed pediatric rooms reported this percentage to be inadequate.

B


Hand washing  
Infection  
Review of research literature  
423 articles related to hand washing published from 1879 to 1986  
Fourteen articles linked hand washing to risk of infection. Nine retrospective studies reported that improved hand washing contributed to the interruption of the spread of an infection outbreak. Five prospective studies established the cause-effect relationship between hand washing and infection. Except for specificity, all the elements for causality, including temporality, strength, plausibility, consistency of the association, and dose response, were present.

Review
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<th>Outcomes</th>
<th>Study Design</th>
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<tr>
<td>Larson, E., Bryan, J., Adler, L., &amp; Blane, C. (1997).</td>
<td>Intensive care units (ICUs) with conventional sinks vs. automated sinks, and/or with educational interventions vs. without educational interventions</td>
<td>Hand-washing compliance rate; self-reported practices and opinions about hand washing</td>
<td>Quasi-experimental; comparison between nursing units and staff across phases—baseline (two months), automated sink interventions, (each for three months), and follow-up (for three months; prospective; hypotheses; observation; questionnaire</td>
<td>301 hours of observation, 2,624 hand-washing indications recorded in two ICUs, one as experimental with interventions, one as control, in a 350-bed health center</td>
<td>Differences were found between the experimental and control medical units with proportions of observed hand washes significantly higher initially when automated sinks were present. These increases, however, were only transient; hand-washing rates returned to baseline rates by the follow-up phase.</td>
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<td>Larson, E., McGeer, A., Quraishi, Z. A., Krenzischek, D., Parsons, B. J., Holdford, J., et al. (1991).</td>
<td>Automated sinks vs. conventional sinks</td>
<td>Hand-washing compliance rate and quality; attitudes of staff to the automated sinks</td>
<td>Quasi-experimental; crossover design; hypotheses; observation in natural setting; automated programmable counting controller; questionnaire</td>
<td>1,610 hand washes by 55 patient care staff in two acute care units (a six-bed postanesthesia recovery room with three sinks, and one 15-bed neonatal intensive care unit with four sinks) in two tertiary hospitals</td>
<td>For both sites at both hospitals, hands were washed better or more thoroughly but significantly less often with the automated sink. Staff expressed negative attitudes about certain features of the automated sink (e.g., they avoided washing their hands when busy because of a 15-second water-flow interruption programmed in the automated sinks). These negative attitudes toward the automated sinks increased over the study period.</td>
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<td>46</td>
<td>Laurel, V. L., Meier, P. A., Astorga, A., Dolan, D., Brockett, R., &amp; Rinaldi, M. G. (1999). Pseudoepidemic of Aspergillus niger infections traced to specimen contamination in the microbiology laboratory. <em>Journal of Clinical Microbiology</em>, 37(5), 1612-1616.</td>
<td>Air and surface contamination in a laboratory during construction</td>
<td>Specimen contamination resulting in pseudo-epidemic of <em>Aspergillus niger</em></td>
<td>A series of air-sampling experiments were conducted using settle plates in a microbiology laboratory after 14 inpatients were classified as infected based on cultures; however, they did not manifest clinical manifestations of the disease</td>
<td>Varying number of settle plates were exposed in each experiment</td>
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<p>| 47 | Loo, V. G., Bertrand, C., Dixon, C., Vitye, D., DeSalis, B., McLean, A. P., et al. (1996). Control of construction-associated nosocomial aspergillosis in an antiquated hematology unit. <em>Infection Control and Hospital Epidemiology</em>, 17(6), 360-364. | Environmental interventions to control airborne pathogens (portable HEPA air purifiers, copper-8-quinolinolate paint, nonperforated ceiling tiles, window sealing, and systematic regular cleaning of surfaces) | Incidence of invasive aspergillosis | Quasi-experimental; sequential before-after comparison; retrospective/prospective; hypotheses; microbial surveillance; chart records | 141 patients (231 admissions, January 1988 to September 1993) with bone marrow transplants or leukemia in seven single rooms in a hematology-oncology unit | The incidence of aspergillosis in the preconstruction period was 3.18 per 1,000 patient days at risk. During construction activity—before the implementation of a control strategy—the incidence increased dramatically to 9.88 per 1,000 days at risk. With environmental measures implemented as construction continued, the incidence decreased to 2.91 per 1,000 days at risk, comparable to the preconstruction baseline rate. | B |
| 48 | <strong>Lutz, B. D. J., Rinaldi, J., Wickes, M. G., Huycke, B. L., Mark M. (2003).</strong> | <strong>Operating theater air quality: particle counts were measured as surrogate measures for Aspergillus conidia</strong> | <strong>Outbreak of Aspergillus infection among surgery patients</strong> | <strong>Retrospective study: cases were identified over a two-year period by hospital records and analysis of pathology databases and microbiology laboratory records; environmental contamination measured using settle plates and multichannel portable counter; a confined-space color camera with a wide-angle lens and video recorder was used to survey ductwork that could not be directly visualized</strong> | <strong>Six patients met the case definition</strong> | <strong>A confined-space video camera identified moisture and contamination of insulating material in ductwork and variable airflow volume units downstream of final filters. No additional invasive <em>Aspergillus</em> wound infections were identified after the operating theater air-handling systems were remediated, suggesting that this unusual outbreak was due to the deterioration of insulating material in variable airflow volume units.</strong> |
| 49 | <strong>Mahieu, L. M., De Dooy, J. J., Van Laer, F. A., Jansens, H., &amp; Ieven, M. M. (2000).</strong> | <strong>Introduction of mobile air-filtration devices in a medium-care area undergoing renovation in a neonatal intensive care unit (NICU)</strong> | <strong>Aspergillus spore air concentrations in a high-care area close to the medium-care unit undergoing renovation; nasopharyngeal colonization in the neonates</strong> | <strong>Quasi-experimental; before-after comparison; regression analysis; retrospective/prospective; hypotheses; air sampling; chart records</strong> | <strong>Weekly air samples in three locations over several months in a NICU in Belgium; 311 neonates in a high-care area with 17 beds; no physical barrier between the high-care unit and the medium-care unit undergoing renovation</strong> | <strong>Renovation works and air concentration of <em>Aspergillus</em> spores in the medium-care area resulted in a significant increase in the concentration in the high-care area. Use of a mobile HEPA air-filtration system caused a significant decrease in <em>Aspergillus</em> spore concentration. No relationship was found between <em>Aspergillus</em> spore air concentration and nasopharyngeal colonization in the neonates.</strong> |</p>
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<th>ID</th>
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<td>50</td>
<td>Malamou-Ladas, H., O'Farrell, S., Nash, J. Q., &amp; Tabaqchali, S. (1983).</td>
<td>Isolation of Clostridium difficile from patients and the environment of hospital wards. Journal of Clinical Pathology, 36(1), 88-92.</td>
<td>Rectal swabs from 122 patients and 497 environmental swabs from several wards in a UK hospital</td>
<td>Environmental and patient contamination with <em>Clostridium difficile</em></td>
<td>Similar antibiogram patterns were demonstrated in the strains obtained from patients and their physical environment, indicating the possible occurrence of cross-infection. Environmental contamination is important in the spread of <em>C. difficile</em> in hospitalized patients.</td>
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<td>51</td>
<td>McDonald, L. C., Walker, M., Carson, L., Arduino, M., Aguero, S. M., Gomez, P., et al. (1998).</td>
<td>Outbreak of Acinetobacter spp. bloodstream infections in a nursery associated with contaminated aerosols and air conditioners. Pediatric Infectious Disease Journal, 17(8), 716-722.</td>
<td>Nursery settle plates were more likely to grow <em>Acinetobacter</em> than were settle plates from other hospital areas. Cultures from nursery air conditioners also grew <em>Acinetobacter</em>. Environmental conditions that increase air-conditioner condensate may promote airborne dissemination via contaminated aerosols and increase the risk of nosocomial A-BSI.</td>
<td>Staff contact; air-conditioner condensate</td>
<td>Quasi-experimental; retrospective cohort study; hypotheses; chart records; microbiologic surveillance</td>
<td>Patients with peripheral IV catheters were more likely to develop A-BSI. Among those with IV catheters, only exposure to one nurse was an independent risk factor for developing A-BSI. Nursery settle plates were more likely to grow <em>Acinetobacter</em> than were settle plates from other hospital areas. Cultures from nursery air conditioners also grew <em>Acinetobacter</em>. Environmental conditions that increase air-conditioner condensate may promote airborne dissemination via contaminated aerosols and increase the risk of nosocomial A-BSI.</td>
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<td>52</td>
<td>McKendrick, G. D., &amp; Emond, R. T. (1976).</td>
<td>Investigation of cross-infection in isolation wards of different design. Journal of Hygiene (Lond), 76(1), 23-31.</td>
<td>Higher incidence of cross-infection of both chicken pox and measles was recorded in large wards with ventilation to corridors. Small wards with no ventilation to corridors had lower incidence of cross-infection. Door opening and staff shortage were also related to higher incidence.</td>
<td>Different multibed ward designs: large with ventilation to corridors, small with no ventilation to corridors, doors open and closed</td>
<td>Rate of cross-infection of varicella-zoster (chicken pox) and measles</td>
<td>Seven isolation wards of different size and design in seven hospitals; detailed architectural descriptions provided</td>
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<td>Table 53</td>
<td>McManus, A. T., Mason, A. D., Jr., McManus, W. F., &amp; Pruitt, B. A., Jr. (1992). Control of <em>Pseudomonas aeruginosa</em> infections in burned patients. <em>Surgical Research Communications, 12</em>, 61-67.</td>
<td>Open multibed ward vs. unit with single-bed rooms</td>
<td>Pathogen colonization rate; postburn day of colonization; mortality</td>
<td>Quasi-experimental; before-after; retrospective; hypotheses; chart records</td>
<td>2,316 burn patients admitted in an open ward (1980-1983) or a single-room unit (1984-1990)</td>
<td>Regarding <em>Pseudomonas aeruginosa</em> (PA) colonization, the unit with single-bed rooms had the same incidence rate as the open ward, but had a more delayed postburn day of colonization. Regarding <em>Pseudomonas bacteremia</em>, pneumonia, and invasive burn-wound infection, the single-room unit had a lower frequency and later day of postburn colonization. Predicted mortality increased with PA infection in the open ward unit but did not increase with PA infection in the single-bed room unit.</td>
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<td>Table 54</td>
<td>McManus, A. T., Mason, A. D., Jr., McManus, W. F., &amp; Pruitt, B. A., Jr. (1994). A decade of reduced gram-negative infections and mortality associated with improved isolation of burned patients. <em>Archives of Surgery, 129</em>(12), 1306-1309.</td>
<td>Burn unit with open multibed ward vs. unit with single-bed rooms</td>
<td>Colonization rate of gram-negative bacteremia (GNB); mortality</td>
<td>Quasi-experimental; before-after; retrospective; hypotheses; chart records</td>
<td>2,519 consecutive patients with large burns in an army burn center</td>
<td>In the single-room environment, incidence of GNB was lower and the post-injury time of first GNB was delayed. Increased mortality was present in the open ward, but not in the single-room unit.</td>
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<td>Table 55</td>
<td>McManus, A. T., McManus, W. F., Mason, A. D., Jr., Aitcheson, A. R., &amp; Pruitt, B. A., Jr. (1985). Microbial colonization in a new intensive care burn unit. A prospective cohort study. <em>Archives of Surgery, 120</em>(2), 217-223.</td>
<td>Renovated burn unit with more single-bed rooms (unit A, nine single bed room, seven beds in four rooms, more sinks) vs. unit B, an interim eight-bed open burn unit</td>
<td>Infection rates</td>
<td>Quasi-experimental; before-after comparison; prospective; hypotheses; microbial surveillance; chart records</td>
<td>50 patients in the two units (25 from each unit)</td>
<td>A significantly lower incidence of <em>Providencia stuartii</em> and <em>Pseudomonas aeruginosa</em> (type 15) endemics occurred in unit A (single-bed rooms) than in unit B (eight-bed open ward). No evidence of bacterial cross-contamination was observed between A and B. A new unit with more single rooms may prevent cross-contamination with the endemic flora.</td>
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<td>Mehta, G. (1990). Aspergillus endocarditis after open heart surgery: An epidemiological investigation. <em>Journal of Hospital Infection</em>, 15(3), 245-253.</td>
<td>Air contamination</td>
<td>Four patients developed aspergillus endocarditis after open heart surgery within a period of 10 months in a hospital in New Delhi, India. With the exception of the operating room, which was fitted with laminar airflow, it was possible to isolate <em>Aspergillus</em> spp from all rooms in the operating suite. Air-conditioner cooling coils and pigeon droppings on the ledges outside the suite were found to harbor <em>Aspergillus</em> spores in large amounts.</td>
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<td>Merriman, E., Corwin, P., &amp; Ikram, R. (2002). Toys are a potential source of cross-infection in general practitioners' waiting rooms. <em>British Journal of General Practice</em>, 52(475), 138-140.</td>
<td>Soft surface toys vs. hard surface toys in waiting room. Bacteria counts on surfaces of toys. Quasi-experimental; prospective; hypotheses; bacteria counting</td>
<td>10 soft and 22 hard toys from six general practitioners' surgeries in New Zealand. Soft toys had far higher bacteria counts than hard toys; 90% of soft toys showed evidence of coliform contamination, while only 13.5% of hard toys showed evidence of such contamination. There was little difference, however, in the percentage of hard and soft toys contaminated (100% vs. 91%); soft toys were more likely to have moderate to high contamination rates. Soft toys are harder to disinfect and tend to rapidly become re-contaminated after cleaning; therefore, soft toys may pose an infection risk.</td>
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<td>Morawska, L., Jamriska, M., &amp; Francis, P. (1998). Particulate matter in the hospital environment. <em>Indoor Air</em>, 8, 285-294.</td>
<td>Detergent-cleaned surfaces, ventilation system, air filters. Particle concentrations of airborne infectious agents. Experimental study: measurements were performed at the Royal Children's and Royal Brisbane Hospitals; the ventilation and filtration systems were investigated. Outdoor and indoor air samples were taken about every two hours to monitor changes to ambient air characteristics.</td>
<td>No affect of detergent-cleaned surfaces; low particle concentration where high-efficiency NEPA or HEPA filters are used. High concentration in areas that used dry media filters and return air ventilation.</td>
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<td>Variables analyzed</td>
<td>Study design</td>
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<td>[59]</td>
<td>Hospital falls: A persistent problem.</td>
<td>Morgan, V. R., Mathison, J. H., Rice, J. C., &amp; Clemmer, D. I. (1985).</td>
<td>Age, sex, admission diagnosis, location, hour, reported activity</td>
<td>Retrospective study: information on inpatient falls was abstracted from patient incident reports for a 152-private room acute-care specialty hospital without pediatrics or obstetrical care</td>
<td>229 patients accounted for 250 falls over a consecutive 22-month period; among the 229 falls, 18 patients experienced two or more falls</td>
<td>Sixty-five percent of the falls occurred within the patients' room, most near the bed. Twenty-nine percent occurred in the private bathroom attached to each room, two-thirds of them near the toilet. Of the 167 falls in the patients' rooms, 57 occurred on the way to or from the bathroom. At least half of the total falls were bathroom related.</td>
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<td>[60]</td>
<td>Association of private isolation rooms with ventilator-associated Acinetobacter baumanii pneumonia in a surgical intensive-care unit.</td>
<td>Mulin, B., Rouget, C., Clement, C., Bailly, P., Julliot, M. C., Viel, J. F., et al. (1997).</td>
<td>Isolation rooms with hand-washing facility in each room vs. multibed open rooms in a surgical intensive care unit (SICU)</td>
<td>Quasi-experimental; comparison between two groups of patients cared before-after renovation; prospective; hypotheses; specimen collection and bacteriological analysis</td>
<td>314 patients hospitalized and mechanically ventilated for more than 48 hours in the 15-bed SICU at a university hospital in France</td>
<td>Infection rates were respectively 28.1% and 5.0% in the old open-bay ICU and the new private-room ICU with hand-washing facility in each room. Bronchopulmonary colonization rates were respectively 9.1 and 0.5 per 1,000 patient days of mechanical ventilation.</td>
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<td>[61]</td>
<td>Hand hygiene rates unaffected by installation of dispensers of a rapidly acting hand antiseptic.</td>
<td>Muto, C. A., Sistrom, M. G., &amp; Farr, B. M. (2000).</td>
<td>Medical intensive care unit (MICU) and step-down unit with vs. without alcohol-based hand-rub dispensers installed in hall next to every door</td>
<td>Quasi-experimental; before-after comparison; prospective; hypotheses; observation in natural setting</td>
<td>239 hand-washing indications observed in two wards—the medical intensive care unit and its step-down unit—in a university hospital</td>
<td>The baseline hand-washing rate was 60%. After hallway installation of an alcohol-based hand antiseptic rub dispensers and a brief educational campaign, overall hand-hygiene rates did not change.</td>
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<td>Neely, A. N., &amp; Maley, M. P. (2001). Dealing with contaminated computer keyboards and microbial survival. <em>American Journal of Infection Control, 29</em>(2), 131-132.</td>
<td>Computer keyboards at bedside: before vs. after contact control procedure (hand washing and glove change between patients)</td>
<td>Bacteria transfer rate; bacteria survival on keyboards</td>
<td>Brief article (letter to editor); before-after; prospective; hypotheses; microbial surveillance</td>
<td>Computer keyboards</td>
<td>Bacteria survival might be a component of the keyboard-contamination problem. After introduction of the contact-control procedure, the transfer rate was at or below the rate before the use of bedside computers.</td>
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<td>Noskin, G. A., Bednarz, P., Suriano, T., Reiner, S., &amp; Peterson, L. (2000). Persistent contamination of fabric-covered furniture by Vancomycin-resistant Enterocci: Implication for upholstery selection in hospitals. <em>American Journal of Infection Control, 28</em>(4), 311-313.</td>
<td>Furniture cover materials (fabric and vinyl)</td>
<td>Contamination and disinfection of vancomycin-resistant Enterocci (VRE)</td>
<td>Quasi-experimental; comparison of two materials; hypotheses; chart records; microorganism surveillance; simulated experiment</td>
<td>10 seat cushions in five randomly chosen hospital rooms; five simulated samples</td>
<td>VRE was found on 3 of 10 sampled seat cushions. The contamination was associated with patients being or having been in the rooms. In the simulated experiment, VRE was found at 72 hours and seven days after inoculation on fabric and vinyl upholstered chairs. Routine disinfection was successful in removing VRE from vinyl surfaces but not from fabric surfaces. Staff hands were colonized after contact with a contaminated chair.</td>
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<td>Obbard, J. P., &amp; Fang, L. S. (2003). Airborne concentrations of bacteria in a hospital environment in Singapore. <em>Water Air and Soil Pollution, 144</em>(1), 333-341.</td>
<td>Occupant density, temperature, and humidity</td>
<td>Airborne concentrations of bacteria</td>
<td>Prospective study: measured concentrations of airborne bacteria in different locations within a general hospital in Singapore</td>
<td>Airborne bacteria were collected in each selected location using Anderson Particle Impactors at a specific air-sampling rate for a total of five minutes</td>
<td>Occupant density and humidity were identified as important factors affecting concentrations of airborne bacteria.</td>
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<td>Outcome Measures</td>
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<td>Opal, S. M., Asp, A. A., Cannady, P. B., Jr., Morse, P. L., Burton, L. J., &amp; Hammer, P. G., (1986). Efficacy of infection control measures during a nosocomial outbreak of disseminated aspergillosis associated with hospital construction. <em>Journal of Infectious Diseases, 153</em>(3), 634-637.</td>
<td>Environmental interventions, e.g., construction of airtight plastic and drywall barriers about the construction sites, HEPA filters, etc.</td>
<td>Incidence of disseminated aspergillosis</td>
<td>Prospective study: cases of disseminated aspergillosis were identified from hospital records; environmental interventions were put into place, and a six-stage microbial air sampler was used to determine spore counts in different areas of the hospital during the construction phase. Eleven patients in Fitzsimmons Army Medical Center, a military teaching hospital, contracted disseminated aspergillosis during the construction period. High spore counts were found within and outside construction sites in the hospital. After control measures were instituted, no further cases of disseminated aspergillosis were identified. The combination of the four control measures reduced the dissemination of airborne conidia near the construction sites. The barriers were effective only when extending from ceiling to the floor. The use of HEPA filters in patient rooms reduced the number of airborne spores.</td>
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<td>Oren, I., Haddad, N., Finkeinstein, R., &amp; Rowe, J. M. (2001). Invasive pulmonary aspergillosis in neutropenic patients during hospital construction: Before and after chemoprophylaxis and institution of HEPA filters. <em>American Journal of Hematology, 66</em>(4), 257-262.</td>
<td>Air counts of <em>Aspergillus</em> organisms on a regular ward vs. on a ward with HEPA filters</td>
<td>Infection rate of invasive pulmonary Aspergillus (IPA) in acute leukemia patients</td>
<td>Before and after study with nonconcurrent and concurrent comparison groups; comparison of infection rates among acute leukemia (AL) patients during three different periods when extensive hospital construction and renovation were taking place. Period 1: 12 AL patients. Period 2: 28 AL patients. Period 3: 71 AL patients (45 treated on a regular ward and 26 were hospitalized in the new ward). When patients were treated in the new hematology ward (period 3), none of the AL or Bone Marrow Transplant (BMT) patients who were hospitalized exclusively in the new ward developed IPA, although 29% of the AL patients who were housed in the regular ward (due to space shortage) still contracted IPA. The reduced incidence of IPA among patients in the new ward was attributed solely to the HEPA filters (other treatment measures did not result in significant reduction in infection rates).</td>
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<td>67</td>
<td>Palmer, R. (1999). Bacterial contamination of curtains in clinical areas. <em>Nursing Standard</em>, 14(2), 33-35.</td>
<td>Bed and window curtains</td>
<td>Bacteria contamination of bed and window curtains</td>
<td>Microbial surveillance; prospective; chart records</td>
<td>28 bed and window curtains sampled from seven surgical, medical, and orthopedic wards</td>
<td>Recently cleaned curtains had the lowest levels of contamination. Bed curtains had much higher counts of bacteria than window curtains. Ward bed curtains are a source of contaminants and bacteria, including methicillin-resistant <em>Staphylococcus aureus</em>.</td>
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<td>Panagopoulou, P., Filioti, J., Petrikkos, G., Giakouppi, P., Anatoliotaki, M., Farmaki, E., et al. (2002). Environmental surveillance of filamentous fungi in three tertiary care hospitals in Greece. <em>Journal of Hospital Infection</em>, 52(3), 185-191.</td>
<td>Environmental fungal load from air, surfaces and water</td>
<td>No health outcome measured.</td>
<td>Prospective study: the environmental fungal load (FL) of three hospitals in Greece was studied; air, surfaces, and tap water from high-risk departments were sampled monthly during one year</td>
<td>Three hospitals from representative regions of Greece; air, surface, and tap water samples were taken</td>
<td>No correlation between fungal species, season, hospital, or departments was observed. Sixty percent of all surfaces examined yielded filamentous fungi and/or blastomycetes. The highest Air Fungal Load (AFL) recorded was in wards located in direct proximity to renovation works. Special protection measures implemented, such as the plastic coverage of opening, were found inadequate.</td>
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<td>69</td>
<td>Passweg, J. R., Rowlings, P. A., Atkinson, K. A., Barrett, A. J., Gale, R. P., Gratwohl, A., et al. (1998). Influence of protective isolation on outcome of allogeneic bone marrow transplantation for leukemia. <em>Bone Marrow Transplant</em>, 21(12), 1231-1238.</td>
<td>Conventional isolation (single room, glove, hand washing, mask, and gown) vs. HEPA/LAF (isolation in rooms designed to lower exposure to airborne infectious agents using high-efficiency particulate air filtration with or without</td>
<td>Graft vs. host disease; fungal pneumonia; one-year transplant-related mortality (TRM); one-year survival</td>
<td>Quasi-experimental; analysis using existing data; retrospective; hypotheses</td>
<td>5,065 patients receiving allogeneic bone marrow transplants between 1988 and 1992 and reported to the International Bone Marrow Transplant Registry by 222 teams</td>
<td>Among patients receiving alternative donor transplants, the probability of fungal pneumonia was lower in the HEPA/LAF isolation. TRM was lower and one-year survival higher for patients treated with HEPA/LAF isolation, whether the transplant was from an HLA (human leukocyte antigen)-identical sibling or alternative donor. Patients treated with HEPA/LAF had lower relative risks of TRM and overall mortality in the first 100 days post-transplant.</td>
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Having a roommate vs. no roommate in a nursing home

Nosocomial infection rates

Quasi-experimental; retrospective/prospective; risk analysis; hypotheses; chart records; questionnaire

120 residents and 49 employees in a nursing home during the outbreak.

The risk of becoming ill one to two days after a roommate became ill was significantly greater than that of becoming ill at other times during the outbreak. The risk of developing illness was greater for female residents and for employees who reported handling residents' soiled linen, stools, or vomit more frequently.
| 71 | Pettinger, A., & Nettleman, M. D. (1991). Epidemiology of isolation precautions. *Infection Control and Hospital Epidemiology, 12*(5), 303-307. | Occupation and gender of persons entering the room; time spent in the room; number of persons entering the room at a time; type of patient isolation | Isolation-precaution compliance rate | Survey; prospective; hypotheses; observation; chart records | 467 persons entering the isolation room of a 24-bed surgical intensive care unit in a 900-bed university hospital | Visitors were much more compliant than staff with strict isolation precautions (88% vs. 41%; \( p < .01 \)). Spending more time in the room was associated with improved compliance. Compliance was higher for persons entering with a group compared with those entering alone. The compliance rate for nurses tended to improve as the nurse-patient ratio increased. Compliance was independent of severity of illness. The amount of time spent in the room and being a visitor were independent predictors of compliance with isolation precautions. |

| 72 | Pittet, D., Hugonnet, S., Harbarth, S., Mourouga, P., Sauvan, V., Touveneau, S., et al. (2000). Effectiveness of a hospital-wide programme to improve compliance with hand hygiene. *Lancet, 356*(9238), 1307-1312. | Promotion posters; bedside, alcohol-based hand-disinfection solution | Hand-washing compliance rate; nosocomial infection rates; rates of methicillin-resistant *Staphylococcus aureus* (MRSA); consumption of hand-rub disinfectant | Quasi-experimental; before-after comparison; prospective; hypotheses; observation in natural setting; chart records | A large acute care teaching hospital in Geneva, Switzerland | After the installation of posters and hand-disinfection dispensers, the hand-washing compliance rate improved from 48% in 1994 to 66% in 1997. Frequency of hand disinfection increased substantially, nosocomial infection decreased (16.9% in 1994 to 9.9% in 1998), MRSA transmission rates decreased (2.16 to 0.93 episodes per 10,000 patient days; \( p < .001 \)), and the consumption of alcohol-based hand-rub solution increased from 3.5 to 15.4 L per 1,000 patient-days between 1993 and 1998. |
|---|---|
| Renovation of an intensive care unit from a six-bed open unit with two sinks to 14 single-bed rooms, each with one sink | Number of persons in the vicinity of patients; staff hand-washing behavior; colonization and infection | Quasi-experimental; before-after comparison; prospective; hypotheses; observation; microbial surveillance; chart records | 410 open-unit patients and 1,022 single-room unit patients in an intensive care unit (for infection rates comparison); 168 patient-hours (99 patients) observation/air sampling during nine months in open unit and 113 patient-hours (68 patients) in single-room units during 12 months | Single rooms with more sinks tended to have higher observed-to-expected ratio of hand washing (30%) than open unit (16%, $p = 0.06$). Respiratory tract infection rate was lower in single-bed room units (3.6 per 100 patients vs. 5.4 per 100) than in the open unit. No differences were found in other types of infections and nosocomial acquisition of the six surveillance organisms. Numbers of persons interacting with a patient in an hour averaged 6.1 in the open units and 4.9 in the isolation rooms ($0.05 < P < 0.10$). |

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<td>Location of falls in a retirement community</td>
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<td><strong>Interventions:</strong></td>
<td>cleaning of environmental surface, review of hand-washing practice</td>
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<td><strong>Isolates of <em>Acinetobacter baumannii</em></strong></td>
<td>Quasi-experimental; before-after comparison; retrospective/prospective; hypotheses; microbial surveillance; DNA typing; chart records</td>
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<td><strong>Patients:</strong></td>
<td>15 patients (12 from burns intensive care unit) involved in an outbreak of a multidrug resistant <em>A. baumannii</em> infection; environmental surfaces; 21 healthcare workers in a burns intensive care unit</td>
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<td><strong>Before interventions, the room environment was contaminated with the <em>A. baumannii</em>, as was the handle of the door leading from the antechamber between both rooms. This allowed the hands of healthcare workers to be contaminated by <em>A. baumannii</em> despite appropriate hand-washing procedures prior to leaving the rooms. Two staff members were colonized with <em>A. baumannii</em>. After interventions, no isolates of <em>A. baumannii</em> were found among patients in the burns intensive care unit.</strong></td>
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<td><strong>Old open ward vs. new ward with more single rooms (6 four-bed rooms, 1 two-bed room, and 4 single rooms)</strong></td>
<td>Infection; contamination</td>
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<td><strong>Infection; contamination</strong></td>
<td>Quasi-experimental; before-after comparison; retrospective/prospective; hypotheses; microbial surveillance; DNA typing; chart records</td>
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<td><strong>Patients:</strong></td>
<td>1,337 patients; 1,811 air samples; 613 curtain samples; 2,004 blanket samples from the new surgical ward in a British hospital</td>
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<td><strong>The sepsis rate of <em>Staphylococcus</em> in the patients’ wounds was 9% in the new ward (10% for men, 7% for women), which was lower than the rate of 14% in the old ward. 28% of these were due to multiple antibiotic-resistant &quot;hospital&quot; strains, which was less than the rate of 56% in the old ward. There was a reduction in the contamination of air and bedding.</strong></td>
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<td>77</td>
<td>San Jose-Alonso, J. F., Velasco-Gomez, E., Rey-Martinez, F. J., Alvarez-Guerra, M., &amp; Pelaez, C. G. (1999).</td>
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<p>| 78   | Sanderson, P. J., &amp; Weissler, S. (1992). | Recovery of coliforms from the hands of nurses and patients: Activities leading to contamination. | Nurses' and patients' hands | Coliform contamination | Coliforms were frequently recovered from nurses' hands after touching patients' washing materials and clothing as well as after bed making, sluice-room activities, and handling clean or dirty linen and curtains. The recovery rates were higher in wards for spinally injured patients than in the surgical wards. Coliforms were recovered with similar frequencies from the hands of patients in both types of wards. Hands might be a media of cross-infection. |</p>
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<th>No.</th>
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<th>Study Details</th>
<th>Main Findings</th>
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<tr>
<td>79</td>
<td>Sherertz, R. J., &amp; Sullivan, M. L. (1985).</td>
<td>Wet mattresses; Burn wound colonization with <em>Acinetobacter</em></td>
<td>Discarding each patient's mattress on the day of the patient's discharge led to a reduced risk of burn wound colonization with <em>Acinetobacter</em> ($P &lt; 0.05$) and, ultimately, resulted in the complete elimination of the organism from the burn unit.</td>
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<td>80</td>
<td>Shirani, K. Z., McManus, A. T., Vaughan, G. M., McManus, W. F., Pruitt, B. A., Jr., &amp; Mason, A. D., Jr. (1986).</td>
<td>Old unit vs. new unit with separate bed enclosures; Infection rate; mortality</td>
<td>Infection rate was significantly reduced in the new unit with separate bed enclosure (from 28.9% to 19.2%). Reduction in observed mortality compared with predicted mortality (calculated on the basis of burn size and age alone), was not apparent in the early group, but was apparent in the new unit (reduction from 48.7% to 28.3%) and was restricted to the subgroup of patients with predicted mortality of 25% to 75%. The overall proportion of patients with bacteremia was reduced from 20.1% to 9.4% in new unit. The incidences of both pneumonia and burn wound invasion remained unchanged. <em>Providencia</em> and <em>Pseudomonas</em> species, endemic in the early cohort, were eliminated in the new unit.</td>
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<td>Study Title</td>
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<td>Skoutelis, A. T., Westenfelder, G. O., BeckerJite, M., &amp; Phair, J. P. (1994).</td>
<td>Hospital carpeting and epidemiology of Clostridium difficile.</td>
<td>American Journal of Infection Control, 22(4), 212-217.</td>
<td>Carpet Microorganism (Clostridium difficile) contamination; colonization; infection</td>
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<td>Smylie, H. G., Davidson, A. I., Macdonald, A., &amp; Smith, G. (1971).</td>
<td>Ward design in relation to postoperative wound infection.</td>
<td>British Medical Journal, 1(740), 67-72.</td>
<td>Before (1964-6): Nightingale open ward; after (1966-8): racetrack surgical ward with 40% beds in single rooms and controlled ventilation</td>
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<td>84</td>
<td>Thompson, J. T., Meredith, J. W., &amp; Molnar, J. A. (2002).</td>
<td>The effect of burn nursing units on burn wound infections. Journal of Burn Care Rehabilitation, 23(4), 281-286.</td>
<td>Burn isolation unit vs. other area without isolation, where burn patients were treated during renovation of the burn unit</td>
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<td>85</td>
<td>Utrup, L. J., Werner, K., &amp; Frey, A. H. (2003).</td>
<td>Minimizing pathogenic bacteria, including spores, in indoor air. Journal of Environmental Health, 66(5), 19-26.</td>
<td>Picking up of pathological bacteria by coagulated particulates introduced in the room electric field</td>
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<td>86</td>
<td>Vernon, M. O., Trick, W. E., Welbel, S. F., Peterson, B. J., &amp; Weinstein, R. A. (2003).</td>
<td>Adherence with hand hygiene: Does number of sinks matter? Infection Control and Hospital Epidemiology, 24(3).</td>
<td>Sink-to-bed ratio Hand-washing compliance rate by all healthcare workers in intensive care unit (ICU)</td>
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<td>87 Williams, H. N., Singh, R., &amp; Romberg, E. (2003). Surface contamination in the dental operatory: A comparison over two decades. <em>Journal of the American Dental Association, 134</em>(3), 325-330.</td>
<td>Improvements in clinic design and equipment (reduce the number of surface areas, mobile countertops, central sterilization facility, autoclavable handpieces, foot-pedal controlled sinks); more stringent infection control procedures</td>
<td>Surface contamination</td>
<td>Quasi-experimental; before (1976)/after (1998) comparison; retrospective/prospective; hypotheses; microbial surveillance</td>
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<td>88 Wong, S., Glennie, K., Muise, M., Lambie, E., &amp; Meagher, D. (1981). An exploration of environmental variables and patient falls. <em>Dimensions in Health Service, 58</em>(6), 9-11.</td>
<td>Environmental factors associated with fall</td>
<td>Falls</td>
<td>Two-stage study: pilot study of incident reports followed by a questionnaire used by the hospital staff to collect fall-related data; data were collected about patient falls during a one-month period</td>
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### Reduce Stress and Improve Outcomes

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<tr>
<th>No.</th>
<th>Study</th>
<th>Environmental variable(s) studied</th>
<th>Outcome measure(s)</th>
<th>Research design</th>
<th>Sample description</th>
<th>Major findings</th>
<th>Grade</th>
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<tbody>
<tr>
<td>1</td>
<td>Aaron, J. N., Carlisle, C. C., Carskadon, M. A., Meyer, T. J., Hill, N. S., &amp; Millman, R. P. (1996). Environmental noise as a cause of sleep disruption in an intermediate respiratory care unit. <em>Sleep, 19</em>(9), 707-710.</td>
<td>Noise measured by sound meter</td>
<td>Sleep disruption measured by polysomnography</td>
<td>Quasi-experimental; hypotheses; sound meter; polysomnography (diagnostic test involving measurement of number of physiologic variables during sleep)</td>
<td>Six patients in an intermediate respiratory care unit (IRCU) recorded in 61 half-hour segments</td>
<td>There was a strong positive correlation ((r = 0.57)) between the number of sound peaks of (\geq 80) dBA and arousals from sleep. When the periods were classified as quiet, moderately loud, and very loud based on the number of sound peaks, there were significantly fewer arousals during quiet periods than during very loud periods. Environmental noise may be an important cause of sleep disruption in the IRCU.</td>
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<td>2</td>
<td>Ackerman, B., Sherwonit, E., &amp; Fisk, W. (1989). Reduced incidental light exposure: Affect on the development of retinopathy of prematurity in low birth weight infants. <em>Pediatrics, 83</em>(6), 958-962.</td>
<td>Incidental lighting within the newborn intensive care unit</td>
<td>Development of retinopathy of prematurity</td>
<td>Experimental study with historical control group: data obtained retrospectively for control group</td>
<td>Control group: 129 infants admitted to the newborn special care unit at Yale-New Haven Hospital; experimental group: 161 infants admitted to the same unit</td>
<td>There was no difference in the incidence and severity of retinopathy of prematurity between the two groups.</td>
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<td>3</td>
<td>Allaouchiche, B., Duflo, F., Debon, R., Bergeret, A., &amp; Chassard, D. (2002). Noise in the postanaesthesia care unit. <em>British Journal of Anaesthesia, 88</em>(3), 369-373.</td>
<td>Noise sources and dBA levels/peaks in a postanesthesia care unit (PACU)</td>
<td>Noise levels; patient perceptions of noise; self-reported discomfort</td>
<td>Quasi-experimental; prospective; decibel recordings; observation of noise peaks; questionnaire assessing patient discomfort</td>
<td>26 patients in an open ward, five-bed PACU in a 35-bed surgical department; 20,187 measurements of noise</td>
<td>The mean dBA level (over 5s intervals) was 67.1, the maximum (over 5s intervals) was 75.7, and the minimum 48.6. The average of peak noises using a linear scale was 126.2 dBL. Five percent of noises exceeded 65 dBA. Staff conversation in open ward caused 56% of sounds greater than 65 dB. Other noise sources (alarm, telephone, and nursing care) each comprised less than 10% of these sounds. Five patients reported disturbance from noise, and there was no significant difference in average levels measured for patients who found the PACU noisy and those who did not.</td>
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<td>4</td>
<td>Astedt-Kurki, P., Paunonen, M., &amp; Lehti, K. (1997). Family members' experiences of their role in a hospital: A pilot study. <em>Journal of Advanced Nursing, 25</em>(5), 908-914.</td>
<td>Location in hospital of visits by family members with patients</td>
<td>Family members’ experience</td>
<td>Survey questionnaire</td>
<td>50 family members of patients in a neurological ward in a Finnish hospital</td>
<td>Family members spent a lot of time at their relative's bedside, most of them up to several hours a day. Almost half of all visits (49%) took place in the patient’s room, 20% were in the ward lounge, and 21% in the hospital café. Family members sought out spaces where they could spend time alone with the patient. The most important way in which the hospital supported families was to keep them informed about the patient's care and treatment.</td>
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<td>5</td>
<td>Baker, C. F. (1984). Sensory overload and noise in the ICU: Sources of environmental stress. <em>Critical Care Quarterly, 6</em>(4), 66-80.</td>
<td>Environmental sources of sensory overload with emphasis on noise</td>
<td>Various effects on intensive care unit (ICU) patients</td>
<td>Review of research literature</td>
<td>About 40 articles</td>
<td>The article mainly surveyed studies on noise. It reviewed and discussed the physical properties of noise (loudness, perceived noisiness, response to noise), noise's physiological (blood pressure, heart rate) and psychological effects on patients (sleep deprivation, ICU psychosis, pain), the sources and levels of noise, and noise-control measures.</td>
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<td>Baker, C. F. (1992). Discomfort to environmental noise: Heart rate responses of SICU patients. <em>Critical Care Nursing Quarterly</em>, 15(2), 75-90.</td>
<td>Noise levels and sources</td>
<td>Heart rate</td>
<td>Quasi-experimental; correlational; prospective; hypotheses; ECG monitor; sound level meter</td>
<td>28 adult patients in a 14-bed single-room surgical intensive care unit</td>
<td>The lowest sound level experienced by most patients was 59 dBA, due to oxygen ventilators near the patients’ heads. Fourteen patients were exposed to 65–69 dBA. Categories of noise sources included conversation in the room, conversation outside the room, nonconversation noise, and ambient noise (listed in the order of average loudness). Patients’ heart rates increased with dBA increases (2–12 bpm with a 6-dBA increase), particularly in response to noises from conversation.</td>
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<td>Baker, C. F., Garvin, B. J., Kennedy, C. W., &amp; Polivka, B. J. (1993). The effect of environmental sound and communication on CCU patients’ heart rate and blood pressure. <em>Research in Nursing &amp; Health</em>, 16(6), 415-421.</td>
<td>Environmental noise from equipment; social noise from conversation</td>
<td>Heart rate, blood pressure</td>
<td>Quasi-experimental; correlational; hypotheses; ECG monitor; sound meter; blood pressure monitor; self-reported anxiety</td>
<td>20 patients in a 29-bed coronary critical care unit studied over two days</td>
<td>The loudest sounds exceeded 70 dBA. Maximum heart rates were higher during conversation than during low ambient sounds (quiet). Blood pressure did not significantly change during any of the sound conditions.</td>
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<td>No.</td>
<td>Authors</td>
<td>Title</td>
<td>Journal and Volume Information</td>
<td>Study Design</td>
<td>Setting</td>
<td>Sample Size</td>
<td>Findings</td>
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<td>8</td>
<td>Barnhart, S. K., Perkins, N. H., &amp; Fitzsimonds, J. (1998).</td>
<td>Behaviour and outdoor setting preferences at a psychiatric hospital.</td>
<td>Landscape and Urban Planning, 42(2-4), 147-156.</td>
<td>Quasi-experimental; prospective; hypotheses; a patient-interactive computer survey located in one of the secure hospital wards</td>
<td>Both staff and patients selected natural open settings for passive behaviors such as sitting and viewing scenery, and natural enclosed settings for active behaviors, such as walking and talking with others. Few significant differences were found between staff and patients.</td>
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<td>9</td>
<td>Bay, E. J., Kupferschmidt, B., Opperwall, B. J., &amp; Speer, J. (1988).</td>
<td>Effect of the family visit on the patient's mental status.</td>
<td>Focus on Critical Care, 15(1), 11-16.</td>
<td>Quasi-experimental; before-after; prospective; hypotheses; Adams Mental Status Examination; family self-rated closeness and anxiety; chart records</td>
<td>Family visits had no consistent effect on patient mental status. Some patients improved after the visit, whereas others experienced a decline in their mental status. Patients who had undergone surgery were more likely to have a negative change in mental status after a visit. Family members who saw themselves as having moderate amounts of mutuality (closeness) with patients had the most positive effects on patient mental status.</td>
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<td>10</td>
<td>Bayo, M. V., Garcia, A. M., &amp; Garcia, A. (1995).</td>
<td>Noise levels in an urban hospital and workers' subjective responses.</td>
<td>Archives of Environmental Health, 50(3), 247-251.</td>
<td>Descriptive; survey of noise distribution; prospective; sound meter; questionnaire</td>
<td>Noise outside the building ranged from 52 to 75 dBA. The main sources were road traffic, human voices, aircraft, and sirens. Noise levels inside the building ranged from 52 to 82 dBA, and the main sources were human voices, vehicles, and equipment. From the staff perspective, noise levels were sufficiently high to interfere with their work and to affect patient comfort and recovery.</td>
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<td>11</td>
<td><strong>Beauchemin, K. M., &amp; Hays, P. (1996).</strong> Sunny hospital rooms expedite recovery from severe and refractory depressions. <em>Journal of Affective Disorders, 40</em>(1-2), 49-51.</td>
<td>Sunlight: sunny rooms vs. dull rooms</td>
<td>Length of stay, mortality</td>
<td>Natural experiment</td>
<td>568 cases with a nonfatal outcome processed—272 in the bright rooms (men 209, women 63) and 296 in dark rooms (men 222, women 74)</td>
<td>Patients stayed a shorter time in sunny rooms, but significant difference was confined to women (2.3 days in sunny rooms, 3.3 days in dull rooms). Mortality in both sexes was consistently higher in dull rooms.</td>
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<td>12</td>
<td><strong>Beauchemin, K., &amp; Hays, P. (1998).</strong> Dying in the dark: Sunshine, gender and outcomes in myocardial infarction. <em>Journal of the Royal Society of Medicine, 91</em>(7), 352-354.</td>
<td>Sunny (bright) rooms vs. dull (dim) rooms</td>
<td>Length of stay</td>
<td>Retrospective natural experiment: random assignment of patients</td>
<td>174 admissions to two psychiatric wards at a hospital in Edmonton, Alberta, Canada</td>
<td>Patients in sunny rooms had an average stay of 16.6 days compared to 19.5 days for those in dull rooms, a difference of 2.6 days (15%). The difference was more marked for males: bright rooms, 15.3 days vs. dull rooms, 22.1 days.</td>
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<td>13</td>
<td><strong>Benedetti, F., Colombo, C., Barbini, B., Campori, E., &amp; Smeraldi, E. (2001).</strong> Morning sunlight reduces length of hospitalization in bipolar depression. <em>Journal of Affective Disorders, 62</em>(3), 221-223.</td>
<td>Sunlight: east-facing room (direct morning sunlight) vs. west-facing rooms</td>
<td>Length of stay</td>
<td>Naturalistic retrospective observation days were analyzed</td>
<td>Consecutively admitted 415 and 187 bipolar depressed inpatients, stratified by diagnosis, rooms of hospitalization, and season of hospitalization</td>
<td>Bipolar patients in east rooms had a mean 3.67-day shorter hospital stay than patients in west rooms. No effect was found in unipolar patients.</td>
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<td>14</td>
<td><strong>Bentley, S., Murphy, F., &amp; Dudley, H. (1977).</strong> Perceived noise in surgical wards and an intensive care area: An objective analysis. <em>British Medical Journal, 2</em>(6101), 1503-1506.</td>
<td>Noise in an open Nightingale ward, a cubicle, and a mixed intensive therapy unit (ITU)</td>
<td>Sources and levels of noise</td>
<td>Descriptive survey of noise distribution; sound meters mounted on walls above heads of patients</td>
<td>Five 24-hour periods in an open Nightingale ward, a cubicle of the ward, and an ITU in the UK</td>
<td>Noise levels in all three areas were higher than internationally recommended levels at all times of day. Loud noises above 70 dBA were common in all areas, particularly the ITU. Noise reached levels known to cause annoyance during the day in the ward and cubicle, and during both the day and the night in the ITU. Equipment and staff conversations</td>
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<td>15</td>
<td><strong>Berg, S. (2001).</strong> Impact of reduced reverberation time on sound-induced arousals during sleep. <em>Sleep, 24</em>(3), 289-292.</td>
<td>Acoustic characteristics of ceiling tiles (sound-reflecting vs. sound-absorbing)</td>
<td>Reverberation time; sleep arousals or fragmentation</td>
<td>Quasi-experimental; within-subjects; prospective; recording of dB levels and reverberation period; sleep recording via EEG</td>
<td>12 healthy student volunteers (six male, six female) studied in a one-bed room over four nights in a refurbished (former) surgical ward</td>
<td>Sound-absorbing ceiling tiles reduced the reverberation time by 0.12 seconds in a frequency range of 200–5,000Hz. At the same time, arousal responses/sleep fragmentations were significantly reduced, indicating improved sleep quality.</td>
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<td>16</td>
<td><strong>Blackburn, S., &amp; Patteson, D. (1991).</strong> Effects of cycled light on activity state and cardiorespiratory function in preterm infants. <em>Journal of Perinatal &amp; Neonatal Nursing, 4</em>(4), 47-54.</td>
<td>Cycled light (lights turned off for a portion of the 24-hour day) vs. continuous lighting</td>
<td>Heart rate, activity levels, and respiratory rate</td>
<td>Natural experiment</td>
<td>18 infants born at or prior to 34-weeks gestation, admitted to a tertiary neonatal intensive care unit</td>
<td>Heart rates and activity levels were significantly lower for the cycled (lights off) group than the continuous lighting group. Also, infants in the cycled-light group tended to have longer periods of quiescence and inactivity similar to quiet sleep.</td>
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<td>17</td>
<td><strong>Blomkvist, V., Eriksson, C. A., Theorell, T., Ulrich, R. S., &amp; Rasmanis, G. (in press, 2004).</strong> Acoustics and psychosocial environment in coronary intensive care. <em>Occupational and Environmental Medicine.</em></td>
<td>Reverberation time (altered by changing the ceiling tiles in a coronary critical care unit (CCU) from sound-reflecting tiles to sound-absorbing tiles of identical appearance)</td>
<td>Reported psychosocial work environment and staff moods; speech intelligibility</td>
<td>Quasi-experimental; repeated measurements; prospective; hypotheses; sound-level recordings; staff questionnaire; Rapid Speech Transmission (RASTI) measure</td>
<td>36 nurses working regularly over three shifts for several weeks in the CCU in a large Swedish teaching hospital</td>
<td>Shorter reverberation times were recorded after ceiling tiles were changed from sound-reflecting ceiling tiles to sound-absorbing ceiling tiles (0.8-0.9 to 0.4 seconds). The staff experienced significantly lower work demands and improved workplace atmosphere (less pressure and strain) during the afternoons. Speech intelligibility improved on the RASTI scale when the sound-reflecting ceiling was changed to sound absorption.</td>
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<td>18</td>
<td><strong>Brown, B., Wright, H., &amp; Brown, C. (1997).</strong> A post-occupancy evaluation of wayfinding in a pediatric hospital: Research findings and implications for instruction. <em>Journal of Architectural &amp; Planning Research, 14</em>(1), 35-51.</td>
<td><strong>Wayfinding aids</strong></td>
<td><strong>Staff involvement in giving directions for wayfinding, influence on work commitments; visitor wayfinding experiences; patient wayfinding experiences</strong></td>
<td><strong>Postoccupancy evaluation; five systematic methods were used to assess problems: staff and visitor interviews, staff-maintained logs to record visitor wayfinding requests, photographed traces, behavior observation and tracking, cognitive maps drawn by patients and parents</strong></td>
<td><strong>66 staff interviews, 47 visitor wayfinding interviews, 46 summaries of one week of direction giving, 193 observations of initial wayfinding, 13 visitors tracked to destination-cognitive maps drawn by 11 inpatients and three parents</strong></td>
<td><strong>Spatial organization and layout often resulted in wayfinding problems. Problems were exacerbated by inadequate or conflicting cues—signs, colors, lighting. Important to understand entire wayfinding system to diagnose and remedy wayfinding problems. Detailed findings related to the specific conditions at the hospital. However, these are commonly occurring situations in hospitals.</strong></td>
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Observation of behaviors (closeness to incubator, parent-staff interaction, eye contact between parent and child, physical contact); number and duration of parental visits  
|   | 49 set of parents with infants in the NICU separated into three groups: visits in house while mother hospitalized; visits requiring one hour or less travel time; visits requiring more than one hour of travel time  
Travel time was found to influence the number of visits, with fewer visits from those parents who lived furthest from the NICU. The duration of these infrequent visits was longer in comparison to those visits from parents living closer to the NICU, therefore, the total duration of visiting time over a two-week period was the same. Observation of behaviors indicated no difference in interaction between parents and infants among the groups. |   |
Clarity and desirability of different numbering systems for wayfinding  
Prospective study  
Stratified random sample: 60 patients (15 inpatients, 15 outpatients) and visitors (15 inpatient visitors and 15 outpatient companions) were interviewed; 350 staff members were interviewed  
|   | Patients and visitors preferred SUB1, SUB2 over other options. Staff preferences were different—they preferred naming the floors 1 and 2 based on a concern that B1, B2 and SUB1, SUB2 schemes project a poor image—basement floors had a negative association. |   |
Patients’ and visitors’ understanding of technical and lay hospital-related terms  
Patient and visitor interviews  
Study 1: random sample of 125 patients and visitors; study 2: random sample of 105 visitors  
<p>|   | For the most part, terms suggested most often in study 1 were also selected the 'best' by participants in study 2. Participants preferred simple terms such as walkway, general hospital to more complex or less familiar terms such as overhead link, medical pavilion, or health sciences complex. |   |</p>
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<tr>
<th>Plan view vs. perspective view in you-are-here maps; use of insets in YAH maps</th>
<th>Clarity of spatial representation</th>
<th>Prospective study; random assignment</th>
<th>70 randomly selected patients and visitors</th>
<th>Perspective view was preferred over the plan view (whether presented with or without inset). Maps with insets were preferred over those without, whether dealing with plan or perspective views.</th>
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<td>Location and spacing of signs; decision points</td>
<td>Travel time; number of hesitations; number of times directions asked; reported level of stress; number of additional signs requested; number of signs available to participant</td>
<td>Experimental design; multiple outcomes measured; random sample</td>
<td>105 randomly selected inpatients and inpatient visitors; 26 participants in each of the experimental groups and 26 in a fourth group without any signs</td>
<td>The number of signs available to the participant had a significant effect on wayfinding along many different measures including travel time, number of hesitations, number of times directions were asked, as well as reported level of stress. Results suggest that directional signs should be placed at or before every major intersection, at major destinations, and where a single environmental cue or a series of such cues (e.g., change in flooring material) convey the message that the individual is moving from one area into another. If there are no key decision points along a route, signs should be placed approximately every 150–250 feet.</td>
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<td>24</td>
<td><strong>Carpman, J., Grant, M. A., &amp; Simmons, D. A. (1985).</strong> Hospital design and wayfinding: A video simulation study. <em>Environment &amp; Behavior, 17</em>(3), 296-314.</td>
<td>Alternative locations of entrance doors to parking structure</td>
<td>Turning behavior and wayfinding</td>
<td>Experimental, video simulation study</td>
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<td>25</td>
<td><strong>Causey, D. L., McKay, M., Rosenthal, C., &amp; Darnell, C. (1998).</strong> Assessment of hospital-related stress in children and adolescents admitted to a psychiatric inpatient unit. <em>Journal of Child and Adolescent Psychiatric Nursing, 11</em>(4), 135-145.</td>
<td>Stressors related to a psychiatric inpatient unit</td>
<td>Reported hospital-related stressors; reported coping efforts, depression, and anxiety; observed behaviors and patient adjustment</td>
<td>Questionnaire; observation</td>
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<td>26</td>
<td><strong>Chang, Y. J., Lin, C. H., &amp; Lin, L. H. (2001).</strong> Noise and related events in a neonatal intensive care unit. <em>Acta Paediatrica Taiwanica = Taiwan Er Ke Yi Xue Hui Za Zhi, 42</em>(4), 212-217.</td>
<td>Noise</td>
<td>dBA levels and peaks</td>
<td>Descriptive; recordings of noise distribution, peak noise, and sources at different locations; decibel meter; observation of noise sources</td>
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</table>
related source was monitor alarms. These results imply that modifications of staff behavior, care procedures, and apparatus may reduce the noise levels in the NICU.

| 27 | Cheek, F. E., Maxwell, R., & Weisman, R. (1971). Carpeting the ward: An exploratory study in environmental psychiatry. *Mental Hygiene, 55*(1), 109-118. | Carpet | Patient and staff satisfaction; ease of maintenance | Exploratory; before-after study | Interviews with administrative personnel (A-2, B-3), ward staff (A-6, B-3), and patients (A-4, B-5); questionnaires from ward staff (A-16, B-6) at two psychiatric units located at state mental institutions | While staff members reacted very negatively to the carpet in ward A, administration considered it a success. Patients reacted positively. Carpeting was a success in ward B as it was incorporated into the design before people moved in and efforts were made to have cleaning systems in place from the beginning. All respondents had a favorable opinion. |

<p>| 28 | Cmiel, C. A., Karr, D. M., Gasser, D. M., Oliphant, L. M., &amp; Neveau, A. J. (2004). Noise control: A nursing team's approach to sleep promotion. <em>American Journal of Nursing, 104</em>(2), 40-48. | Noise levels as function of changes in staff behavior and equipment modification | Noise levels and peaks in dBA | Quasi-experimental; prospective; a priori hypotheses; sound dosimeter; patient questionnaire | Three empty rooms and one semiprivate room (simulated occupied) before noise-reduction interventions in a surgical thoracic intermediate care nursing unit; one empty room after interventions in the same unit | Before interventions, the average sound level recorded in empty rooms was 45 dBA, and in the simulated occupied semiprivate room, 53 dBA, both exceeding the recommended 35 dBA level. Peak sound level in the empty rooms was 113 dBA. After interventions, sound levels in an empty room averaged 42 dBA, and peaked at 86 dBA. Staff reported efforts to close patient room doors and to advocate awareness of noise level. Patients commented positively on closing of doors. |</p>
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<th>Method</th>
<th>Sample Size</th>
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<td>29</td>
<td>Cohen-Mansfield, J., &amp; Werner, P. (1999).</td>
<td>Mail survey questionnaire</td>
<td>320</td>
<td>Sixty-nine percent of respondents rated outdoor spaces as extremely useful and as having several positive impacts on patients. Higher levels of perceived benefits were linked to the presence of more design features, such as gazebos and benches, and to a greater number of activities offered in the area. Problems cited frequently included lack of benches, absence of shade, difficulty in accessing space from inside facility, and patient safety.</td>
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<td>30</td>
<td>Couper, R. T., Hendy, K., Lloyd, N., Gray, N., Williams, S., &amp; Bates, D. J. (1994).</td>
<td>Eight 24-hour periods (Friday to Saturday) over eight weeks; four periods in each of the two open bay wards—one for infant (eight beds), one for older children (10 beds)</td>
<td>820</td>
<td>Open bays generate very high traffic volumes and coincident noise. In an average 24-hour period, 5.5 patients in the infants' ward and 9.5 patients in the children's ward received 617 and 683 visits by 104 and 110 individuals, respectively. Maximum noise levels of 57.3 dBA and 64.6 dBA occurred at 10:00 Saturday and 19:00 Friday, which coincided with peak traffic volumes. Consideration should be given either to abolishing or substantially modifying open-bay areas to control noise.</td>
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<td>31</td>
<td>Deep, P., &amp; Petropoulos, D. (2003). Effect of illumination on the accuracy of identifying interproximal carious lesions on bitewing radiographs. Journal (Canadian Dental Association), 69(7), 444-446.</td>
<td>Experimental</td>
<td>14</td>
<td>There was no significant difference ($p = 0.07$) in the accuracy of identifying simulated interproximal carious lesions on bitewing radiographs in the light mean accuracy (72% +/- 12%) and dark (75% +/- 12%) conditions.</td>
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<td>32</td>
<td>Diette, G. B., Lechtzin, N., Haponik, E., Devrotes, A., &amp; Rubin, H. R. (2003). Distraction therapy with nature sights and sounds reduces pain during flexible bronchoscopy: A complementary approach to routine analgesia. <em>Chest, 123</em>(3), 941-948.</td>
<td>Nature scene mural with a tape of nature sounds vs. blank ceiling of procedure room</td>
<td>Patient ratings of pain control and anxiety; satisfaction; ability to breathe</td>
<td>Experiment; randomized; prospective; hypotheses; questionnaire</td>
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<td>33</td>
<td>Dijkers, M., Yavuzer, G., Ergin, S., Weitzenkamp, D., &amp; Whiteneck, G. G. (2002). A tale of two countries: Environmental impacts on social participation after spinal cord injury. <em>Spinal Cord, 40</em>(7), 351-362.</td>
<td>Environmental barriers (e.g., accessibility of public spaces, buildings, public transportation, businesses)</td>
<td>Patients’ independence in activities of daily living; aspects of the physical environment that facilitate or hinder daily living; social integration</td>
<td>Survey questionnaires (Craig Handicap Assessment and Reporting Technique, Craig Hospital Inventory of Environmental Factors)</td>
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<td>Bright light treatment</td>
<td>Depression (SIGH-SAD questionnaire); measures of sleep; patient expectations</td>
<td>Experimental, random assignment of patients to one of three treatment groups</td>
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<td>Noise in three different types of patient physical environments</td>
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<td>Noise levels in dBA</td>
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<td>Descriptive; recordings of noise levels and observation of noise sources at different locations; sound-level meter</td>
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<td>Six infant incubators, a 17-bed surgical recovery room, and two rooms in a seven-bed acute-care unit in an 800-bed hospital.</td>
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<td>Noise in incubators averaged 57.7 dBA, and was generated mainly by an electric motor and fan. The average noise level in the recovery room was 57.2 dBA, and in the acute care unit rooms 60.1 and 55.8 dBA; peaks frequently exceeded 70–80 dBA. Noise levels in the recovery room and acute care unit rooms were significantly correlated with the numbers of staff members and patients. Noise levels are given for specific medical equipment and patient care activities.</td>
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<td>Single-bed rooms vs. four-bed wards in a large nursing home</td>
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<td>Perceptions regarding physical and social aspects of the nursing home environment; satisfaction; preferences with regard to privacy, socializing, noise, etc.</td>
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<td>Structured interview</td>
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<td>66 residents (39 single-room residents; 27 ward residents) over 60 years of age in a 400-bed nursing home; age range of residents: 60-89 years</td>
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<td>Residents of four-bed rooms viewed the nursing home as less secure and lacking privacy in comparison to the single-bed room residents. Single-room residents expressed greater preference for isolation and greater concern for confidentiality.</td>
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<td>Intensive care units vs. general medical-surgical wards</td>
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<td>Family members’ needs with respect to being near or with the patient and the physical environment to support the family</td>
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<td>Questionnaire</td>
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<td>25 family members of patients in general medical and surgical wards; 25 family members of patients in intensive care units (ICU) in a V.A. hospital</td>
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<td>Categories of family needs that were considered important or very important by respondents both in general wards and ICUs included: patient information, being near or with the patient (waiting room, overnight accommodations), emotional support, and a physical environment to support personal needs (nearby bathroom, convenient telephone, comfortable furniture in waiting room, food available 24 hours a day). ICU family also assigned high</td>
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<td><strong>Uninterrupted visibility lines decision points (using space syntax measures such as connectivity, integration, intelligibility, etc.)</strong></td>
<td><strong>Wayfinding behavior and cognitive understanding</strong></td>
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<td><strong>Effects of quiet vs. noisier environment (+10 dB) under two levels of reverberation time (RT = 0.6 s and 1.6 s) [RT defined as the time required for a noise signal to decay 60 dB upon termination of the noise]</strong></td>
<td><strong>Speech-discrimination performance</strong></td>
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<td>Noise levels in multibed rooms in a neonatal intensive care unit (NICU) and inside infant incubators. Noise levels and peaks in dBA. Descriptive; sound-level meter recordings of noise levels, peaks, and distribution. Six 12-hour and four 24-hour periods measured inside incubators and in three rooms (six patients in each room) in the NICU in a Canadian hospital. Mean hourly noise levels inside the incubator (61 dBA) were significantly higher than outside (55 dBA); both values exceeded the recommended level of 50 dB. Noise levels were also higher in a higher-acuity room where staff activity was greatest (59 dB). In addition, peak noise levels of 120 dB were measured in incubators, indicating that noise levels in the NICU are greatly excessive.</td>
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<td>Traditional vs. nouveau waiting areas in outpatient clinic. Multiple outcome measures: patients’ affective appraisal of environment, self-reported stress and arousal, satisfaction ratings, pulse readings. Two-sample comparative design with data being collected pre and post-relocation to a neurology outpatient clinic; a priori hypotheses. 145 neurology patients interviewed in two groups: 81 (traditional), 64 (nouveau) waiting area. Convergent evidence that the nouveau waiting area is associated with more positive environmental appraisals, improved mood, altered physiological state, and greater reported satisfaction.</td>
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<td>Windows in private and shared offices: level of illumination; view accessibility and quality; sunlight penetration (max floor area that could be covered in direct sunlight). Reported job strain; job satisfaction; intention to quit; well-being, including fatigue and tension. Questionnaire-based survey of employees. 100 white-collar and blue-collar employees (66 males, 34 females; mean age 41.8 years) of a large organization in a region of Southern Europe. Employees experienced a wide range of window conditions, ranging from very dim to very bright illumination levels, no sun patches (no penetration) to total coverage of floor, and from no view of nature to a full nature view. There was a positive impact for the level of sunlight penetration on job satisfaction, intention to quit, and general well-being. Window views of nature helped to buffer the impact that job stress had on the intention to quit, and had a positive effect on general well-being of the employees. There were no effects for the level of...</td>
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<td><strong>Lewy, A. J., Bauer, V. K., Cutler, N. L., Sack, R. L., Ahmed, S., Thomas, K. H., et al. (1998).</strong> Morning vs. evening light treatment of patients with winter depression. <em>Archives of General Psychiatry, 55</em>(10), 890-896.</td>
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<td>Presence of a female relative vs. absence of a relative during labor and delivery in multibed labor rooms</td>
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<td>Labor outcomes: pain drugs; percent vaginal deliveries; drugs to augment labor; oxytocin; vacuum extractions; cesarean sections</td>
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<td>Prospective experiment with random assignment of patients; hypotheses; several labor outcomes</td>
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<td>109 women in uncomplicated spontaneous labor in a hospital and maternity clinics in Botswana</td>
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<td>Patients with a female relative, compared to those with no relative present, had reduced need for obstetric interventions and a higher frequency of normal deliveries. When a female relative was present, patients had a higher rate of spontaneous vaginal delivery, needed less analgesia, less oxytocin, fewer amniotomies to augment labor, required vacuum extraction less often, and had fewer cesarean sections.</td>
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<td>Noise levels in a multibed open-plan cardiac surgical intensive care unit (CSICU)</td>
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<td>Noise levels</td>
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<td>Descriptive; recordings of noise levels, peaks, and distribution in environment; concealed sound-level meter</td>
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<td>Six 16-hour recordings of sound levels in a 12-bed open-plan cardiac surgical intensive care unit in the UK</td>
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<td>Maximum sound levels occurring in one-minute periods ranged from 61 to 101 dBA. Peaks frequently exceeded 80 dBA. Continuous background noise (one minute continuous-sound pressure levels) ranged from 57 to 77 dBA. Noise in the CSICU was consistently and far above the World Health Organization recommended levels (35 dBA at night and 40 dBA during the day).</td>
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<td>Noise, light, and interruptions in an intensive care unit (ICU)</td>
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<td>Noise levels in dBA; light levels in foot candles; patient interruption by doctors, nurses, therapists</td>
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<td>Descriptive; recordings of noise distribution, peak noise, noise sources; light levels; staff interruptions; decibel meter; observation by staff</td>
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<td>24 hours of observation of patient interruptions; more than one week of recordings of sound and light on a general medical floor</td>
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<td>Peak noise levels were much higher than those recommended in all areas. The number of sound peaks greater than 80 dBA was especially high in the intensive and respiratory care areas. Light levels in all areas had a day-night rhythm. Patient interruptions by staff tended to be erratic, leaving little time for condensed sleep.</td>
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<td>Noise simulated by playing pre-recorded audio tape of operating room noise, Speech reception threshold; speech discrimination</td>
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<td>Nelson-Shulman, Y. (1983-84)</td>
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<td>Intensive care unit (ICU) noise and other environmental factors</td>
<td>Sleep abnormalities</td>
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<td>Spatial configuration</td>
<td>Intelligibility; ability to reach destinations</td>
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<td>Shankar, N., Malhotra, K. L., Ahuja, S., &amp; Tandon, O. P. (2001)</td>
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<td>103</td>
<td>Sherman, S. A., Varni, J. W., Ulrich, R. S., Malcarne, V. L. (in press)</td>
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was found between patient-room window use and the number of visitors in the gardens. Preliminary data suggested that emotional distress were lower for patients, parents, and staff members when they were in a garden in comparison to being inside the hospital.

| 104 | **Shertzer, K. E., & Keck, J. F. (2001).** | Music and the PACU environment. *Journal of Perianesthesia Nursing, 16*(2), 90-102. | Effects of music vs. no music on pain in a pediatric intensive care unit (PACU) | Pain intensity; comfort with aspects of the PACU stay | Quasi-experimental; hypotheses; reported pain and comfort | 97 pediatric patients undergoing same-day surgery | The group exposed to music experienced a reduction in pain during the PACU stay, while there was no reduction experienced by the control group (no music). Also, the group with music reported less noise from both the staff and equipment, perceived the nurses as more available, and reported a more positive stay experience in the PACU. |

<p>| 105 | <strong>Simpson, T., &amp; Shaver, J. (1991).</strong> | A comparison of hypertensive and nonhypertensive coronary care patients' cardiovascular responses to visitors. <em>Heart Lung, 20</em>(3), 213-220. | Family visit vs. an interview by an investigator | Blood pressure (systolic and diastolic), heart rate, and premature ventricular contractions | Quasi-experimental; repeated measurements; hypotheses | 24 patients (12 with hypertension, 12 without) in a coronary critical care unit in a hospital in the U.S. Northwest | Group means for systolic blood pressure and heart rate were higher for patients with hypertension than for patients without hypertension. Cardiovascular data indicated for both groups of patients (those with hypertension and those without hypertension) that family visits were no more physiologically stressful than a comparative interaction condition consisting of an interview. |
| 106 | Slevin, M., Farrington, N., Duffy, G., Daly, L., &amp; Murphy, J. F. (2000). Altering the NICU and measuring infants' responses. <em>Acta Paediatrica</em>, 89(5), 577-581. | Quiet period (reduced light, noise, alarm events, staff conversation, staff activity, and infant handling) vs. period without quieting in a neonatal intensive care unit (NICU) | Blood pressure; heart rate; oxygen saturation; infants' observed movements | Quasi-experimental; before-after; within-subjects; hypotheses; decibel meter; light meter; video camera; physiology monitor; observation | 10 preterm infants in a NICU in Ireland | During the quiet period (reduced light, noise, alarm events, staff conversation, staff activity, and infant handling), infants' diastolic blood pressure and mean arterial blood pressure declined significantly (2 mm Hg), and infants' movements dropped from 84 to 14.5. |
| 107 | Sommer, R., &amp; Ross, H. (1958). Social interaction on a geriatrics ward. <em>The International Journal of Social Psychiatry</em>, 4(2), 128-133. | Different furniture arrangements in a geriatric ward | Verbal interactions among patients (sustained and transient) | Experiment; within-subjects; observation | 83 female subjects (mean age 74); 57 diagnosed as arteriosclerotic; 24 diagnosed as schizophrenic or manic depressive; 2 diagnosed as GPI (general paralysis of the insane). | Both transient and sustained verbal interactions almost doubled after the implementation of the new furniture arrangement. There were no recorded verbal interactions that occurred between more than three subjects. |
| 108 | Soutar, R. L., &amp; Wilson, J. A. (1986). Does hospital noise disturb patients? <em>British Medical Journal (Clinical Research Ed.)</em>, 292(6516), 305. | Noise in a general medical ward, acute admission ward, and psychiatric ward | Noise levels in dBA; sleep quality | Descriptive; survey of noise distribution; hypotheses; sound-level meter; sleep quality reported by patients and staff | 91 patients and 21 nursing staff members in a general medical ward, an acute admission ward, and a psychiatric ward | The average noise levels in the general medical ward, the acute admission ward, and the psychiatric ward were respectively 68, 66, and 49 dBA. The psychiatric unit was quieter than the other units. In comparison to sleep at home, 39 patients reported unaltered sleep, 28 reported worse sleep, and 24 reported better sleep when in the hospital. Staff reported noise was sufficient to disturb 40% of patients. |
| 109 | Southwell, M. T., &amp; Wistow, G. (1995). Sleep in hospitals at night: Are patients' needs being met? <em>Journal of Advanced Nursing, 21</em>(6), 1101-1109. | Sources of sleep disturbance in different hospital environments | Patient sleep quality survey; questionnaire | 454 patients and 129 nurses in four hospitals in the UK | Patients reported they had insufficient sleep in the hospital at night and experienced discomfort, worries, and pain. Sleep was disrupted by a variety of sources of disturbance, including inadequately dimmed lights at night and that staff awakened patients early in the morning. Major sources of noise disturbance were other patients, nurses attending other patients, phone rings, and patients’ and nurses’ conversations. | B |
| 110 | Starks, M. A. (2003). Restoring attention in pregnancy: The natural environment. <em>Clinical Nursing Research, 12</em>(3), 246-265. | Activities in nature vs. no activities in nature | Test errors Quasi-experimental; pre/post-test with control group; hypotheses; test performance accuracy | 57 women attending prenatal classes (29 in group exposed to nature, 28 in control group) | After the nature intervention, women in the experimental group (spending 120 minutes each week in restorative activities involving nature) had fewer errors compared to the control group without nature experience. Other measures did not reveal differences. | B |
| 111 | Stoneham, J., &amp; Jones, R. (1997). Residential landscapes: Their contribution to the quality of older people's lives. <em>Activities, Adaptation &amp; Aging, 22</em>(1-2), 17-26. | Gardens or landscapes in sheltered houses | Residents' self-reported behaviors and perceptions with respect to gardens and landscapes Descriptive; survey; hypotheses; questionnaire; interview | 106 residents (aged 60–94 years old) in six sheltered houses in the UK | The main reported uses of landscapes were passive. Most residents viewed landscapes to be important and of high value. | B- |
| 112 | <strong>Thomas, K. A. (1990).</strong> Design issues in the NICU: Thermal effects of windows. <em>Neonatal Network, 9</em>(4), 23-26. | Location of incubators near windows vs. interior walls | Incubator air temperature, incubator exterior wall temperature, and temperature of window and wall surfaces as estimates of gradients supporting convective and radiant heat loss | Natural experiment | A total of 10 single-walled, manually operated incubators (Isolette C-86) were studied, five located adjacent to exterior windows and five adjacent to interior walls. Incubators in the wall location evidenced slightly warmer wall temperatures and slightly cooler indoor air temperatures than those in window locations. Gradient driving heat loss was larger in the window location, the incubators located adjacent to exterior windows appeared to have greater convective and radiant heat loss. | A- |
| 113 | <strong>Topf, M., &amp; Davis, J. E. (1993).</strong> Critical care unit noise and rapid eye movement (REM) sleep. <em>Heart Lung, 22</em>(3), 252-258. | Audiotaped critical care unit noise (noisy vs. quiet conditions) played in a sleep laboratory | REM (rapid eye movement) sleep | Experiment; randomized assignment to noisy and quiet conditions; hypotheses; audiotape played; polysomnography | 70 healthy (nonpatient) females attempting to sleep in a sleep laboratory | During the noisy condition, participants showed poorer REM sleep on 7 of 10 measures. They had lower REM activity and shorter REM durations throughout the night, during the first and second halves of the night, as well as a longer interval between the first and second REM cycles. | A- |
| 114 | <strong>Topf, M., &amp; Dillon, E. (1988).</strong> Noise-induced stress as a predictor of burnout in critical care nurses. <em>Heart Lung, 17</em>(5), 567-574. | Noise in critical care units | Staff life-event stress; occupational stress; sensitivity to noise; noise-induced stress; burnout | Survey; hypotheses; correlational; Jones's Staff Burnout Scale for Health Professionals; Maslach's Burnout Inventory; other self-reports | 100 critical care nurses (91% female) in two large U.S. hospitals | The three noise sources listed by nurses as most important were telephones, alarms, and beepers. Reported noise-induced occupational stress was positively related to reported burnout. Nurses more sensitive to noise were not at more risk of burnout due to noise-induced stress. | B |</p>
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<th>Author(s)</th>
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<td>115</td>
<td>Topf, M., &amp; Thompson, S. (2001)</td>
<td>Interactive relationships between hospital patients' noise-induced stress and other stress with sleep. <em>Heart Lung</em>, 30(4), 237-243.</td>
<td>Noise and other environmental stressors (e.g., light)</td>
<td>Self-reported sleep quality, stress, anxiety, pain</td>
<td>Secondary analysis using existing data; hypotheses; self-report inventories; regression analysis</td>
<td>97 cardiac patients in a general unit</td>
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<td>116</td>
<td>Topf, M., Bookman, M., &amp; Arand, D. (1996)</td>
<td>Effects of critical care unit noise on the subjective quality of sleep. <em>Journal of Advanced Nursing</em>, 24(3), 545-551.</td>
<td>Audiotaped critical care unit noise (noisy vs. quiet conditions) in a sleep laboratory</td>
<td>Self-reported sleep quality</td>
<td>Experiment with random assignment; comparison between noisy and quiet condition; prospective; hypotheses; audiotape; self-reports</td>
<td>60 females attempting to sleep in a laboratory (33 of them listened to an audiotape of noise in a critical care unit)</td>
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<td>117</td>
<td>Tse, M. M. Y., Ng, J. K. F., Chung, J. W. Y., &amp; Wong, T. K. S. (2002)</td>
<td>The effect of visual stimulation via the eyeglass display and the perception of pain. <em>Cyberpsychology &amp; Behavior</em>, 5(1), 65-75.</td>
<td>Exposure to soundless video display of natural scenery vs. exposure to a blank display (control)</td>
<td>Self-reported ratings of anxiety level, simulation sickness, and degree of simulation immersion; pain threshold; pain tolerance</td>
<td>Experiment; random assignment; crossover; reported pain; behavioral measure of pain tolerance; pain produced by modified tourniquet</td>
<td>72 (36 female, 36 male) Chinese students (nonpatients) with the average age of 20.97 +/- 1.97 years, in good health, and with normal or corrected vision</td>
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<td>118</td>
<td>Tse, M. M., Ng, J. K., Chung, J. W., &amp; Wong, T. K. (2002). The effect of visual stimuli on pain threshold and tolerance. <em>Journal of Clinical Nursing</em>, 11(4), 462-469.</td>
<td>Exposure to soundless video display of natural scenery vs. exposure to a blank display (control)</td>
<td>Pain threshold (time when participants reported the first detectable pain); pain tolerance (time that pain was reported as intolerable)</td>
<td>Experiment; randomized; cross-over; hypotheses; pain was produced by a modified tourniquet</td>
<td>46 healthy volunteers assigned to two groups: with video nature display or with blank display</td>
<td>Nonpatient volunteers exposed to the nature scenery, compared to participants assigned the blank display, had higher pain thresholds and greater pain tolerance. Gender and the sequence of visual stimuli did not influence the effect of the nature display on pain threshold and pain tolerance.</td>
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<td>119</td>
<td>Tsiou, C., Eftymiatos, D., Theodossopoulou, E., Notis, P., &amp; Kiriakou, K. (1998). Noise sources and levels in the Evgenidion Hospital intensive care unit. <em>Intensive Care Medicine</em>, 24(8), 845-847.</td>
<td>Noise in a multibed intensive care unit (ICU)</td>
<td>Noise levels in dBA</td>
<td>Descriptive; recordings of noise levels; distribution; sound-level meter; questionnaire</td>
<td>10 patients (six male, four female); nine eight-hour sound recording periods in a six-bed ICU in Greece</td>
<td>Human activity, operating equipment, and construction engineering of the hospital building were identified as major noise sources. Average noise levels in the ICU ranged from 60.3–67.4 dBA and exceeded recommended hospital levels by 27 dBA.</td>
</tr>
<tr>
<td>120</td>
<td>Ulrich, R. S. (1984). View through a window may influence recovery from surgery. <em>Science</em>, 224(4647), 420-421.</td>
<td>Views through windows: natural view vs. view of brick wall</td>
<td>Length of stay; number and strength of analgesic doses; number and strength of anti-anxiety doses; minor complications; nurses’ notes</td>
<td>Quasi-experimental design; random-like assignment; retrospective; clinical data from patient records</td>
<td>46 patients grouped into 23 matched pairs (15 female and 8 male) who had undergone cholecystectomy</td>
<td>Patients with the window view of nature (trees) had shorter postoperative stays, took fewer potent pain drugs, and received more favorable comments about their conditions in nurses’ notes, than matched patients in similar rooms with windows facing a brick building wall. There was a nonsignificant tendency for patients with the window view of trees to develop fewer minor complications.</td>
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<td>Reference</td>
<td>Description</td>
<td>Setting</td>
<td>Outcomes</td>
<td>Methodology</td>
<td>Findings</td>
<td>Additional Information</td>
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<td>Ulrich, R. S. (1999).</td>
<td>Effects of gardens on health outcomes: Theory and research.</td>
<td>Gardens in healthcare facilities</td>
<td>Health outcomes</td>
<td>Review of research literature</td>
<td>More than 100 studies</td>
<td>According to research reviewed from the behavioral sciences and health-related fields, gardens that foster control, social support, physical exercise, and exposure to nature can reduce stress among patients, family, and staff. There is increasing evidence that simply viewing gardens can mitigate pain. Certain negative distractions in healthcare gardens, including urban or mechanical noise and ambiguous design or art features, can worsen stress and other outcomes. In addition to reducing stress and pain, gardens can heighten satisfaction and facilitate wayfinding or navigation in healthcare buildings by patients and visitors.</td>
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<td>Ulrich, R. S., &amp; Gilpin, L. (2003).</td>
<td>Healing arts: Nutrition for the soul.</td>
<td>Visual art</td>
<td>Various outcomes, for example, blood pressure, heart rate, intake of pain drugs, reported pain and anxiety</td>
<td>Review of research literature</td>
<td>Approximately 20 studies</td>
<td>Certain types of psychologically appropriate artwork, including representational images with themes relating to waterscapes, natural landscapes, flowers, and gardens, and figurative art with emotionally positive gestures and facial expressions, can reduce stress and improve outcomes such as pain. However, there is increasing evidence that emotionally inappropriate art styles and subject matter can worsen patient stress and other outcomes. Abstract or ambiguous images or emotionally challenging subject matter can evoke dislike or other distinctly negative reactions in many patients. The limited amount of art research supports the conclusion that art selection for healthcare facilities should be evidence-based.</td>
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A blood donor clinic waiting room with a television monitor that displayed either: a nature videotape, a tape of urban settings, daytime television, or a blank monitor. Donor stress measured by blood pressure, pulse rate, fainting episodes, and reported anxiety. Experiment; semi-randomized; prospective; hypotheses; physiological measures; self-reported anxiety; fainting episodes recorded by staff. 872 blood donors in a U.S. clinic. Blood pressure and pulse rate recordings converged to indicate that donor stress was lower during no television (blank monitor) than daytime television, and during low-stimulation (nature tape + no TV) than high-stimulation conditions (urban tape + TV). Pulse rates were much lower during exposure to nature rather than urban tapes. There were no differences in the number or severity of fainting episodes during phlebotomy or in anxiety reported after the phlebotomy phase.

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Videotapes of different natural environments vs. different urban environments. Electrocardiogram; pulse transit time; skin conductance; muscle tension; self-reported affective states. Experiment with random assignment; hypotheses; physiological measures; self-reported emotional states; movie to elicit stress. 120 healthy undergraduate students (60 males, 60 females). Findings from all physiological and self-report measures converged to show that recovery from stress was faster and more complete when persons were exposed to the natural rather than urban environments. During the first four minutes of exposure, participants assigned to view a nature tape achieved recovery from stress approaching baseline (pre-stressor) levels in autonomic and somatic activity. Also, participants reported less anger/aggression and fear and higher levels of positive affects after exposure to the natural settings in comparison to the urban settings.
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<th>Sample Size</th>
<th>Findings</th>
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<tr>
<td>125</td>
<td>Verderber, S. (1986). Dimensions of person-window transactions in the hospital environment. <em>Environment &amp; Behavior, 18</em>(4), 450-466.</td>
<td>Hospital rooms with windows vs. without windows; different types of window-view content</td>
<td>Patient and staff preferences; self-ratings of satisfaction with/without windows; behaviors associated with/without windows</td>
<td>Questionnaire; interview</td>
<td>250 subjects: 125 staff (62% female), and 125 inpatients (50% female); 58% of patients were wheelchair-dependent and the average age was 62 years</td>
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<td>127</td>
<td>Vessey, J. A., Carlson, K. L., &amp; McGill, J. (1994). Use of distraction with children during an acute pain experience. <em>Nursing Research, 43</em>(6), 369-372.</td>
<td>Kaleidoscope distraction vs. no kaleidoscope</td>
<td>Children's pain and behavioral distress during routine blood draws</td>
<td>Experiment; randomized; hypotheses; self-reported pain; staff observation of patient behaviors</td>
<td>100 children, ages 3.5–12 years</td>
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| 128 | Vogelsang, J. (1988). Effect of visitors on patient behavior in the postanesthesia period. *Dimensions of Critical Care Nursing, 7*(2), 91-100. | Family visitor vs. special nurse visitor | Frequency of social interaction between patients and visitors | Quasi-experimental; hypotheses; observation of social interaction | 40 post-anesthesia patients (20 with family visitor, 20 with nurse visitor) | Patients who had family visitor exhibited more frequent social interactions than those having nurse visitors. |

<p>| 129 | Walder, B., Francioli, D., Meyer, J. J., Lancon, M., &amp; Romand, J. A. (2000). Effects of guidelines implementation in a surgical intensive care unit to control nighttime light and noise levels. <em>Critical Care Medicine, 28</em>(7), 2242-2247. | No guidelines vs. guidelines to decrease light and sound levels in an intensive care unit (ICU) (closing doors, lowering alarm sound, limiting nursing interventions, limits on conversation, phone, radio, direct light in | Light levels; sound levels; patient sleep quality perceived by nurses | Quasi-experimental; before-after; hypotheses; sound-level meter; light meter; questionnaire | 17 patients in an 18-bed surgical ICU (nine patients in period 1 and eight in period 2) | Night-light levels were low during both periods, and lowering the light levels induced a greater variation of light, which may impair sleep quality. Noise levels remained high during both periods (with and without guidelines), which could contribute to sleep disturbance. Implementation of the guidelines decreased the mean noise level (51.3 dB to 48.3 dB), peak noise level (74.9 dB to 70.8 dB), and the number of identified alarms. |
| 130 | <strong>Walker, J. S., Eakes, G. G., &amp; Siebelink, E. (1998).</strong> The effects of familial voice interventions on comatose head-injured patients. <em>Journal of Trauma Nursing, 5</em>(2), 41-45. | Familial voice vs. no familial voice in intensive care unit (ICU) | Physiologic measures (intracranial pressure, blood pressure, pulse, respiratory rate, oxygen saturation level); restlessness | Quasi-experimental; repeated measurements; hypothesis; taped familial voice; physiologic measures and behavior observation | 10 comatose head-injured patients in two ICUs | No significant changes were recorded in physiologic criteria after introduction of the tapes of a familial voice. This implied that family interactions would not have negative effects on comatose patients. | B |
| 131 | <strong>Wallace-Guy, G., Kripke, D., Jean-Louis, G., Langer, R., Elliott, J., &amp; Tuunainen, A. (2002).</strong> Evening light exposure: Implications for sleep and depression. <em>Journal of the American Geriatrics Society, 50</em>(4), 738-739. | Illumination level in the evening and over 24-hour period | Sleep amount, sleep efficiency, sleep latency, wake within sleep, or mood | Prospective trial; nonrandomized | 154 menopausal women, mean age 66.7; data were selected from a larger study of participants in the Women's Health Initiative | Illumination in the four hours before bedtime was quite dim; median 24 lux. Nevertheless, evening light exposure was not significantly related to sleep amount (in bed or out of bed), sleep efficiency, sleep latency, wake within sleep, or mood. In contrast, the overall amount of light throughout the 24 hours was negatively correlated with sleep latency, wake within sleep, and depressed mood. | A- |</p>
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<th>Study Design</th>
<th>Participants</th>
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<tr>
<td>Warren, N. A. (1993)</td>
<td>Perceived needs of the family members in the critical care waiting room. <em>Critical Care Nursing Quarterly</em>, 16(3), 56-63.</td>
<td>Descriptive; questionnaire</td>
<td>Family members of patients in a critical care unit waiting room</td>
<td>94 family members (mean age 50 years; 24 males and 70 females) of critically ill patients</td>
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<tr>
<td>Whall, A. L., Black, M. E., Groh, C. J., Yankou, D. J., Kupferschmid, B. J., &amp; Foster, N. L. (1997)</td>
<td>The effect of natural environments upon agitation and aggression in late stage dementia patients. <em>American Journal of Alzheimer's Disease and Other Dementias</em>, 216-220</td>
<td>Quasi-experimental; prospective; hypotheses; observation by clinical staff of patient behaviors indicating aggression and agitation</td>
<td>Five shower rooms for Alzheimer’s patients either without nature distraction or with nature distractions (recorded bird songs, sound of babbling brooks, bird pictures)</td>
<td>31 patients (in five nursing homes) diagnosed with late-stage Alzheimer’s disease (4 males, 27 females); 15 were assigned to nature condition, 16 to control group with usual care but no nature</td>
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<td>134</td>
<td>Whitehouse, S., Varni, J. W., Seid, M., Cooper-Marcus, C., Ensberg, M. J., Jacobs, J. R., et al. (2001). Evaluating a children's hospital garden environment: Utilization and consumer satisfaction. <em>Journal of Environmental Psychology</em>, 21(3), 301-314.</td>
<td>An outdoor garden planned as a soothing healing space for patients, families, and staff in a large children’s hospital. Perceived benefits of garden for patients’ parents and staff; satisfaction; utilization; user-recommended changes for improving garden. Postoccupancy evaluation; hypotheses; behavioral observation of garden users; questionnaire; interviews with staff, parents of patients, patients, and patients’ siblings. 28 adult garden visitors and 55 adult family members and staff (17 males and 66 females) in a large children’s hospital in San Diego; 52 adult respondents had been to the garden; also, 12 children and adolescents in the garden and 10 in the hospital (12 males and 10 females). Most adults who were surveyed spent time in the garden to relax and rest and to improve their mood, while children mostly explored and actively played. The garden was perceived as a place of restoration and healing, and use was associated with increased general satisfaction with the hospital. The garden, however, was not used as often or as effectively as intended. Most visits by adults and children were of short duration. Changes for the garden recommended frequently by staff, parents, and children included adding more greenery and trees (suggested by 50% of parents), and more interactive features for children’s activities or “things for kids to do” (18% of adults, 66% of children).</td>
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<td>135</td>
<td>Whitis, G. (1994). Visiting hospitalized patients. <em>Journal of Advanced Nursing</em>, 19(1), 85-88.</td>
<td>Hospital visiting policies for different patient groups (including implementation of the policies). Visiting policies in hospitals; visitor provisions; implementation of visiting policies by nurses. Descriptive; questionnaire survey of nurse managers. 49 accredited hospitals in 10 southeastern states in the U.S. Most of the hospitals surveyed had more liberal visiting policies for pediatric patients than for adult patients (86% allowed 24-hour visitation of pediatric patients in general medical units). However, 64% of the hospitals prohibited visitation by children 12–14 years or younger. Visiting policies for intensive care units were more restrictive or limiting for both pediatric and adult patients. Factors affecting implementation of visiting policies by nurses (and exceptions made for those visiting adult patients) included the acuity and prognosis of the patients, other patient or family requirements, and staff workload. Factors influencing exceptions made for visitors of pediatric patients.</td>
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<td>136</td>
<td><strong>Wilson, L. M. (1972).</strong> Intensive care delirium: The effect of outside deprivation in a windowless unit. <em>Archives of Internal Medicine, 130</em>(2), 225-226.</td>
<td>Intensive care units (ICUs) with windows vs. without windows</td>
<td>Delirium and depression</td>
<td>Quasi-experimental; retrospective; not randomized; hypotheses; chart data. ICUs were in different hospitals; unknown differences between ICUs (e.g., nurses) may effect findings</td>
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| 137 | **Wright, P., Hull, A. J., & Lickorish, A. (1993).** Navigating in a hospital outpatients' department: The merits of maps and wallsigns. *Journal of Architectural and Planning research, 10*(1), 76-89. | Handheld sketch maps; wall signs | Navigation adequacy; how often people retraced steps, speed | Experimental | 24 paid women volunteers recruited from the volunteer panel of the applied psychology unit | People moving without the map were faster, though they retraced their steps more often to check they were going in the right direction. During subsequent debriefing, those using the map found it helpful, and half the group without the map thought it would have been useful. |
| 138 | Yinnon, A. M., Ilan, Y., Tadmor, B., Altarescu, G., & Hershko, C. (1992). | Home vs. hospital | Sleep quality (duration of sleep, number of awakenings, need for sleeping pills); reasons for impaired sleep quality | Comparison of reported preadmission/postadmission sleep quality; hypotheses; patient interview sleep-quality scales | 134 patients in two medical departments and a coronary critical care unit in two Jerusalem hospitals | Compared to sleeping at home, 51% of 134 patients had a lower total sleep score in the hospital. Deterioration of sleep was found in number of awakenings (37%), reported quality of sleep (32%), duration of sleep (31%), and the need for using sleeping pills (26%). Reported reasons for impaired quality of sleep were noise made by other patients or by the medical staff (47%), and the patient's own disease (30%). Differences existed in the quality of sleep between the two medical departments located in different hospitals. |

| 139 | Zahr, L. K., & de Traversay, J. (1995). | Noise in neonatal intensive care unit (NICU) incubators for infants with vs. without earmuffs | Physiological responses (respiratory rate, heart rate, oxygen saturation); behavioral responses (behavior-state scale) | Experiment; within-subjects; treatment/control and crossover design; prospective; hypotheses; physiological monitoring; observation | 17 premature infants in one hospital (randomly assigned to treatment and control groups) and 13 in another hospital (served as their own controls with crossover design) | Earmuffs reduced noise for infants by 7 –12 dB. In the NICU where infants served as their own controls, they had higher mean oxygen saturation levels, less fluctuation in oxygen saturation, less frequent behavioral state changes, spent more time in the quiet sleep state, and had longer episodes of sleep, when they wore the earmuffs. In the hospital where two concurrent groups were compared, no significant results were found, possibly because of individual variability. It is imperative that noise be reduced in NICUs. |
**Improve Overall Health-Care Quality**

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<th>No.</th>
<th>Study</th>
<th>Environmental variable(s) studied</th>
<th>Outcome measure(s)</th>
<th>Research design</th>
<th>Sample description</th>
<th>Major findings</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Devlin, A. S. (1992). Psychiatric ward renovation: Staff perception and patient behavior. Environment &amp; Behavior, 24(1), 66-84.</td>
<td>Environmental improvements including new day-hall furniture, plants, wallpaper, brighter lighting</td>
<td>Staff response to design changes (higher staff morale hypothesized)</td>
<td>Before-after study (methods: staff surveys and behavior mapping)</td>
<td>Before phase: 37 staff; after phase: 24 staff; study conducted at a 40-year-old state psychiatric facility</td>
<td>Results indicate significant pre-post improvements in the ratings of day-hall furnishings and plants. Behavioral data showed a significant decrease in patient stereotypy and a preference for more private seating areas in the day hall following renovation.</td>
<td>D</td>
</tr>
<tr>
<td>2</td>
<td>Holahan, C., &amp; Saegert, S. (1973). Behavioral and attitudinal effects of large-scale variation in the physical environment of psychiatric wards. Journal of Abnormal Psychology, 82(3), 454-462.</td>
<td>Remodeled psychiatric admissions ward (repainted, new furniture, bedspreads, partitions in bedroom areas) vs. an identical unchanged admissions ward</td>
<td>Social and active behavior attitudes toward ward environment</td>
<td>Experimental design; post-test-only control group design; a priori hypotheses</td>
<td>25 patients were randomly selected on each of the two wards; 13 males and 12 females were studied on each ward</td>
<td>Significantly more socializing and less passivity occurred on the remodeled than on the control ward, and patients of the remodeled ward demonstrated more positive attitudes toward the ward physical environment. Also, patients on the remodeled ward viewed their environment more positively than the patients on the control ward.</td>
<td>A</td>
</tr>
<tr>
<td>3</td>
<td>Shepley, M. M. (1995). The location of behavioral incidents in a children's psychiatric facility. Children's Environments, 12(3), 352-361.</td>
<td>Ward environment: redesign phase, antiquated dormitory style buildings, post-occupancy phase, new structures with semiprivate and private rooms housing 22 patients each</td>
<td>Location and incidence of negative behaviors in a children's psychiatric facility</td>
<td>Two-phase study: Predesign and post occupancy phase; a priori hypotheses present</td>
<td>Phase 1: seven workshops with staff, 25 interviews with children, 20 drawings by children; phase 2: 37 staff questionnaires, 10 drawings by children</td>
<td>The location for negative behaviors changed from the previous building and the number of behaviors dropped significantly following initial building occupation. The data indicated that more negative behaviors occurred in the new semiprivate patient rooms than in the dormitories of the old building, although staff supported continued use of semiprivate rooms.</td>
<td>D</td>
</tr>
<tr>
<td>No.</td>
<td>Authors</td>
<td>Title</td>
<td>Journal</td>
<td>Volume, Issue, Pages</td>
<td>Methodology</td>
<td>Findings</td>
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<tr>
<td>4</td>
<td>Shepley, M. M., Bryant, C., &amp; Frohman, B. (1995).</td>
<td>Validating a building prototype: A post-occupancy evaluation of a women's medical center.</td>
<td>Journal of Interior Design</td>
<td>21(2), 15-29</td>
<td>Inpatient unit, neonatal intensive care unit (NICU), administration/support spaces, and surgery suite in a women's medical center. Human factors such as social interaction, family-centered care, staff morale, and general building factors related to appearance, ambience, and functionality were assessed. Multimethod postoccupancy evaluation: questionnaire, interviews, and behavior-mapping techniques</td>
<td>Findings describe positive and negative aspects of the different departments studied from the staff perspective. The inpatient unit was reviewed favorably, though specific improvements were suggested such as providing footwall storage in the patient rooms and reexamining the use of the nurses stations. The open plan of the NICU was also positively received by staff.</td>
<td>D</td>
</tr>
<tr>
<td>5</td>
<td>Stahler, G. J., Frazer, D., &amp; Rappaport, H. (1984).</td>
<td>The evaluation of an environmental remodeling program on a psychiatric geriatric ward.</td>
<td>Journal of Social Psychology</td>
<td>123(1), 101</td>
<td>Furniture rearrangement Activity levels (social and nonsocial), pathological behavior, self-care skills, management problems, attitude toward ward environment</td>
<td>Before-after study with comparison group; methods used included behavior observations, Norristown Behavior checklist (patient behavior assessment checklist), and structured interviews (follow-up stage). Experimental group: 69 female patients; control group: 67 male patients</td>
<td>Patient-staff interaction increased following the remodeling, but patients also displayed increased hostility and tension as well as decreased sociability and self-maintenance skills. Five weeks later, however, it was found that pathological behavior had decreased below the level found prior to remodeling. None of these changes were observed in the comparison ward. Interviews indicated that environmental enhancement improved morale among patients and staff.</td>
</tr>
<tr>
<td>6</td>
<td>Teresi, J. A., Holmes, D., &amp; Monaco, C. (1993).</td>
<td>An evaluation of the effects of commingling cognitively and noncognitively impaired individuals in long-term care facilities.</td>
<td>Gerontologist</td>
<td>33(3), 350-358</td>
<td>Living with or next to a demented individual in integrated long-term care facilities Depression/demoralization; dissatisfaction measured by scales</td>
<td>Interview 77 non-cognitively impaired residents of a long-term care facility (mean age 81 years) Those residents living with or next to a demented individual were found to be less cognitively and more physically impaired, had fewer contacts with family, and reported more distress.</td>
<td>B</td>
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</tbody>
</table>
Just as medicine has increasingly moved toward “evidence-based medicine,” where clinical choices are informed by research, healthcare design is increasingly guided by rigorous research linking the physical environment of hospitals to patients and staff outcomes and is moving toward “evidence-based design” (Hamilton, 2003). A large evidence base exists linking the physical environment with patient and staff outcomes. In a recent report to The Center for Health Design in a project funded by the Robert Wood Johnson Foundation, researchers from Georgia Tech and Texas A&M combed through several thousand scientific articles and identified more than 700 studies—most in top peer-reviewed journals—that establish how hospital design can impact clinical outcomes.

The team found scientific studies that document the impact of a range of design characteristics, such as single-rooms versus multi-bed rooms, reduced noise, improved lighting, better ventilation, better ergonomic designs, supportive workplaces and improved layout that can help reduce errors, reduce stress, improve sleep, reduce pain and drugs, and improve other outcomes. The team discovered that, not only is there a very large body of evidence to guide hospital design, but a very strong one.

Presented below is a summary of the strength of the evidence base in four main outcome areas:

1. Reduce staff stress and fatigue and increase effectiveness in delivering care
2. Improve patient safety
3. Reduce stress and improve outcomes
4. Improve overall healthcare quality

Within each outcome area, factors that contribute to the outcome are identified. For example, patient stress would be reduced by reducing noise stress, reducing spatial disorientation and so on. Next to each topical area are stars that indicate the strength of the evidence in that area.

Topics with 4 or 5 stars are those where the researchers found many good studies linking environmental factors with the outcome or fewer strong studies that provided convergent evidence linking the environmental factor with the outcome. These are considered high action areas.

Topics with 3 stars are those which have relatively fewer studies associated with them. However, these are high importance outcome areas and ones in which additional research is needed.

Topics with one or two stars (e.g. reducing staff turnover, increasing handwashing compliance among staff) have few studies associated with them or few studies that conclusively provide a link between environmental factors and the outcome. These are important areas where there is need for additional research.
PATIENT STRESS SCORECARD

<table>
<thead>
<tr>
<th>Reduce stress, improve quality of life and healing for patients and families</th>
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</thead>
<tbody>
<tr>
<td>Reduce noise stress</td>
</tr>
<tr>
<td>Reduce spatial disorientation</td>
</tr>
<tr>
<td>Improve sleep</td>
</tr>
<tr>
<td>Increase social support</td>
</tr>
<tr>
<td>Reduce depression</td>
</tr>
<tr>
<td>Improve circadian rhythms</td>
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<tr>
<td>Reduce pain (intake of pain drugs, and reported pain)</td>
</tr>
<tr>
<td>Reduce helplessness and empower patients &amp; families</td>
</tr>
<tr>
<td>Provide positive distraction</td>
</tr>
<tr>
<td>Patient stress (emotional duress, anxiety, depression)</td>
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</tbody>
</table>

STAFF STRESS SCORECARD

<table>
<thead>
<tr>
<th>Reduce staff stress/fatigue, increase effectiveness in delivering care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce noise stress</td>
</tr>
<tr>
<td>Improve medication processing and delivery times</td>
</tr>
<tr>
<td>Improve workplace, job satisfaction</td>
</tr>
<tr>
<td>Reduce turnover</td>
</tr>
<tr>
<td>Reduce fatigue</td>
</tr>
<tr>
<td>Work effectiveness; patient care time per shift</td>
</tr>
<tr>
<td>Improve satisfaction</td>
</tr>
</tbody>
</table>
PATIENT SAFETY SCORECARD

**Improve patient safety and quality of care**

- Reduce nosocomial infection *(airborne)*
- Reduce nosocomial infection *(contact)*
- Reduce medication errors
- Reduce patient falls
- Improve quality of communication *(patient → staff)*
- *(staff → staff)*
- *(staff → patient)*
- *(patient → family)*
- Increase hand washing compliance by staff
- Improve confidentiality of patient information

QUALITY SCORECARD

**Improve overall healthcare quality and reduce cost**

- Reduce length of patient stay
- Reduce drugs (see patient safety)
- Patient room transfers: number and costs
- Re-hospitalization or readmission rates
- Staff work effectiveness; patient care time per shift
- Patient satisfaction with quality of care
- Patient satisfaction with staff quality
Six Sigma

From Wikipedia, the free encyclopedia

Not to be confused with Sigma 6.

Six Sigma is a set of practices originally developed by Motorola to systematically improve processes by eliminating defects.[1] A defect is defined as nonconformity of a product or service to its specifications.

While the particulars of the methodology were originally formulated by Bill Smith at Motorola in 1986,[2] Six Sigma was heavily inspired by six preceding decades of quality improvement methodologies such as quality control, TQM, and Zero Defects. Like its predecessors, Six Sigma asserts the following:

- Continuous efforts to reduce variation in process outputs is key to business success
- Manufacturing and business processes can be measured, analyzed, improved and controlled
- Succeeding at achieving sustained quality improvement requires commitment from the entire organization, particularly from top-level management

The term "Six Sigma" refers to the ability of highly capable processes to produce output within specification. In particular, processes that operate with six sigma quality produce at defect levels below 3.4 defects per (one) million opportunities (DPMO).[3] Six Sigma's implicit goal is to improve all processes to that level of quality or better.

Six Sigma is a registered service mark and trademark of Motorola, Inc.[4] Motorola has reported over US$17 billion in savings[5] from Six Sigma as of 2006.

In addition to Motorola, companies that also adopted Six Sigma methodologies early-on and continue to practice it today include Bank of America, Caterpillar, Honeywell International (previously known as Allied Signal), Raytheon, Merrill Lynch and General Electric (introduced by Jack Welch).

There have been a few retail companies that have attempted to adapt this methodology to their business with mixed success. Perhaps the most notable was former CEO Bob Nardelli's attempt to adapt his systems from his former employer, General Electric, to the retail industry. There is one inherent problem with attempting to apply Six Sigma to retail. Retail=people, Six Sigma=defects. So, you have to look at your lacking areas as defects by your employees. Home Depot attempted to solve this by thinning out their workforce and implementing training programs for the remaining employees in order to reduce defects. On paper, this may work well but once the human factor was applied it led to massive frustration from the employees and the customers due to the lack of salespeople on the floor at any one time. Although the employees were better trained, they were now required to help 22.8 customers per hour rather than the previous 13.4. Other retailers are learning from these mistakes of the first big box retailers to attempt this and are tweaking the methodology to better suit their company goals.

Recently some practitioners have used the TRIZ methodology for problem solving and product design as part of a Six sigma approach,[6]

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   1.2 DMADV
   1.3 Other Design for Six Sigma methodologies
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4. Origin
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5. Criticism
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### Methodology

Six Sigma has two key methodologies:[7] DMAIC and DMADV, both inspired by W. Edwards Deming's Plan-Do-Check-Act Cycle: DMAIC is used to improve an existing business process, and DMADV is used to create new product or process designs for predictable, defect-free performance.

#### DMAIC

Basic methodology consists of the following five steps:

- Define the process improvement goals that are consistent with customer demands and enterprise strategy.
- Measure the current process and collect relevant data for future comparison.
- Analyze to verify relationship and causality of factors. Determine what the relationship is, and attempt to ensure that all factors have been considered.
- Improve or optimize the process based on the analysis using techniques like Design of Experiments.
- Control to ensure that any variances are corrected before they result in defects. Set up pilot runs to establish process capability, transition to production and thereafter continuously measure the process and institute control mechanisms.
DMADV

Basic methodology consists of the following five steps:

- Define the goals of the design activity that are consistent with customer demands and enterprise strategy.
- Measure and identify CTQs (critical to qualities), product capabilities, production process capability, and risk assessments.
- Analyze to develop and design alternatives, create high-level design and evaluate design capability to select the best design.
- Design details, optimize the design, and plan for design verification. This phase may require simulations.
- Verify the design, set up pilot runs, implement production process and handover to process owners.

Some people have used DMAICR (Realize). Others contend that focusing on the financial gains realized through Six Sigma is counter-productive and that said financial gains are simply byproducts of a good process improvement.

Other Design for Six Sigma methodologies

Six Sigma as applied to product and process design has spawned an alphabet soup of alternatives to DMADV. Notable examples include:

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Proponent</th>
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<tbody>
<tr>
<td>DCCDI (Define, Customer Concept, Design and Implement)</td>
<td>Geoff Tennant</td>
</tr>
<tr>
<td>CDQC (Conceptualize, Design, Optimize, Control)</td>
<td>SBTI</td>
</tr>
<tr>
<td>DCDOV* (Define, Concept, Design, Optimize, Verify)</td>
<td>Uniworld</td>
</tr>
<tr>
<td>DMADOV (Define, Measure, Analyze, Design, Optimize and Verify)</td>
<td>General Electric</td>
</tr>
<tr>
<td>DMEDI (Define, Measure, Explore, Develop and Implement)</td>
<td>PricewaterhouseCoopers</td>
</tr>
<tr>
<td>IDOV (Identify, Design, Optimize and Validate)</td>
<td></td>
</tr>
<tr>
<td>IDEOV (Invent, Innovate, Develop, Optimize, Validate)</td>
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Statistics and robustness

The core of the Six Sigma methodology is a data-driven, systematic approach to problem solving, with a focus on customer impact. Statistical tools and analysis are often useful in the process. However, it is a mistake to view the core of the Six Sigma methodology as statistics; an acceptable Six Sigma project can be started with only rudimentary statistical tools.

Statistics and robustness

Still, some professional statisticians criticize Six Sigma because practitioners have highly varied levels of understanding of the statistics involved.

Six Sigma as a problem-solving approach has traditionally been used in fields such as business, engineering, and production processes.

Implementation roles

One of the key innovations of Six Sigma is the professionalizing of quality management functions. Prior to Six Sigma, Quality Management in practice was largely relegated to the production floor and to statisticians in a separate quality department. Six Sigma borrows martial arts ranking terminology to define a hierarchy (and career path) that cuts across all business functions and a promotion path straight into the executive suite.

Six Sigma identifies several key roles for its successful implementation.

- **Executive Leadership** includes CEO and other top management team members. They are responsible for setting up a vision for Six Sigma implementation. They also empower the other role holders with the freedom and resources to explore new ideas for breakthrough improvements.
- **Champions** are responsible for the Six Sigma implementation across an organization in an integrated manner. The Executive Leadership draws them from the upper management. Champions also act as mentors to Black Belts. At GE this level of certification is now called "Quality Leader".
- **Master Black Belts**, identified by champions, act as in-house expert coaches for the organization on Six Sigma. They devote 100% of their time to Six Sigma. They assist champions and guide Black Belts and Green Belts. Apart from the usual rigor of statistics, their time is spent on ensuring integrated deployment of Six Sigma across various functions and departments.
- **Experts** This level of skill is used primarily within Aerospace and Defense Business Sectors. Experts work across company boundaries, improving services, processes, and products for their suppliers, their entire campuses, and for their customers. Raytheon Incorporated was one of the first companies to introduce Experts to their organizations. At Raytheon, Experts work not only across multiple sites, but across business divisions, incorporating lessons learned throughout the company.
- **Black Belts** operate under Master Black Belts to apply Six Sigma methodology to specific projects. They devote 100% of their time to Six Sigma. They primarily focus on Six Sigma project execution, whereas Champions and Master Black Belts focus on identifying projects/functions for Six Sigma.
- **Green Belts** are the employees who take up Six Sigma implementation along with their other job responsibilities. They operate under the guidance of Black Belts and support them in achieving the overall results.
- **Yellow Belts** are employees who have been trained in Six Sigma techniques as part of a corporate-wide initiative, but have not completed a Six Sigma project and are not expected to actively engage in quality improvement activities.

In many recent programs, Green Belts and Black Belts are empowered to initiate, expand, and lead projects in their area of responsibility. The roles as defined above, therefore, conform to the older Mikel Harry/Richard Schroeder model, which is not universally accepted.

Origin

Bill Smith did not really "invent" Six Sigma in the 1980s; rather, he applied methodologies that had been available since the 1920s developed by luminaries like Shewhart, Deming, Juran, Ishikawa, Ohno, Shingo, Taguchi and Shainin. All tools used in Six Sigma programs are actually a subset of the Quality Engineering discipline and can be considered a part of the ASQ Certified Quality Engineer body of knowledge. The goal of Six Sigma, then, is to use the old tools in concert, for a greater effect than a sum-of-parts approach.

The use of "Black Belts" as itinerant change agents is controversial as it has created a cottage industry of training and certification. This relieves management of accountability for change; pre-Six Sigma implementations, exemplified by the Toyota Production System and Japan's industrial ascension, simply used the technical talent at hand—Design, Manufacturing and Quality Engineers, Toolmakers, Maintenance and Production workers—to optimize the processes.

The expansion of the various "Belts" to include "Green Belt", "Master Black Belt" and "Gold Belt" is commonly seen as a parallel to the various "Belt Factories" that exist in martial arts.

The term Six Sigma
Sigma (the lower-case Greek letter σ) is used to represent standard deviation (a measure of variation) of a population (lower-case 's', is an estimate, based on a sample). The term "six sigma process" comes from the notion that if one has six standard deviations between the mean of a process and the nearest specification limit, there will be practically no items that fail to meet the specifications. This is the basis of the Process Capability Study, often used by quality professionals. The term "Six Sigma" has its roots in this tool, rather than in simple process standard deviation, which is also measured in sigmas. Criticism of the tool itself, and the way that the term was derived from the tool, often sparks criticism of Six Sigma.

The widely accepted definition of a six sigma process is one that produces 3.4 defective parts per million opportunities (DPMO).\[11\] A process that is normally distributed will have 3.4 parts per million beyond a point that is 4.5 standard deviations above or below the mean (one-sided Capability Study). This implies that 3.4 DPMO corresponds to 4.5 sigmas, not six as the process name would imply. This can be confirmed by running on QuickSigma or Minitab a Capability Study on data with a mean of 0, a standard deviation of 1, and an upper specification limit of 4.5. The 1.5 sigmas added to the name Six Sigma are arbitrary and they are called "1.5 sigma shift" (SBI Black Belt material, ca 1998). Dr. Donald Wheeler dismisses the 1.5 sigma shift as "goody".\[12\]

In a Capability Study, sigma refers to the number of standard deviations between the process mean and the nearest specification limit, rather than the standard deviation of the process, which is also measured in "sigmas". As process standard deviation goes up, or the mean of the process moves away from the center of the tolerance, the Process Capability sigma number goes down, because fewer standard deviations will then fit between the mean and the nearest specification limit (see S’). The notion that, in the long term, processes usually do not perform as well as they do in the short term is correct. That requires that Process Capability sigma based on long term data is less than or equal to an estimate based on short term sigma. However, the original use of the 1.5 sigma shift is as shown above, and implicitly assumes the opposite.

As sample size increases, the error in the estimate of standard deviation converges much more slowly than the estimate of the mean (see confidence interval). Even with a few dozen samples, the estimate of standard deviation often drags an alarming amount of uncertainty into the Capability Study calculations. It follows that estimates of defect rates can be very greatly influenced by uncertainty in the estimate of standard deviation, and that the defective parts per million estimates produced by Capability Studies often ought not to be taken too literally.

Estimates for the number of defective parts per million produced also depends on knowing something about the shape of the distribution from which the samples are drawn. Unfortunately, there are no means for proving that data belong to any particular distribution. One can only assume normality, based on finding no evidence to the contrary. Estimating defective parts per million down into the 100s or 10s of units based on such an assumption is wishful thinking, since actual defects are often deviations from normality, which have been assumed not to exist.

The ±1.5 Sigma Drift

The ±1.5σ drift is the drift of a process mean, which is assumed to occur in all processes.\[13\] If a product is manufactured to a target of 100 mm using a process capable of delivering σ = 1 mm performance, over time a ±1.5σ drift may cause the long term process mean to range from 98.5 to 101.5 mm. This could be of significance to customers.

The ±1.5σ shift was introduced by Mikel Harry (http://www.mikeljharry.com/). Harry referred to a paper about tolerancing, the overall error in an assembly is affected by the errors in components, written in 1975 by Evans, "Statistical Tolerancing: The State of the Art. Part 3. Shifts and Drifts". Evans refers to a paper by Bender in 1962, "Benderizing Tolerances – A Simple Practical Probability Method for Handling Tolerances for Limit Stack Ups". He looked at the classical situation with a stack of disks and how the overall error in the size of the stack, relates to errors in the individual disks. Based on "probability, approximations and experience", Bender suggests:

\[ v = 1.5\sqrt{\text{var}(X)} \]

Harry then took this a step further. Supposing that there is a process in which 5 samples are taken every half hour and plotted on a control chart, Harry considered the "instantaneous" initial 5 samples as being "short term" (Harry's n=5) and the samples throughout the day as being "long term" (Harry's g=50 points). Due to the random variation in the first 5 points, the mean of the initial sample is different from the overall mean. Harry derived a relationship between the short term and long term capability, using the equation above, to produce a capability shift or "Z shift" of 1.5. Over time, the original meaning of "short term" and "long term" has been changed to result in "long term" drifting means.

Harry has clung tenaciously to the "1.5" but over the years, its derivations has been modified. In a recent note from Harry, "We employed the value of 1.5 since no other empirical information was available at the time of reporting." In other words, 1.5 has now become an empirical rather than theoretical value. Harry further softened this by stating "... the 1.5 constant would not be needed as an approximation". Interestingly, 1.5σ is exactly one half of the commonly accepted natural tolerance limits of 3σ.

Despite this, industry is resigned to the belief that it is impossible to keep processes on target and that process means will inevitably drift by ±1.5σ. In other words, if a process has a target value of 0.0, specification limits at 6σ, and natural tolerance limits of ±3σ, over the long term the mean may drift to +1.5 (or -1.5).

In truth, any process where the mean changes by 1.5σ, or any other statistically significant amount, is not in statistical control. Such a change can often be detected by a trend on a chart. A process that is not in control is not predictable. It may begin to produce defects, no matter where specification limits have been set.

Digital Six Sigma

In an effort to permanently minimize variation, Motorola has evolved the Six Sigma methodology to use information systems tools to make business improvements absolutely permanent. Motorola calls this effort Digital Six Sigma.

Criticism

Originality

Noted Quality expert Joseph Juran has criticized Six Sigma as "a basic version of quality improvement", stating that "[t]here is nothing new there."\[14\]

Studies that indicate negative effects caused by Six Sigma

A Fortune article stated that "of 58 large companies that have announced Six Sigma programs, 91 percent have trailed the S&P 500 since." The statement is attributed to "an analysis by Charles Holland of consulting firm Qualpro (which espouses a competing quality-improvement process).\[15\] The gist of the article is that Six Sigma is effective at what it
is intended to do, but that it is "narrowly designed to fix an existing process" and does not help in "coming up with new products or disruptive technologies."

When Six Sigma is used as a cost cutting program, it has been shown to stifle new product innovation.\(^{116}\)

### Based on arbitrary standards

While 3.4 defects per million might work well for certain products/processes, it might not be ideal for others. A pacemaker might need higher standards, for example, whereas a direct mail advertising campaign might need less. The basis and justification for choosing 6 as the number of standard deviations is not clearly explained.

### Examples of some key tools used

- 5 Whys
- ANOVA
- ANOVA Gage R&R
- Axiomatic design
- Catapult Exercise on variability
- Cause & Effects Diagram (also known as Fishbone or Ishikawa Diagram)
- Chi-Square Test of Independence and Fits
- Control Charts
- Correlation
- Cost Benefit Analysis
- CTQ Tree
- SIPOC (Suppliers Inputs Process Outputs Customers) Maps

### Software used for Six Sigma

### List of Six Sigma companies

### References


See also

- Business process
- Business process improvement
- Corrective and preventative action
- Design for Six Sigma
- Lean manufacturing
- Lean Six Sigma
- Process improvement
- Statistical process control

### External links

- GE Six Sigma [http://www.ge.com/sixsigma/makingcustomers.html]
- Honeywell Six Sigma Plus [http://www.honeywell.com/sixsigma/]
- Motorola University [http://www.motorola.com/motorolauniversity.jsp]

Retrieved from "http://en.wikipedia.org/wiki/Six_Sigma"

Categories: Semi-protected | All articles with unsourced statements | Articles with unsourced statements since February 2007 | Business terms | Evaluation methods | General Electric | Motorola | Process management | Production and manufacturing | Quality

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Six Sigma Trends: Six Sigma Leadership And Innovation Using TRIZ

By Dr. Elena A. Averboukh

The fourth installment in a series of articles about the on-going research of advanced strategies and trends in deploying and team-training Six Sigma.

- Six Sigma Trends: Next Generation of Projects
- Six Sigma Trends: Upgrade for Supply Chains and Solution Providers
- Six Sigma Trends: Management Of Six Sigma Deployments

I am pleased to present another article on Six Sigma Trends that concerns enhancing traditional Six Sigma methodologies and tools with the systematic innovation management known as TRIZ (pronounced “TREEZ”, the Russian acronym for the Theory of Inventive Problem Solving).

In this article, a summary of current Six Sigma deployment roadblocks and limitations are identified. Many of these roadblocks can be eliminated with the use of TRIZ, which can lead to a much more advanced and productive version of Six Sigma. Finally, lessons learned from real-world training are shared.

Why has it taken so long to accept and to start implementing TRIZ? Why only now is the interest growing at such a fast rate, especially within Six Sigma professional circles and deployments? The answer sounds obvious: We are currently facing a new reality when Voice of Customer has become a moving target which needs to be identified, predicted and influenced under growing competitive pressure. There is no time for traditional trial and error decision making methods and endless discussions. TRIZ may be the methodology "missing link" from your Six Sigma deployment.

Six Sigma Bottlenecks and New Demands for Future Deployments

Just-in-Time Six Sigma Deployment

There are often significant delays in Six Sigma projects and intermediate deliveries. One of the most frequent reasons is decision-making errors that lead to rework and time-consuming data collection activities. Other reasons are listed below in relation to Six Sigma project phases:

**Define/Identify Phases**

- Poor project selection and/or problem formulation
- Non-exhaustive list of potential directions for change and/or for innovation
- Underestimated secondary problems which may arise during and/or as a result of primary problem solving
- Poor definition of alternative causes and effects and screening of significant inputs
- Failures caused by narrowing the scope of the projects in the wrong direction
- Non-exhaustive failure analysis

**Measure Phase**

- Time-consuming data-collection and measurements
- Lack and/or high variability of measurement systems (Gage R&R)
- Failure in finding root cause

**Improve/Design Phase**
- Lack of really productive and/or innovative ideas for improvements (upgrade to 4 sigma level and higher) or lack of competitive design or redesign
- Time and labor consuming DOE

**Verify/Control Phases**

- Non-systematic and non-exhaustive failure prediction

These reasons lead not only to delays, but also increase the Cost of Poor Quality (COPQ) due to rework. Repeated idea collection, endless meetings and discussions, screening the alternatives, measurements and analysis also significantly deteriorate overall acceptance and support of further deployments.

The need for additional efficient analytical techniques and tools, which not only accelerate the above decision-making activities but also

- make decision-making and problem-solving activities error-prone,
- increase their productivity and reduce cycle time, and
- increase Roll Throughput Yield of innovative and competitive solutions through the whole Six Sigma process,

is apparent and urgent.

**Low Cost Six Sigma**

Small and medium size companies or business units, who actively enter the Six Sigma community, have additional limitations when deploying Six Sigma methodology:

- Personnel are limited and often working overtime.
- It is often difficult (if not impossible) to find suitable candidates for Black and Green Belt positions to lead Six Sigma projects on either a full-time or part-time basis.
- Resources, both financial and human, for Six Sigma projects are extremely limited. Black and/or Green Belts are often left to conduct their projects on an overtime basis.
- Innovative products and services are critical to business survival and should be introduced or updated as quickly as possible.
- Big capital investments are often avoided or postponed, even when their return on investment is very high and financial justification convincing.

Therefore, the need for a successful, just-in-time Six Sigma deployment becomes especially critical when:

- Methods and tools for efficient generating low-cost Six Sigma solutions must be readily available.
- Solutions have to be innovative and competitive if they relate to (re-)design of new product, technology or service.
- Cycle-time of Six Sigma projects must be further reduced.
- Costly errors in decision making, especially at the early phases of Six Sigma projects, which lead to rework (e.g., extra and/or redundant measurements), must be avoided.

**Zero Defect Challenges For Forecast-Based Business Processes**

There are core business processes where the Cost of Defect or Failure is extremely high and critical to the overall business longevity. These include:

1. Forecast-based business development strategic decisions
   - Should the company focus on new products or other growth strategies?
   - What role do new products play in the overall growth strategy?
   - Which know-how/processes should remain in the company and which one have to be outsourced?

2. Forecast-based intellectual property protection decisions
   - How should the company develop a high-quality patent umbrella, which provides
long-term protection for the current and future product lines? 
  - How should the company develop patents efficiently (within a reasonable time-scale and budget)?

The application of analytical tools, which support analysis of trends and patterns of market development, are in strong demand. Such tools are complementary to the quantitative data-driven statistical tools and also make use of qualitative data to analyze and predict further evolution of technology, market, etc.

**Detect and Eliminate Root Causes**
This is a typical task for any Six Sigma project. Nearly each company has some painful areas, where many man-years of multiple trials and errors and even application of Six Sigma tools did not lead to an insight into the root causes of problem areas.

The application of alternative, e.g. I-TRIZ analytical knowledge-based tools for Anticipatory Failure Analysis and Prediction, supports efficient and effective problem solving in such situations.

**TRIZ Can Help You Avoid Six Sigma Bottlenecks**
TRIZ is an established science, methodology, set of tools, and knowledge- and model-based technology for stimulating and generating innovative ideas and solutions. It was invented by Henrich Altshuller, who published many books, technical publications, and patents on this topic from the early 1960s up to 1985. TRIZ basic postulates, methods and tools, including training methodologies invented by Henrich Altshuller have been further developed and significantly enhanced by his followers, researchers and trainers (from 1985 to present). These enhancements are known as the I-TRIZ generation of methodology and tools.

TRIZ is ubiquitous in Eastern Europe, particularly in the countries of the former USSR. Since the early 1970s, TRIZ has been part of many university-, college- and school-education programs. Now, more and more European, and particularly German, universities in cooperation with industries successfully integrate TRIZ into their curriculum. Recently, it has been successfully used in different industries and also in Pacific countries.

Originally TRIZ was primarily used for analysis and innovative problem solving for manufacturing processes (e.g. process/product/performance improvement, failure correction, innovative design, etc.). TRIZ science extends traditional system engineering approaches and provides powerful systematic methods and tools for problem formulation, system- and failure analysis, for both existing and future issues, by using system patterns of evolution. Many software vendors offer TRIZ tools as either a stand-alone package or in combination with other software.

The following table shows differences and novel aspects in TRIZ in comparison with traditional innovative or decision-making techniques used in Six Sigma:

<table>
<thead>
<tr>
<th></th>
<th>Traditional</th>
<th>TRIZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem definition</td>
<td>No systematic approach.</td>
<td>○ Intensifying contradictive requirements instead of avoiding or compromising contradictions at the early stages of problem formulation (i.e. define phase)</td>
</tr>
<tr>
<td>Decision-making for generating directions</td>
<td>A) Idea Collection techniques: data-based and process</td>
<td>A) Idea Collection techniques, and B) Idea Stimulation techniques:</td>
</tr>
</tbody>
</table>
of innovation and/or innovative solutions

They are often not efficient enough for complex problems and/or for finding low-cost efficient innovative solutions in a short time and/or finding solutions to upgrade the performance from 2-3-4 to higher sigma levels etc.

B) Idea Stimulation techniques:
psychological techniques (brain storming, six hats, morphological analysis etc.) and DOE.

May be time-, labor- and cost-consuming.

<table>
<thead>
<tr>
<th>Idea generation process</th>
<th>Traditional Idea-Generation Process consists of three steps</th>
<th>TRIZ offers efficient knowledge-based tools for accelerating these process steps and supports error-prone decision making and evaluation.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. generate alternatives</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. screen alternatives</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. evaluate top concepts</td>
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</table>

These steps involve a lot of not sufficiently structured or directed discussion and are time and labor consuming.

**I-TRIZ Is An Advanced, Productive Enhancement To Six Sigma**

I-TRIZ is a research-based enhancement of classical TRIZ science, methodology, tools and applications which:

- Expands the TRIZ methodology to non-technical areas (business, management, scientific research, transactional processes, etc.) and adopts it to the Western world (i.e. mental-, cultural-, language-, business-, teaching-models, etc.).

- Provides knowledge-based integration of classical and new TRIZ tools and lines of evolution for higher repeatability, reproducability and re-usability of innovation processes and results.

- Expands classical TRIZ way of thinking towards so-called Directed Evolution.

- Provides advanced decision-support knowledge-based tools and E-learning.

The I-TRIZ methodology and tool set is the subject of further research by private corporations, universities and research teams all over the world. Broadening the application of I-TRIZ in Six Sigma deployments provides valuable user-feedback for adopting tools and knowledge bases and stimulates its further "directed evolution."

**The Expected Impact Of Combining Six Sigma With I-TRIZ**

Advanced I-TRIZ methods and tools can be used for enhancing Six Sigma methodology (DMAIC and DMADV or DFSS) especially when Six Sigma methods and tools have proven to be inefficient and/or insufficient. These methods and tools can save time, find efficient low-cost improvement solutions at the Define or Identify phase, efficiently screen measurements, avoid errors and reduce rework and consequently the Cost of Poor Quality of Six Sigma.

Integration of I-TRIZ and Six Sigma methodologies generally leads to significantly:
Increased effectiveness of Six Sigma deployments, especially in small and medium business units.

Increased efficiency in terms of reduced life-cycle time and resources used, as well as higher ROI of Six Sigma projects.

Reduced or avoided "expensive" errors in decision making, especially at the early stages of the deployment (i.e. Define or Identify phase).

Reduced Cost of Poor Quality of Six Sigma due to the rework (i.e. repeated and/or redundant measurements, etc.).

Increased Roll Throughput Yield of Six Sigma projects especially at the Improve/Design phase (i.e. percent of Innovative Competitive Solutions/Amount of Collected Ideas).

Once we have enough measurements, we may quantitatively justify that I-TRIZ integration increases Sigma Level of Six Sigma Deployments, despite the fact that this may seem a paradox to the readers of the article.

**Six Sigma Training Update with I-TRIZ**

Six Sigma training with integration of I-TRIZ tools is a reasonable approach and will be effective across the whole Six Sigma Infrastructure.

Tools are modularized and may be matched with:

- Six Sigma Process areas
  - DMAIC
  - DMADV, DMIDV
  - DFSS
- Phases of Six Sigma Project Life Cycles
- Six Sigma user categories (Champions and Belts), their roles, tasks in projects and background
- Target Business processes
  - Traditional processes, like manufacturing, transactional, etc.
  - High-risk human-machine systems
  - Forecast-based core business development processes

From our European experience, training has proven more efficient when it is administered as a series of progressive modules of one to two days duration. Starting with Champions and Master Black Belts, the training may begin with a presentation at the beginning that highlights:

- The whole spectrum of tools and their applicability.
- First set of tools which are generic for all above mentioned applications and are simple enough to be taught in 1 to 1½ days.

I-TRIZ tools are being introduced in a gradual fashion into the whole Six Sigma training program and are also offered as part of an annual Six Sigma update for Champions, Black Belts and Master Black Belts.

The allocation of efficient tools and methods of training is customer specific and should be incorporated into the existing Six Sigma infrastructure and any business improvement projects. A specific set of e-learning and software tools on I-TRIZ is available and used both at the universities and in industries.

**Conclusion**

There is no doubt that the integration of I-TRIZ tools with the Six Sigma methodology significantly improves the overall potential of Six Sigma in business improvement and development. However, success depends on a user-centered design of training concept and materials and tools and their evolutionary deployment and overall commitment of the Six Sigma leaders.

**About The Author**

Dr. Elena Averboukh is an industry-funded professor at the University of Kassel (Germany) in Quality and Safety Control Systems and works internationally as a
Master Black Belt for manufacturing, transactional, design and e-business companies. She serves as a nominated expert of German standardization body DIN in the European (CEN) working groups on system ergonomics and usability and leads consulting company and business school LUSI-Center. She has two Master degrees in electrical/system engineering and in mathematics/computer science and three Doctoral degrees in process automation, modelling and identification of complex systems and in quality and safety control systems. She may be reached via e.averbukh@ieee.org.
Introduction

Up to 25% of an average landfill is construction and demolition waste. Dumping fees in our region will continue to rise as more landfills close, encouraging us to further ‘Reduce, Reuse, and Recycle’ (the three R’s) our construction and demolition waste materials. As landfill tipping fees rise, it will become more cost effective to recycle an increasing number of materials.

REDUCE WASTE

The economic benefits are immediately apparent. The builder or contractor saves by not buying excess material and then having to haul it away. These savings can be used to offset rising material prices. Waste reduction can be achieved by estimating materials accurately; using no more than necessary; "measuring twice, cutting once"; careful demolition to allow existing materials to be reused; selling, donating, or trading excess materials. Purchase items that do not rely on extensive packaging or contact the manufacturer/distributor and let them know of your concern.

REUSE MATERIALS

Reusing materials is particularly relevant to renovations. Cabinets, fixtures, hardware and appliances that are no longer suitable for one building may be appropriate for another. Refer to the listings in this guide for sources of used building materials. Check with the architectural salvage yards in your area, advertise in the classifieds under "Building Materials", or help establish a materials exchange program in your community. Also contact schools (art departments, in particular), and non-profit groups, such as Habitat for Humanity, to see if they have a use for your building materials.

RECYCLE

Of the many construction and demolition waste products generated, several stand out as readily recyclable:

- **Paper**
  Though not strictly a building material, a great deal of paper waste is generated during the design and construction of a building. Many types of paper are now recyclable. In addition to white office paper and computer paper, colored paper, fax paper, and even junk mail can be recycled. Newspapers, magazines, catalogs and phone books are also recyclable, though they need to be sorted. Unfortunately, blueprints are not currently being recycled in this region. An alternative is to use xerographic reproduction on bond paper, which is recyclable. Ask your blueprinting service about this. Use recycled paper
in your office, have business cards and letterhead printed on recycled stock, with soy-based inks. Print on both sides of paper. Set up strategically located, clearly marked recycling bins at the office and on the job site.

- **Concrete**
  Concrete waste is ground up for road base and reused as aggregate for new concrete. See Division 2 - Sitework and Division 3 - Concrete.

- **Asphalt**
  Asphalt from shingles and paving can be recycled into paving or road base. See Division 2 - Sitework.

- **Metals**
  Most steel has been reincarnated at least once. See Division 5 - Metals, for building materials made from recycled metals. Some recyclers will accept metals mixed in with wood wastes because they can be separated magnetically, but check first. Did you know that it only takes 11% of the energy to recycle aluminum as it does to produce it initially from bauxite ore?! That is why there is always a market for aluminum cans. Copper is so valuable that pipes are routinely recycled.

- **Wood**
  Wood waste can be ground up for particle board, mulch, or to mix with sewage to make fertilizer. Check with the recyclers for any restrictions. See Division 6 - Wood.

- **Corrugated Cardboard**
  Cardboard waste is remade into boxes and packaging.

- **Glass**
  Floor tiles are being made from recycled windshield glass and from light bulbs. Although not yet manufactured in our region, they are locally distributed. Stained glass artisans may be able to use your leftover glass. See Division 9 - Finishes. Please note that for health code reasons, window glass cannot be recycled with glass bottles and jars because these are recycled back into food containers.

The more difficult materials to recycle are:

- **Plastics**
  These can be an environmental problem: rarely recycled, non-biodegradable, and when improperly disposed of, dangerous to fish and wildlife. Animals can become tangled in plastic and drown, suffocate or become injured. Waterfowl eat their fill of foam packaging, which is not digestible, and subsequently starve to death. Plastic is a petroleum-based product and, therefore, is not renewable. Research is being done to develop biodegradable plastics. There are also a variety of building materials and consumer goods that are being made from recycled plastics. See Division 2 - Sitework; Division 6 - Wood and Plastics; Division 7 - Thermal and Moisture Protection; Division 8 - Doors and Windows; Division 9 - Finishes (Carpet); Division 10 - Specialties; Division 11 - Equipment; and Division 12 - Furnishings.

- **Insulation**
  Foamboard and fiberglass are not readily recyclable, although they can often be reused if not damaged in demolition. Cellulose insulation, made from recycled newsprint, is biodegradable. (Biodegradable means that with exposure to air, sunlight and/or moisture,
the material will decompose into naturally occurring, harmless components). Unfortunately, the conditions in a landfill are not conducive to this process. See Division 7 - Thermal and Moisture Protection.

- **Gypsum Board/Drywall**
  Raw gypsum is plentiful and inexpensive therefore recycling is not considered cost effective in our region. Transportation costs quickly exceed the value of the used gypsum board. See Division 9 - Finishes. One local recycler is experimenting with composting drywall waste. It is a biodegradable material.

- **Paint and Solvents**
  It is illegal to dispose of paints and solvents in most landfills. Many communities have special arrangements for toxic waste disposal. Call your city government for information. To prevent or minimize the problem, avoid using or specifying paints with volatile organic compounds (VOCs) and other harmful ingredients, such as heavy metals. See Division 9 - Finishes. Carefully estimate the amount needed to avoid large quantities of leftover paints or solvents. Leftover paint can be used as a primer on another project or given to someone who can use it. In Seattle, Habitat for Humanity has a program where leftover paints are combined and used as primer or finish coat where the desired color happens to be “Seattle Beige.” Check with your community to see if such a program exists.

To encourage recycling, there must be a demand for the end products made from the recycled materials. For example, wood waste is made into oriented strand board siding, particle board (non-formaldehyde preferred), or landscaping mulch. Throughout this guide you will find building products made from recycled materials. Encourage recycling by specifying and purchasing recycled products.

When implementing construction site recycling, presorting is almost always required. Recyclers operate on such a tight margin, that the time required to remove contaminants by hand causes it to be unprofitable. If the load is not pure enough, it is likely to end up in the landfill anyway. Check with your recycler for sorting guidelines. The need to involve and educate everyone on the building team cannot be over emphasized. Consult with the workers to help decide how to best implement the sorting process. Label bins clearly with symbols and words. Use bilingual labels, if appropriate.

Most recyclers accept any size load for drop off at their recycling centers and most are open to the public. Homeowners with a small amount of sorted material can use these services, as can contractors and developers with much larger quantities. Some recyclers will set up dumpsters on site for very large projects.

If the recycler for your area is not listed in this guide, check the yellow pages under Recycling Services, Waste Disposal, or Garbage Collection. You may also want to check with your city or county government. Though your choice of a recycler will likely be driven by proximity rather than cost, we have included “tipping” fees where possible. In most cases, it costs less to take pre-sorted waste to the recyclers than to dispose of the load at the landfill.
SUMMARY

Everyone involved in building including the property owner, architect, interior designer, contractor, foreman, laborer, office manager, engineer, cabinet maker, printer - all can have an impact on the environment. To make it a positive impact, remember the three R's.

- Reduce the amount of waste generated.
- Reuse scraps and building components whenever possible.
- Recycle as much of the remaining material as possible. Help turn the waste stream into a trickle.

SOURCES


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**Introduction**

Division 2 covers the work required to prepare a site for construction, the work done to the site around the building and the site finish work. It includes demolition, site preparation, earthwork, excavation, backfilling, paving, furnishings, recreation equipment planting and irrigation.

The preparation and development of a building site creates numerous adverse environmental impacts. Large projects or those in an environmentally sensitive area generally require an Environmental Impact Statement (EIS). Smaller and medium-sized projects don’t generally require an EIS unless they are located on environmentally sensitive areas such as wetlands.

Much of the responsibility of incorporating environmentally sensitive practices into a project's sitework falls to the design/development team. Building professionals should adopt practices and choose materials that minimize both the direct and indirect environmental impacts of their activities. (Why would we be even developing on a wetland?)
LANDSCAPING MATERIALS

Choose vegetation that is native to the area and minimizes water use. (You should consider expanding this to adaptive species as well. University cooperative extension programs are also a great resource for list and quality contractors). The Denver and Boulder Water Departments use the word xeriscape, from the Greek word xeros meaning dry, to describe water-efficient landscape design and implementation. Municipal water departments have local information about xeriscaping (in Denver, the telephone number is 303-628-6343). Often, xeriscape is misinterpreted to mean covering large areas of land with rock or stone mulch. This actually increases the ground heat and water loss through evaporation and is not encouraged as an overall landscape solution. Covering planting beds and planters with a bark or natural mulch and compost prevents water loss through evaporation, contributes nutrients to the soil, and controls weeds. Stone mulch should be used in guarded quantities.

In addition to using native plant materials, existing trees, shrubs and vegetation can often be preserved in place or transplanted before site improvements are made. Placing barricades around the drip line or canopy of existing trees prior to site excavation prevents fatal root damage. The site's existing and natural conditions, including soil, vegetation, drainage and wildlife, should be preserved as much as possible. (Consider including a discussion about banning invasive species).

Retaining and designing with the natural contours of the land and using native plant material and mulch reduces erosion. Soil and banks can be stabilized with rock or other retaining walls in combination with planting. Section 02270 lists other materials that stabilize soil. Weed-fabric covered with mulch stabilizes soil and reduces water loss and reduction of overall site disturbance. Minimizing impervious surfaces helps control construction site run-off, which can contaminate water supplies.

Drip irrigation or subsurface drip irrigation (SDI) is a simple method for delivering a constant amount of water directly to the roots of plantings and turf, which promotes healthy root growth while using less water. This type of water efficient system will save about 50 percent of the landscape water used when compared to a new overhead spray irrigation system that can be half as efficient as a SDI system. Water runoff, vandalism, broken heads, liability for structural damage, and maintenance will be minimal or non-existent. Check with the municipal water department for local recommendations. Grouping plants in irrigation zones that have similar water requirements reduces water usage. The Denver Botanic Garden and municipal water and parks departments often provide lists of plants appropriate for local use. Fire threatens homes and landscapes in this semi-arid climate. The use of fire resistant or high-moisture materials near a building (see 02900 Landscaping) helps to prevent fire from spreading and destroying buildings and land.

Proper choice and location of plants materials, landform, and structures can improve solar energy benefits and protects from wind and noise. Coniferous trees planted on the north side of a building helps to mitigate radiant heat loss from the wind. Deciduous trees (those that lose their leaves in winter) should be planted on the south side of a building to offer shade in summer and solar gain in winter. Trees and shrubs have less effect on dampening noise than earth berms.
which are very effective sound absorbers. Still more effective is using plant material and/or walls in combination with berms. While berms require more space, they are more effective than any type of wall used alone. Grade changes also reduce noise level.

A greywater reclamation system can be installed to convert building wastewater into usable irrigation water. This system typically employs mechanical filters to remove larger contaminants called "floaters" and organic bio filters often referred to as "constructed wetlands", which further decontaminate the water on site. This approach has the potential to substantially reduce costs related to construction of sewer and run-off piping. Denver's new Coors Field has used this system extensively. Local water and sewer authorities must approve Greywater systems. (Can then be reused for drip irrigation system. Can also be reused for building cooling).

RADON

Radon is an invisible, odorless, tasteless gas resulting from the decay of bedrock that can seep out of ground soil and into buildings. The Environmental Protection Agency considers radon gas to be one of the most threatening of all indoor air pollutants. In fact, the Agency concludes that radon causes more cancer deaths than any other pollutant under its jurisdiction. The real threat of radon gas occurs when it enters a structure through cracks, pores and other openings of a building’s foundation and slowly accumulates in improperly ventilated rooms. The level of radon within the soil of a given site should be determined before site improvements are made. Certain mitigation measures can often be performed early on in the development process to reduce unusually high levels of the gas. Contact the local health department for information on detection and mitigation procedures.

INDIGENOUS MATERIALS

Colorado possesses an abundance of natural resources well suited for site work. Gravel, sand and stone are a few examples. Some plant materials that are found in this region include aspen, spruce, fir and pine. Choosing native materials over imported ones helps to minimize transportation costs, conserve energy, and reduce pollution. It also encourages the local community to adopt more environmentally sensitive acquisition and manufacturing practices. Building professionals can check with local distributors to see if they are supplying materials indigenous to this region.

 ASPHALT AND CONCRETE

Because asphalt and concrete are commonly used materials in site work, they are discussed in some detail here. Additional discussion can be found in Division 3. Recycled concrete can serve as backfill material. In addition, recycled concrete is an acceptable substitute for quarried stone aggregate in many site applications. It can be used as sub grade or base course for roads, embankments and retaining structures. It can also be used in ready mixed concrete for footings, foundations slabs sidewalks, and roadways. Finally, it can be put in bituminous mixes for parking structures and roads. Refer to Sections 02220 and 02500 (as well as Division 3) for
producers and distributors of recycled concrete and asphalt.

Concrete traditionally contains Portland cement as its primary binding agent. The amount of energy required to manufacture Portland cement is extremely high. Therefore, it is responsible for a large amount of energy use and pollution generation. By using fly ash (a by-product of coal-fired power plants) in place of some of the Portland cement in concrete mixes, energy is conserved and pollution avoided. In addition, this material, which otherwise might have been a waste product, is put to productive use. Most power plants in Colorado and the local region are coal-fired, so fly ash is an abundant local resource.

Distributors of fly ash are listed in Section 02500 and in Division 3. Each distributor will know of local concrete ready-mix companies that they are currently supplying. If your local concrete company is not currently using fly ash, they can easily contact any of the listed distributors to place an order.

**SITE IMPROVEMENTS**

This is a great opportunity to specify products made of recycled material. Durable products such as fences, lumber, tiles, pavers, picnic tables, benches, waste receptacles, playground equipment, tire stops and many more products are available at competitive prices. Rocks or lumber found on site can be used as retaining walls and benches.

Before choosing to use plastic lumber, take care to weigh several issues. The kind of plastic lumber chosen may not be appropriate for its designated use. Only some products are rated for friction, expansion, and contraction, which can affect performance. Some products have smooth surfaces and are dangerous for outdoor use. Screws, not nails, generally should be used to minimize warping. However, choosing treated lumber has potentially dangerous consequences, as many treatment processes cause the emission of VOCs (Volatile Organic Compounds).

Although some companies make landscape rock made of recycled plastic, the use of this product is not encouraged, as Colorado is already rich in a variety of rock that can be obtained without mining or harming the landscape. (Are you including a list for these products?)

**DEMOLITION AND CONSTRUCTION DEBRIS**

Demolition and construction debris adds to the ever-growing solid waste problem. In fact, construction and demolition debris makes up roughly 25 percent of North American landfill space. With some effort, those in the building industry are often able to recycle or reuse materials from older buildings that are demolished. Salvage companies, recycling centers and waste management companies are excellent sources for both selling and buying salvaged and recyclable/recycled materials. See Division 1 for a more detailed discussion on construction site recycling.

An equally important environmental consideration in demolition work is the protection of the
workers and the immediate surroundings from potentially hazardous wastes. Local or state departments of health can provide information on the guidelines and proper procedures for the removal and disposal of toxic wastes.

**SUMMARY**

- Preserve and protect the natural condition of the site as much as possible.
- Specify native vegetation to conserve water.
- Use trees, shrubs and earth to protect the building from sun, wind and noise.
- Test for Radon gas.
- Use local materials for site improvements.
- Specify site furnishings (benches, etc.) that are made from recycled material.
- Re-use concrete as backfill, road base, or aggregate.
- Recycle demolition debris (refer to Division 1 for further information).

**GENERAL CRITERIA**

Suppliers listed in this division carry site work materials that either have recycled content, fly ash for cement, or are made of materials that are environmentally safe. Because of the relatively new appearance of sustainable materials on the market, many of these suppliers don’t exclusively carry these materials. However, suppliers listed were helpful and knowledgeable concerning sustainable materials and supply them at prices that are close to competitive and not prohibitive. Separate criteria are listed for sections concerning irrigation and plant materials only.

**CRITERIA FOR SPECIFIC SECTIONS**

**Section 02950 Drought Tolerant Trees and Plants**

Nurseries that provided a wide variety of native and adaptive plants appropriate for Colorado’s semi-arid climate appear in this category. The listings show suppliers who provide detailed information about sun and moisture requirements for plants, as well as seasonal and use descriptions. Plants are either grown on site or dug from Colorado sites and balled and burlapped.

**Section 02900 Landscaping**

Seeding companies listed here are provide grass and flower seeds and mixes appropriate for Colorado’s varied conditions: mountain, plateau, foothills, plains and wetlands. These seeding companies showed knowledge of the fine differences required in highly trafficked (highway) environments vs. residential vs. open space.

**Section 02810 Drip Irrigation Systems**

Suppliers listed here primarily or solely carry drip irrigation systems recommended by local
municipal water departments (such as Boulder) and emphasize low-moisture systems.

**Division 3:**

**Concrete**

**Introduction**

Division 3 includes structural and architectural concrete products such as cast-in-place and precast concrete. The basic ingredients of concrete are water, graded stone aggregates, and a cement binder. Cement is manufactured from limestone in a heated kiln process and reduced to a powdered form. When combined with water the cement reacts chemically to bind the aggregates to form an inert and durable material.

Concrete has high compressive strength, and when combined with steel reinforcing strands, it can have tensile strength as well. When formed and finished appropriately, concrete can provide both structure and architectural finish to interior and exterior elements.

**RECYCLING AND ADAPTIVE REUSE**

Construction waste and demolition material makes up 23-33% of municipal solid waste. Concrete is approximately 50% of that demolished material and construction waste. Only a small amount is recycled in any form. Several “dry” concrete recycling plants operate in the Rocky Mountain Region, crushing concrete into road base and back fill material. This type of road base is specified by a number of Colorado municipalities, and has Colorado Department of Transportation (CDOT) approval. The crushed concrete can also be used as aggregate in new concrete. Larger pieces of demolition debris can be used for retaining walls or for erosion and flood control.

Many materials that are typically though of as waste products can be used in cement production. Blast furnace slag, silica fume, and fly ash are a few ingredients currently being used in cement blends and others are being researched. Waste products such as kiln dust and used tires can be utilized as fuel for cement manufacturing. Recycled polystyrene can also be used in the concrete mix.1
EMBODIED ENERGY

The embodied energy of concrete has been estimated at 3 kWh/lb (see footnote 2) and 90% of this is attributable to the production of Portland cement. While the energy consumption for concrete production has been reduced it is arguably similar to that of steel production. However, concrete production still exceeds the embodied energy of timber products, therefore it is important to consider the life cycle cost of a building and its use when selecting construction materials. The kilns used to produce the cement are fueled by coal, coke, and natural gas. Low energy costs provide little incentive to build more energy-efficient kilns.

POZZOLAN CONCRETE

The sustainability of concrete has been increased by the introduction of fly ash as a substitute for 15 to 30 percent of the Portland cement in the mix. Fly ash is a type of pozzolan, created as a byproduct of coal combustion. Due to its energy and resource conserving properties, use of concrete with pozzolan material is encouraged in projects that are Federally funded, and CDOT accepts it for both structural and paving applications. Its use results in concrete that is smoother, denser, more workable, stronger, and less permeable. There is a cost savings when fly ash is included, although the savings is not always passed on to the consumer. Because fly ash retards setting time, cold weather conditions may require an accelerator. Most Portland cement plants produce pozzolan cement mixes, designated by the letter “P” after the cement type number. Pozzolans which meet ASTM C 618 for mineral admixtures in Portland cement concrete come in two classes: Class C is produced from burning sub bituminous coal and has faster strength gain, while Class F is produced from burning bituminous coal and has higher ultimate strength.

AGGREGATES

Formerly gathered by dredging riverbeds, aggregates in the Denver area are now crushed from radon-free rock. Crushing adds to the embodied energy of concrete products, as does the transportation of the aggregate to the concrete plant. Crushing also produces dust, which can be remedied by a dust collection system. Quarried aggregate can also be more chemically reactive, but can be neutralized by mixing with pozzolans. Crushed recycled concrete or slag may also be used as aggregate.

WATER

The amount of water used to activate a dry mix of cement and aggregate is relatively small. However, the amounts of water used to wash out trucks and equipment is much larger. The Colorado Department of Health requires all wash-down water to be contained on the site, and any water released from the site to have a pH level of less than 12.5.

ADMIXTURES
Admixtures include air-entraining agents, accelerators, retarders, water reducers, curing compounds, and pigment colorants. Accelerators should be specified not to contain calcium chloride, which is corrosive to the steel rebar within the concrete. Air-entraining admixtures improve concrete's workability and freeze-thaw resistance. Retarders and water reducers are used to control curing time and strength. Curing compounds are used on the surface of newly poured concrete. Some curing compounds do release volatile organic compounds (VOC's) while drying. Low VOC, water-based compounds are preferable, as are those with reduced solvents. Biodegradable admixtures are also available. Integral color pigments are made of inert mineral based colorants versus chemical stained concrete.

**PRE-CAST CONCRETE**

Pre-cast concrete refers to the manufacture of concrete products in a factory, rather than mixed and poured on site. Pre-cast concrete is an engineered material, and can be manufactured for structural and architectural uses. Where tight tolerances, finish consistency, or repetitive elements are part of the building design, pre-cast concrete may be a better alternative to cast-in-place concrete. Precast also has the advantage of reducing waste and water usage. Colorado has several pre-casting plants, giving an opportunity to minimize transportation costs by using a material that is locally produced.

**FORMWORK**

Stay-in-place insulated concrete forms (ICF)’s for foundations and walls are available from a number of sources. This formwork insulates and adds mass to the structure. Many of these products, along with other types of reusable forms, significantly reduce the amount of resources used for foundation work.

**TILT-UP**

Tilt-up panels are produced on-site by using the building floor slab as the primary casting surface. Panels are lifted into place to form the building envelope. This eliminates the cost of transporting panels to the site, plus it uses local materials and labor. Tilt-up systems are available that include insulation sandwiched between.

**FROST-PROTECTED SHALLOW FOUNDATIONS**

Conventional practice requires that foundations extend below the frost line to protect against frost heave. An alternative is to insulate the ground from the colder outdoor temperatures to prevent frost heave, minimizing the need for a deep foundation. This reduces excavation requirements, concrete use, and offers the cost savings associated with slab-on-grade construction. The National Association of Home Builders has developed a set of guidelines for frost-protected shallow foundations, which differ for heated and unheated spaces.3 The guidelines document examples of the systems used from Alaska to Iowa. dwellings The Denver
Building Department adopted a modified set of guidelines into the residential building code. Refer to the local building code for specific shallow foundation recommendations.

**THERMAL MASS**

The thermal mass of concrete within the structure of a building tends to stabilize the indoor temperature. When used with a passive solar design the mass of the concrete floors, walls, or ceilings will absorb the sun's energy and reradiate heat during lower fluctuations in temperature. Insulating the exterior surfaces (out-sulation) of concrete is a more effective use of its thermal mass than insulating the interior surface.

**SUMMARY**

Some issues to keep in mind when specifying concrete products are:

- Specify aggregates and concrete products from local manufacturers, so that the energy spent in transporting the material is minimized. Use recycled aggregates. Ask about the manufacturers' pollution control provisions.
- Consider using concrete as the finished surface, by specially forming, coloring, or etching the face. This allows concrete to be used efficiently as both a structural and architectural element.
- On exterior applications concrete can be used to reduce the heat island effect (caused by dark heat absorbing materials such as asphalt) and is less costly to illuminate due to its reflective nature.
- Work with a structural engineer to reduce the amount of cement in the mixture by using pozzolans or other substitutes, while still maintaining the appropriate strength and structural characteristics.
- Consider using stay-in-place insulated concrete forms (ICF’s) in foundation walls. ICF’s can also be used for walls above grade. Use of these forms can reduce the amount of concrete needed and provides insulation value as well.
- Use frost-protected shallow foundations for slab-on-grade applications.

**SOURCES**

1. Environmental Council of Concrete Organizations website. See below
4. A "pozzolan" is defined as "a siliceous or siliceous and aluminous material that in itself possesses little or no cementing property, but will in a finely divided form and in the presence of moisture chemically react with calcium hydroxide at ordinary temperatures to
form compounds possessing cementitious properties." This definition of pozzolans is taken from "Pozzolanic and Cementitious Materials" by Malhotra and Mehta (Gordon and Breach Publishers, 1996) from EcobuildNetwork.org

Division 4: Masonry

Introduction

Masonry construction is one of man’s oldest construction methods. Most early applications used natural stone assembled in a “dry stack” process. Later a cement, sand and water mixture (mortar) was introduced to create a bond between units. The desire for uniformity in size and shape, and the availability of clay led to the development of brick. Brick was first fabricated from mud and baked in the sun. It is now made from clay and fired in high-temperature kilns. More recently, concrete masonry units (CMU) made from cement, sand, small gravel, water and a series of admixtures have been developed to provide a larger, less expensive building block.

One of masonry’s beneficial properties is the thermal mass. Thermal mass stores heat and re-radiates this energy evenly back into the space as the space cools down. Thermal mass is 30% more effective when placed on the interior of a building and insulated to the outside. Additionally, when masonry is used as a thermal mass it is a natural partner to passive and some active solar energy systems.

An important characteristic of all masonry construction is its inherent durability and weather resistance. Most masonry is made from inert materials. Masonry buildings are intended to last a century or more. With proper maintenance the lifespan of a masonry building can extend several centuries. And maintenance is minimal. Although you will spend more time and money to construct a masonry building, it will outlast several generations of cheaper, less durable structures. In the end, the durable, maintenance-free building has much less impact on the environment.

STONE

The Rocky Mountain Region has a tremendous variety of local stone. The environmental impact of stone construction depends on the methods used to extract, transport and finish the stone. The energy used to accomplish each of these tasks combines to determine a stone’s embodied energy. For example, field stones collected locally have a low embodied energy. Imported marble, polished to a fine sheen, has a high-embodied energy. Therefore, when specifying stone evaluate
the impact of the following:

- **Extraction**: What process was used to extract the stone? Locate sources of stone that minimize the impact of mining on the environment; use loose stones found on or near the surface. What reclamation steps does the company incorporate into their practices?
- **Transportation**: How far away is the source of stone? Use stone from a local source.
- **Cutting**: Is stone being shipped abroad for cutting? Use local finishing/manufacturer.
- **Finishing**: What surface finish is required on the stone, and what techniques were used to create the finish? Allow for dimensional variation in size/thickness of stone. Specify a rougher surface finish whenever possible.
- **Use**: Is there another acceptable product that provides the same durability, strength and mass? Consider alternate materials with lower embodied energy.

**BRICK**

Brick is primarily composed of clay that gains its strength through firing in ovens. Clay is an abundant resource and the production process is relatively free of harmful by-products. However, the firing process gives brick a relatively high embodied energy. Although brick has a relatively low R-value, its mass can provide thermal storage to temper a living space and store solar gains. The durability, compressive strength, acoustical performance, chemical makeup and fire resistance of brick make it a more sustainable choice. Brick can also be reused.

- **Durability**: Brick is resistant to damage from wind and water, and does not need additional finishes.
- **Compressive Strength**: Brick can carry heavy loads, but it is often used as a veneer over a separate structural system because of cost. Many brick manufacturers provide larger brick sizes to be used in a single wythe (layer) for load bearing.
- **Acoustical Performance**: Brick’s mass makes it good for reducing sound transmission; however, its hard surface reflects sound.
- **Chemical Makeup**: Brick’s raw materials are chemically inert; consequently, they will not contribute to indoor air pollution. Fire-Protection: Brick is nonflammable and makes an excellent fire barrier.

The Rocky Mountain region, rich in clays, supports many local brick companies. Most brick manufacturers have their own local distribution centers. See listings in this Division.

**CONCRETE MASONRY UNITS (CMU)**

The basic components of concrete block are cement, water, sand and gravel. Concrete block is steam-cured for 1-2 days, which gives it a relatively low embodied energy (Portland cement has a high embodied energy, but it comprises only 9% -12% of concrete block). Concrete block, referred to as CMU, shares with brick durability, compressive strength, acoustical performance, low R-value, chemical make-up and fire resistance, but it generally costs less than brick (refer to itemized attributes in brick section above). However, CMU is not as water resistant as brick. CMU is usually sprayed with a water repellent coating or it is manufactured with an admixture
which gives it water repellence. The spray-applied coating lasts about 10 years, while the admixture lasts for the lifetime of the block. The admixture is generally more expensive but quickly gains advantage over the sprays as the building ages. CMU can be crushed and reused as road base. There are many local manufacturers of concrete block. See listings in this Division.

CAST STONE

GLASS BLOCK

Glass block is available in numerous colors, shapes and patterns and provides diffuse light for daylighting. It can be used in vertical and horizontal applications such as skylights and flooring. Several companies have structural flooring systems for glass block. Solar reflective glass block has been around for some time. A metal oxide coating applied to the block helps reduce the passage of sunlight. New technologies in glass block include fibrous inserts that slightly increase the r-value of the glass block. Light diffusing and light directing block is also available. Pre-assembled panels and grid systems save install time.

SIMULATED STONE

ADOBE

Adobe, an ancient form of masonry, is the Spanish word for plaster that derives from the Arabic word for sun-dried bricks. Adobe is used by approximately one-fifth of the world’s population to build homes and cities. Traditional adobe is a mixture of clay (25-40%), sand, water, and sometimes cut straw. Sand is a filler while the clay and water serve as binders. Adobe typically requires no mechanical energy to produce, is non-polluting, and uses locally available materials. There are mechanical press systems available, however. It is labor intensive, yet forgiving in that mistakes can easily be repaired. It is a massive material that is effective at storing heat and tempering living spaces. Asphalt is sometimes added to make it more durable in transportation and less permeable to water, and Portland cement can be added to increase its structural capabilities. Adobe can be poured into forms to make bricks or “puddled” to create monolithic walls as the Native Americans of the Southwest did. Adobe bricks are typically 10”x4.5”x16” and weigh about 35 pounds. Vulnerable to breakage, adobe bricks do not travel well. Adobe brick walls are plastered with mud to protect them from weathering. Outside of desert climates adobe must be protected from moisture, especially at the top and bottom. Adobe construction is not universally accepted. Check with your local Building Department prior to specification. Other forms of adobe include fired adobe blocks that are fired in place in vaults. Adobe bricks can be crushed and recycled into new adobe bricks.

NON-TRADITIONAL MASONRY

STRAWBALE CONSTRUCTION

Straw is readily available, a renewable resource, and inexpensive. The bales are stacked in
courses over steel reinforcement, and the walls are wrapped in wire mesh and typically finished with stucco. The finished wall is between 16-24 inches thick. This construction provides a tight structure with a high R-value (R-30) and good thermal mass. Straw is also naturally fire resistant because of the high silica content. The walls can be load bearing, although, most of the recently constructed buildings use post and beam construction because of building codes. Other materials, such as bales of waste paper, can be used in the same way, producing low-cost buildings and using waste material.

**EARTHSHIPS**

Used automobile tires are another waste material that can be used as masonry units. The tires can be rammed full of earth and stacked into walls to provide a low cost, energy-efficient structure. Because of the width of the tires no foundation is needed; and, generally these structures use 20% less wood than conventional construction. Numerous houses, typically called “Earthships,” have been constructed in New Mexico and Colorado.

**RAMMED EARTH**

Rammed earth construction is certainly not new technology. In fact it has been around for thousands of years and has been used in well-known structures around the world. Walls are created by compacting layers of earth within a form. When the form is removed the earth wall can be left exposed or can be finished with stucco or plaster. Properly constructed walls are unaffected by the elements and are resistant to fire and termites. Since rammed earth walls are typically thick (18-24”) they are excellent for thermal storage of heat. The mass of rammed earth walls is able to support massive steel beams for door and window openings and is capable of supporting roof loads if properly designed.

**SUMMARY**

- Use local sources of masonry.
- Minimize cutting and surface finishing requirements.
- When possible, take advantage of the structural properties of brick and concrete block. Use as a bearing material.
- Use masonry as thermal mass and insulate it on the outside for the greatest benefit.
- Recycle masonry products from demolition.

Consider straw bale, adobe, or rammed earth construction. They afford inexpensive, yet high quality construction.
Introduction

Division 5 includes a wide variety of construction materials including structural steel, metal deck, cold-formed metal framing (steel studs), railings, sheet metal fabrications, castings and ornamental metals. Metal content commonly used in these categories includes steel, galvanized steel, stainless steel, aluminum, copper, bronze, and brass. All of these materials have the ability to be recycled, especially steel, aluminum, and copper. Metals are unique among building components, in that they can be re-manufactured indefinitely without losing their structural properties.

Metals are not often thought of as an environmentally appropriate material. The mining, manufacture, and transportation of metals result in some of the highest embodied energy of all construction materials. However, metals also have properties that make them environmentally desirable, including: Easy recycling, strength, durability, malleability, and negligible out-gassing. The key to using metals in an environmentally responsible way is to make certain that metals are the most appropriate material for the application; use products with recycled content, and recycle all construction site waste.

The sources for recycled metal material listed in this Division are primarily out of the Colorado and Rocky Mountain Region. This region has relatively small reserves of the iron, coal, and limestone required for production of steel, and therefore relatively few steel mills. Regions in the upper Midwest and East Coast are the primary producers of steel from integrated mills.

DEMOLITION AND JOB SITE ISSUES

Demolition, renovation, and new construction projects are all candidates for job site recycling. Ferrous metals, such as steel and iron, can be separated by using magnets, but all other metals should be sorted before leaving the job site. Ideally, separate bins should be set up on the job site for materials such as copper, lead, aluminum, and other metals. Any waste developed from demolition or new construction should be recycled, and not sent to a landfill.

STRUCTURAL STEEL

Construction materials are the single largest use for steel in the United States; accounting for over 11 million of the 84 million tons of steel products shipped in 1989. Structural steel has an average recycled content of about 66%. The source for the recycled material is primarily scrap steel, including waste from job sites and old cars. The embodied energy of recycled steel is approximately one-fourth of the energy it takes to create steel from virgin material. The embodied energy includes mining the components, manufacturing processes, and transportation. Though steel accounts for only 23% of the tonnage of building materials used nationally, it
accounts for 48% of the energy consumed to make those products.²

The high-embodied energy of virgin steel provides a persuasive reason to request the highest possible level of recycled content. However, use of recycled material also benefits the environment by reducing air and water pollution from manufacturing, environmental degradation through mining, and waste production. New furnace technology, including the electric furnace using high voltage electrodes, will increasingly allow direct steel production from 100% recycled material. However, for now it is realistic to expect approximately 46% recycled content.³

Recycling steel has other environmental benefits as well. For each ton of steel recycled, 2,500 pounds of iron ore, 1,000 pounds of coal, and 40 pounds of limestone are saved.⁴ The savings extends not only to the material and embodied energy, but also in the environmental damage of mining and transporting the material.

Structural steel includes wide-flange beams and columns, tubes, pipes, angles, channels, plates, and connectors. These steel shapes have been engineered to be efficient load-carrying members, and are an appropriate choice where weight, construction schedules, long spans, or flexibility are project concerns.

**STEEL JOISTS AND JOIST GIRDERS**

The manufacturer listed in this guide uses up to 90% recycled materials. Confirm recycled content with each manufacturer prior to specifying their product.

**COLD-FORMED METAL FRAMING / STEEL STUDS**

Cold-formed metal framing is also referred to as steel studs, or steel framing. Recycled content in steel framing is often higher than that achieved by the structural steel industry. Recycled content up to 91% is not uncommon, and 20-24% is readily available from most commercial manufacturers.⁵

However, steel framing offers the advantages of consistent quality, recyclability, and increasingly competitive cost compared to wood framing.

**ORNAMENTAL METAL, FLASHINGS, AND RAILINGS**

Ornamental metals are metal fabrications that are specified and detailed for custom uses. Examples may include special roof details, metal enclosures, railings, column covers, castings, or other custom metal fabrications. Flashings are either made of sheet metals, or extruded to the desired form. Railings, such as guardrails and handrails, often have metal parts or anchorages. Due to the metallic content, most ornamental metals, flashings, and railings are recyclable. However, the recycled content of most of these materials is currently very low. Metal products, such as metal hardware, which have recycled content, tend to be in other divisions.
When specifying recycled content, work with the manufacturers to determine what recycled content is feasible, and to promote the use of recycled material. This section is an area where consumer demand will help to boost the use of recycled material.

**SOURCES**

5. Environmental Building News, Ibid.
7. 1993 ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigeration, Air Conditioning Engineers, Atlanta, Georgia.

**Division 6: Wood & Plastics**

**Introduction**

Division 6 includes products for rough carpentry, heavy timber construction, prefabricated structural or “engineered” lumber, finish carpentry, wood treatment and prefabricated structural plastics. Wood products have played an unique role in the built environment throughout the history of human development. Plastics have come on the scene more recently. And today, architects and builders can take advantage of the myriad of engineered lumber products that offer many advantages over natural wood at competitive costs.

Both wood and plastics are building materials commonly used because of their versatility, durability, availability, and cost. In the past, these materials have been used with little thought to their origin or the impact of their use on the environment. Concern over preserving our natural resources is influencing our selection of wood products. The new wood and plastic products being developed augment the selection process, but careful consideration must be given to their content. With an eye to the natural environment and an eye to the ingredients of our built environment, we can best evaluate the impact our choice in wood has on the overall environment.
WOOD

Wood has the characteristic of being both structural and ornamental. It is used throughout the world for a multitude of tasks from simple structural applications to highly finished decoration. Because of its wide acceptance and many applications the demand for wood remains high. Wood has the environmental advantages of being a natural, renewable material with a very low level of embodied energy. In fact, of all building materials it has nearly the lowest level of embodied energy, as shown in the chart on the next page.

Because wood is a renewable resource, it also has the advantage of being able to be grown, harvested and used at a sustainable rate. Unfortunately, society is not doing this; we are depleting our tropical and old-growth forests at a very unsustainable rate. The building industry's impact on our forests is dramatic. New home construction alone consumes two-fifths of all lumber and plywood used in the United States, and a typical 1700 square foot wood frame home requires the equivalent of clear cutting one acre of forest. Within U.S. national forests alone, at least 70,000 acres of old-growth timber have been harvested each year since the mid-1980's.

Architects and builders are in a position to ensure that the demand for the economic and cultural qualities of wood products can be met without depleting the source. By learning about alternative wood products that increase the efficiency of our use of wood and specifying those products in our projects, we can enjoy the benefits of this unique material and preserve its use for future generations as well. To this end, architects and builders can also choose wood products that are derived from sustainably managed forests. All timber companies vary in regard to their ecologically sustainable forestry practices; and it is important to note that there is more to sustainable forest management than just replanting harvested stands.

Truly sustainable practices include: maintaining a sufficient amount and broad variety of mature, naturally-occurring trees; properly maintaining the health of soil, water, air, and the entire ecosystems; and preserving the integrity of wildlife habitats. In short, sustainable forestry practices preserve the natural biodiversity of forests and communities that depend on them for their survival. Several organizations have conducted research on timber practices in the United States and around the world, and have developed useful certification and rating programs. They are as follows:

Scientific Certification Systems
1939 Harrison St., Suite 400
Oakland, CA 94612
(510) 832-1415 (800) 829-1415

Rainforest Alliance
65 Bleecker St., 6th Floor
New York, NY 10012
(800) 930-7246

Green Seal
Tropical hardwood is especially vulnerable and several species are classified as endangered. The deforestation rate is about 80 acres per minute in the tropics. According to the AIA Environmental Resource Guide, 42 million acres of tropical forest were cleared in 1990, a 40% increase from 1980. At this rate, all of the tropical forests will be gone by the middle of the next century. There are sources of tropical hardwood that are grown and harvested in a sustainable manner. Two such sources are as follows:

Good Wood Alliance (formerly WARP)
289 College St.
Burlington, VT 05401
(802) 862-4448
FAX: (802) 658-4443
e-mail: warp@together.net

EcoTimber International
1020 Heinz Ave.
Berkeley, CA 94710
(510) 549-3000

Another natural wood option is salvaged lumber. Flooring and trim materials are available, and local sources for these can be found in the yellow pages. Reusing heavy timber and framing from dismantled buildings is also possible, although it requires some planning.

ENGINEERED LUMBER

Another important way architects and builders can help preserve wood resources is to specify engineered and composite lumber products, which maximize the efficient use of wood. A general environmental advantage of engineered lumber is that it is manufactured from low density, fast growing varieties of trees. Other factors, such as dimensional stability and custom manufacturing contribute indirectly to the environmental advantages of engineered lumber products in that durability is enhanced and waste is reduced.

Engineered lumber is manufactured by combining wood fibers with plastic resins to produce high quality, structural products such as I-joists, laminated veneer lumber (LVL), parallel strand lumber (PSL), and glue-laminated beams. Sheathing products manufactured in this manner, such as oriented strand board (OSB), wafer board and particle board, are made primarily of saw mill waste. Likewise, finger-jointed lumber made from wood scraps makes use of material that would otherwise be wasted. And composite lumber composed of particle board with a veneer of hardwood makes efficient use of fine hardwood for uses such as paneling and doors.

Many of the engineered lumber products contain formaldehyde or other chemicals that are
detrimental to the environment and to indoor air quality. Some types of particle board are now being manufactured with resin binders that do not contain formaldehyde. If non-formaldehyde containing particle board or plywood products are not available, the next best choice is to seal the particle board to prevent out-gassing. Plywood products should be specified as exterior grade, in lieu of interior grade. Exterior grade contains phenol formaldehyde, which is less harmful than the urea formaldehyde in interior grade plywood.

Additional environmental advantages attributable to specific engineered lumber products include:

**Laminated Veneer Lumber (LVL)**

- No discard due to flaws in wood;
- Available in longer spans, widths and depths - thus connections are reduced or eliminated;
- Low moisture content prevents warping and shrinking, adding to its durability; and
- Very versatile.

**Parallel Strand Lumber (PSL)**

- Uses wood resources more efficiently by making large beams from small tree fiber.

**Gluelam**

- On-site fabrication is reduced and waste minimized.

**Oriented Strand Board (OSB)**

- Low raw material costs - More efficient use of our wood resources.

**PLASTICS**

Plastics are composed of a mixture of organic material created by a chemical manufacturing process. The most common sources are biomass material such as oil, natural gas and coal. Biomass is technically a renewable resource, but the time required to replace it is measured in millions of years making it effectively, a finite resource. For this reason the use of this limited supply of a natural resource deserves careful thought and consideration.

A concern over the use of some plastics stems from the toxic waste that results from their production, installation, and smoke produced during building fires. Plastics made from polyethylene, polyester, and most plastic lumber products which are made from recycled mixed plastics are considered to be less harmful than other types of plastics. Another consideration is the high embodied energy of plastic.
SUMMARY

- Use engineered lumber and laminated wood products.
- Use salvaged lumber.
- Specify composite lumber and/or finger-jointed lumber.
- Specify formaldehyde-free wood products; or specify exterior-grade products for finish carpentry with all surfaces sealed.
- Specify products made from recycled paper or wood fiber in place of lumber.
- Specify wood materials that originate from sustainably-managed sources.
- Specify recycled plastic products.
- Specify that lumber waste on the job site be recycled.

SOURCES


2. Environmentally Responsible Building Products, National Park Service, Denver Service Center, Denver, Colorado, pages 9.6-9.7.

Introduction

BUILDING ENVELOPE PERFORMANCE

Thermal and moisture protection are among the most important and complex considerations when designing a sustainable building. The thermal and moisture conditions of a building in its environment are very dynamic. In addition, the interactions of thermal and moisture protection systems with other building systems such as glazing and exterior wall and finish materials are key issues in designing a high performance building.

Thermal protection affects the thermal and acoustical comfort of building occupants. It also has significant impact on the amount of energy used to cool and heat the building. Nationally the energy needed to heat and cool buildings is roughly one-third the total energy produced, including almost two thirds of all of the electricity. In this region most energy used for heating and cooling is produced by burning coal or natural gas. Mining, extracting and combusting these
non-renewable sources of energy harms the environment. By reducing the amount of fuel used for heating and cooling, both cost and environmental damage are reduced.

The performance of the building envelope also has significant impact on the effects of water on the building. By controlling moisture at the building envelope the longevity, and therefore the sustainability, of the building will be increased. Proper moisture protection at the building envelope is also an important step in controlling and preventing the growth of mold, which affects the indoor air quality of buildings.

Energy Codes

As mentioned above, a building’s envelope has a direct affect on the overall energy consumption of a facility. Over the years, many energy codes have been developed to analyze the performance of a building envelope and set criteria that must be met in an effort to ensure that a building meets a certain minimum level of energy efficiency. The International Code Council, Inc. (ICC) has recently developed the International Energy Conservation Code (IECC) in an effort to standardize the criteria for a building’s energy consumption. Many municipal building codes, conformance with which is mandated by law, have adopted this reference as their model energy code. However, many states and municipalities in the West have not adopted guidelines, or have previously developed their own set of guidelines, calculation methods and criteria to be met. Be sure to check with the local authorities having jurisdiction to be certain that the building design complies with the governing energy code, and that all necessary materials are submitted along with the contract documents for plan review. For more about the IECC, refer to the ICC website at www.iccsafe.org.

Colorado has no statewide building energy code. The Governor’s Office of Energy Management and Conservation has developed voluntary Energy Guidelines for new commercial buildings based on ASHRAE Standard 90.1-1989. As a home rule state, however, municipal and county governments adopt and enforce codes and standards on their own. For the most part, the IECC has been adopted for residential construction, with ASHRAE Standard 90.1 applying to commercial construction. See www.swenergy.org/programs/colorado/energycodes.htm for a listing of the adopted energy codes for the larger localities in Colorado.

Information on energy codes for other states within the region can be found at www.swenergy.org/programs/index.html. Even though a municipality may not have an adopted energy code, meeting the criteria in the IECC or ASHRAE 90.1 is good practice, and exceeding those criteria will further enhance a building’s sustainability.

Energy Modeling

Energy simulation computer software has become more commonplace and more powerful in recent years. The use of energy simulation software can be a valuable tool in evaluating design considerations regarding the thermal protection of a building. Modeling can be used to determine energy savings and the related cost savings of design options. It can also be used to demonstrate compliance with model energy codes. Refer to the Resources section of Division 7 for a list of
some of the available software applications on the market.

THERMAL PROTECTION

Energy Performance

Energy performance is directly related to the thermal protection of a building. The effectiveness of the thermal protection, or insulation, is commonly measured in its thermal resistance value (R-value). R-value is proportional to a material’s U-factor, which is the rate of heat flow in Btu/h through one square foot of surface area when there is a 1°F temperature difference between sides. A lower U-factor, and therefore higher R-value, means better thermal protection.

There are many methods for calculating the R-value of a wall or roof construction assembly. There are also many software applications available as well as online interactive R-value calculators like those available for free through the Oak Ridge National Laboratory at www.ornl.gov/sci/roofs+walls/calculators/index.html.

TYPES OF INSULATION

The following lists some of the attributes for each insulation product type. Check the manufacturer’s literature for complete information and to verify green product attributes.

Batt Insulation

Batt insulation consists of spun fibers formed into batts or rolls and installed between framing elements of the building. The batts are typically available un-faced or faced with kraft paper, foil or polyethylene. The facing material is placed on the winter-warm side of the wall to impede vapor transmission and condensation within the insulation. The insulating quality of the batts comes from the air trapped between the fibers. Batt insulation varies in thickness and R-value, Commonly ranging from R-11 to R-38.

Fiberglass Batts:

- Fibers are made from glass, a product of silica, an abundant material.
- Most manufacturers use 25% or greater post-consumer recycled glass content. Some offer third-party certification of their product’s recycled content through Scientific Certification Systems.
- Some manufacturers offer formaldehyde free insulation.
- Some manufacturers offer insulation certified by GREENGUARD for low emissions.
- Relatively high-energy consumption to manufacture.
- Not manufactured locally and requires shipping long distances.
- Installation may cause irritation to skin, nose and eyes.
- There is some concern and study regarding possible health effects from inhaling fibers.
Cotton Batts:

- Made from post-industrial denim and cotton fibers with high recycled content.
- 100% recyclable.
- Similar to fiberglass in R-value to thickness ratios.
- Low energy consumption to manufacture.
- Cotton is considered a rapidly renewable resource.
- No formaldehyde. • No VOCs or outgassing.
- No installation hazards
- 10 to 15% synthetic fibers used for bonding.
- Few manufacturers, one product is manufactured in Arizona.

Mineral Wool:

- Rock wool made from basalt rock.
- Slag wool made from mineral mining waste.
- Fire-resistant properties.
- High-energy consumption to manufacture.
- Possibly hazardous during production due to heavy metals.
- Similar to fiberglass for concerns regarding health risks and irritation to skin, nose and eyes during installation.
- Not manufactured locally and requires shipping long distances.

**Rigid Insulation**

Rigid insulation is typically extruded or expanded foam and installed in boardstock. Rigid insulations have a higher R-value per inch than batt insulations. Much rigid insulation is now manufactured without CFCs and HCFCs as blowing agents. CFCs and HCFCs are a concern because of their high ozone depleting potential. CFCs have been phased out by 1993. HCFCs have been phased out of polyisocyanurate but will not be phased out of extruded polystyrene until 2010.

Expanded Polystyrene: (EPS)

- Petrochemical derived.
- Does not use CFCs or HCFCs as a blowing agent. Expanded using pentane which contributes to smog.
- Will create toxic fumes when burned (review building codes).
- May contain recycled polystyrene and is recyclable.

Extruded Polystyrene: (XPS)

- Petrochemical derived.
- Currently using HCFCs as a blowing agent. Phase out of the use of HCFCs is scheduled by the year 2010.
- Will create toxic fumes when burned (review building codes).
• May contain recycled polystyrene and is recyclable.

Polyisocyanurate: (Polyiso)

• Petrochemical derived.
• Does not use CFCs or HCFCs as a blowing agent.
• May contain recycled polyisocyanurate.
• Will create toxic fumes when burned (review building codes).

Foamed-In-Place and Sprayed-On Insulation

A liquid injected into building cavities. Once in place the insulation mixture solidifies. These systems are more effective than other insulation systems in reducing air infiltration by filling voids, cracks and areas around pipes and wiring.

Cementitious Foam Insulation: (Air Krete)

• Inorganic, non-toxic, non-expansive, non-flammable.
• Contains no formaldehyde.
• Expanded with compressed air.
• No CFCs or HCFCs used.
• Friable – cannot be reused, but can be recycled. Can be used to enrich soil.

Polyurethane Foam:

• Comes in either closed cell or open cell.
• May use HCFCs
• Open cell foam may be produced with H2O or CO2.
• Petrochemical derived. Some are now soy-based.
• May contain recycled polyurethane.
• Will create toxic fumes when burned (review building codes).

Sprayed-On Loose fill:

• Uses a latex foam binder to spray-on a variety of loose fill insulation.
• The binder contains no CFCs or HCFCs.
• Can utilize fiberglass, rockwool or cellulose.
• Fill cavity similar to a foamed-in-place insulation.
• The distributor of the system is local to Denver.

Loose Fill Insulation

Consists of shredded material or pellets into building cavities or applied loose over a horizontal surface (ceilings). Loose fill insulation can fill voids and get into areas around pipes and wiring that batt insulation cannot. Loose fill insulation can be more prone to settlement than other types
of insulation.

Cellulose:

- Made from post-consumer recycled newspaper, cardboard.
- Contains additives for fire retardancy, a fungicide and sometimes a binder to reduce settling. Borax is recommended over aluminum sulfates. Although the raw material of Borax, Boron is considered to be in short supply.
- Safe to install, non-hazardous fiber.
- Possible odor from printing inks and additives.

Vermiculite and Perlite:

- Primarily used in masonry cavities, insulation plaster or lightweight concrete.
- Expanded by heat during manufacture from natural silicates.
- Hazardous dust created when handling.
- Odor free once installed.
- Easily recovered for re-use.

Polystyrene Beads:

- See same material under Rigid Insulation.
- Used primarily in masonry cavities.
- Easily recovered for re-use.

**RADIANT BARRIERS**

Radiant barriers are typically installed in attics to reduce the cooling load caused by radiant heat transfer from the roof. The surface of a radiant barrier is a shiny metallic finish with a low emittance.

**THERMAL PROTECTION - STRATEGIES AND ISSUES**

**Thermal Bridging**

There are several things to consider when designing the thermal protection system of a wall assembly. Among the significant consideration is thermal bridging. Thermal Bridging is caused by a component in the construction assembly that allows heat transfer at a considerably higher rate than the heat transfer through the adjacent insulated construction assembly. The classic example is steel studs in an exterior wall insulated with batt insulation. The thermal bridging of the steel stud can reduce the effectiveness of the insulation by 30 to 50%. In addition, the reduced effectiveness will result in lower assembly cavity temperatures during the winter and can lead to condensation in the insulated cavity if the dew point is reached, which in turn will further reduce the effectiveness of the insulation. A simple solution is to use insulated sheathing on the exterior of the steel studs. This is just one example. When designing the exterior wall
assemblies it is important to identify and address potential thermal bridges.

**Thermal Mass**

Consideration of a construction assembly’s thermal mass also plays a role in its thermal performance. Thermal mass can significantly delay the heat transfer through a construction assembly. For example, a wall with high thermal mass can absorb and retain heat during the day and release the heat at night. This can work advantageously if considered as part of a design strategy.

**MOISTURE PROTECTION**

After fire, water is arguably a building’s worst nightmare. Moisture, or water, comes in three basic forms: vapor, liquid, and solid, all of which must be addressed in the climate of the Rocky Mountain region. Simply put, proper moisture protection will make a building last longer, and the longer it lasts, the more sustainable it becomes. In addition to its moisture protection properties, a sustainable product’s manufacturing stream, durability, recyclability, and aesthetic value must be analyzed. Select the right product, include it in the right place within the building envelope, detail its relationship with the other materials properly, and a successful project will be functional, beautiful, and ultimately sustainable.

**Water Proofing and Dampproofing**

Historically, waterproofing and dampproofing products have been asphalt based, that is, derived from petro-chemicals extracted from crude oil. As our society moves toward a sustainable future, our dependence upon this raw material will be curbed in favor of materials less taxing upon the earth. The latest technology in water and dampproofing products mainly fluid-applied products, made from a variety of raw materials including water-based products that are formaldehyde free, flame resistant and low in volatile organic compound (VOC) content.

**Vapor and Air Barriers**

Although vapor and air barriers can enhance the thermal and moisture protection properties of a building, care must be taken that good air quality is maintained throughout the life of the project as well. Polyvinyl sheet goods are effective and inexpensive, and still dominate the market in this arena. However, sustainable products such as foil-laminated kraft paper are also available. In addition, as with the water and dampproofing products, new water-based fluid-applied vapor and air barriers are beginning to appear that rival the effectiveness if not the cost of their petroleum-based sheet-good cousins. There are now vapor retarders that change permeability with seasonal climate changes to allow wall and ceiling cavities to breathe and dry out during the summer.

**Roofing and Siding**

Sustainable roofing and siding materials consist of enhanced raw materials (stone, slate, wood
siding and shingles, bamboo, straw, etc.), tile products (fiber-cement composites, concrete, etc.), recycled products (post-consumer metals and cellulose products), and even reused products. Of all the materials that make up a building, roofing and siding are perhaps the best opportunity to select a sustainable solution.

Enhanced Raw Materials

An "enhanced raw material" refers to a material that is applied to the building in essentially the same form that it exists in nature, with a little enhancement by humans to make them easier to work with, last longer, or go further.

Stone:
- Usually used in siding or cladding applications
- Sustainable if mined locally and correctly to minimize environmental impact.
- Life-cycle costs (embodied energy vs. longevity) require analysis.

Slate:
- A type of stone, naturally occurring in large, thin sheets suitable for roofing applications.
- Sustainable if mined locally and correctly.
- Heavy, requires stronger structure.
- Life-cycle costs require analysis.

Wood Siding and Shingles:
- High quality cedar shakes and siding board come from slow-growth cedars.
- Sustainable if harvested locally from renewable sources.
- Fire retardants should be considered.

Bamboo or Straw Products:
- Composite products made from rapidly renewable plant species.
- Bonded together using heat and pressure to create siding or shingles more dense and durable than traditional wood products.

Tile Products

Fiber-Cement Composite Tiles:
- Made from wood fiber, sand and cement.
- May contain autoclaved concrete and/or post-consumer newsprint.
- Relatively lightweight, fireproof, long lasting (up to 60 year warranties), low maintenance.
- Can be pulverized and recycled after its useful life.
Concrete Tiles:

- Heavy, requires stronger structure.
- Durable, low maintenance, fireproof.
- Sustainable if life-cycle cost analysis is positive.
- Can be pulverized and recycled as aggregate.

Recycled Products

Metal Roofing and Siding:

- High embodied energy, but contain high amounts of recycled material.
- Lightweight, durable, low maintenance, fire resistant.
- Can be recycled again and again.

Recycled Plastics:

- High recycled content, but limited in how many times it can be recycled.

Recycled Asphalt Shingles:

- These products are being developed, and are a good use of otherwise discarded material, but are still not a preferred sustainable product.

Roofing and Wall Panels

These types of products employ materials similar to those mentioned above, manufactured into larger panels or entire systems that speed production and installation. Recycled metal or plastics are rolled or formed into shapes, often that mimic the size and texture of wood products. A variety of wood products use wood fibers and other byproducts from waste, recycled or managed sources to produce various types of sheathing or finished siding. Care should be taken when specifying these materials because some may off-gas toxins, such as formaldehyde, from their binding agents. These engineered wood products are more resource efficient and durable than solid wood.

Preassembled, pre-manufactured panelized systems combine finished cladding, substrate, insulation and even structural components into a single product shipped to the jobsite ready for installation. Sandwich panels made up of a rigid insulation core bound by oriented strand board sheathing have good structural, thermal, and vapor transmission qualities. While these characteristics may support sustainable strategies, it is important to evaluate them in terms of the environmental impact of each component and the assembly process to fully comprehend their green-product status.

Low-Slope Roofing
Typically a commercial application, low-sloped roofing can be a major player in the thermal performance as well as provide moisture protection. Many manufacturers are producing white roofs in contrast of the black roofing that we've seen in the past. These white roofs utilize a technique known as cool roof. A cool roof has a high reflectance and high emissivity and reduces the cooling load of a building by reducing the heat gain from roofs associated with black or dark roof colors. This technique is applicable depending on your climate and building loads. During the winter some heat gain may be desirable especially in colder locations and in buildings that are not cooling load dominated. The Oak Ridge National Laboratory offers a free web-based calculator for determining the energy savings and the heating penalty for using a cool roof. It is available at www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm.

It is important to avoid polyvinyl chloride (PVC) based products when selecting low-sloped roofing. Notwithstanding its dangers during the manufacturing process, it is a derivative of petroleum that also will break down and become brittle with exposure to ultraviolet radiation from the sun. Even with the introduction of so-called UV stabilizers, PVC-based materials will eventually harden and crack and need replacing, often within 10 to 20 years.

One non-PVC product available is an engineered thermoplastic polyolefin (TPO), which is recyclable, chlorine free, and comes in reflective white color in addition to other colors. There are also many coatings that can be applied over roofing surfaces that are considered a cool roof. Look for the Energy Star label to identify products that meet Energy Star’s program for cool roofs. The Cool Roof Rating Council also maintains a directory of cool roof products and specifies their reflectance and emittance. It is available at www.coolroofs.org/ratedproductsdirectory.html.

**Green Roofs**

Green roofs use vegetation on top of the building structure to provide thermal and moisture protection, as well as aesthetics. The vegetation should be a combination of native plants and grasses designed to survive in this region without irrigation. Rich topsoil is required in a thickness that is naturally heavy, and the structure will need to be sized accordingly. But the thickness and mass of the material also provides excellent thermal insulation and storage, with the vegetation often absorbing all of the moisture before it can migrate to the building envelope below. Substrates for the landscaped system are typically a low-sloped roofing product supported by rigid insulation on top of the structural system. Additional benefits of a green roof include longer roof membrane life, reduced cooling and heating loads, reduced urban heat island effect, reduced storm water runoff and enhanced sound insulation.

**Fireproofing**

Although the International Building Code places more emphasis on egress and less emphasis on protecting a building's structure, fireproofing is still required depending upon the size, occupancy and conditions of a facility. Typical products are a sprayable blend of Portland cement or gypsum, vermiculite, cellulose, and various other additives. These are not particularly harmful once in place, but can be harmful if ingested or inhaled during application, and the
manufacturing processes are questionable as far as sustainability is concerned.

Sustainable fireproofing products include recycled content and resist the growth of mold and mildew.

**Sealants**

Many of the urethane sealants that are used in buildings employ solvents containing VOCs or other toxins as components of the sealing agent. These materials are released as the product cures and off-gas into the building’s atmosphere where they are harmful to the inhabitants. They can also be inadvertently consumed by small children and be harmful to their health. As with the new water proofing and dampproofing products mentioned previously, there are new sealants, often water-based, on the market today that are low or non-toxic that perform equally as well.

**MOISTURE PROTECTION - STRATEGIES AND ISSUES**

**Cold Roofs**

The freeze-thaw cycle of water can wreak havoc on a building, especially in the northern Rocky Mountain climates and at high altitudes. There will be a certain amount of heat transfer through the roofing system just by the adjacency of the materials. This heat transfer, even in well insulated buildings, can result in ice damming problems at the eaves or overhangs of buildings in the winter, and unnecessary heat gain in the summer. Cold roof strategies that employ air spaces between the exterior weather barrier and the substrate beyond employ natural ventilation to circulate the outside air, and can minimize this transfer of energy and eliminate the problems mentioned above.

**Ventilation**

As mentioned before, moisture should not only be permitted from entering the building envelope, it should be allowed to escape as well. For example, water vapor that works its way into the wall cavity should have a way to rise to the top of the wall and escape through an attic vent, just as liquid water that condenses within the cavity should have a way to migrate out through a weep hole at the bottom. This ventilation should not be confused with ventilation of the occupied spaces. Proper detailing can separate the two systems, thus providing a “tight” building as far as air infiltration, while ensuring that conditions that promote mold growth and poor air quality conditions are avoided.

**Indoor Air Quality and Mold**

It is not a matter of if moisture will get into your building, but when. From landscape irrigation malfunctions, to plumbing leaks, to roof leaks, the number of ways that moisture can infiltrate a project is endless. During the construction process, the materials are exposed to the weather during their installation, at which time they become susceptible to taking on moisture. The
problem is not necessarily that they get wet, but staying wet is a huge concern. Moisture and the right temperature is a recipe for growing mold, some varieties of which can be toxic, all of which can be unsightly. In addition to ensuring that moisture cannot infiltrate a building from the outside, it is equally important that moisture be allowed to escape once it gets inside the basement, wall or roof-ceiling cavities.

Many of the building products, solvents and chemicals used within a building during its lifetime will emit (or off-gas) chemicals into the air that can be harmful to the occupants in some cases. There are more and more building materials being introduced to the market with limited off gassing in mind, and this quality should be considered along with other sustainable principles when specifying products.

Both mold and chemicals, once airborne, can travel throughout the building, and without an escape route can infect or at least disturb the inhabitants that are exposed to them for periods of time. Whether mechanical or natural, buildings need good ventilation of the occupied spaces to function properly for the inhabitants.

**SUMMARY**

When evaluating thermal and moisture protection productions for inclusion in a building assembly consider the following:

- Products that reduce the energy consumption of the building – a building's energy use is one of the most significant factors for sustainable design.
- Recycled content and future recyclability for reducing the demand on resources.
- Locally produced products that reduce the environmental impacts of shipping.
- Low embodied energy which reduces the initial energy investment of the product.
- No CFCs, HCFCs or other ozone depleting substances.
- No formaldehyde, no VOCs and no off-gassing for promoting indoor air quality.

**RESOURCES**

**Computer Building Energy Simulation Software**

**BLAST:**

- Hourly simulations.
- BLAST (Building Loads Analysis and System Thermodynamics)
- Uses the fundamental heat balance method.
- Detailed reports.
- Can be used with the graphical interface HBLC (Heat Balance Loads Calculator) to visualize the building model as it is being developed.
- Developed by Building Systems Laboratory – University of Illinois.
- [www.bso.uiuc.edu/BLAST/index.html](http://www.bso.uiuc.edu/BLAST/index.html)
DOE-2:

- Hourly simulations.
- Widely used in the industry.
- Detailed reports.
- Requires expertise to use.
- Many versions available with different interfaces.
- Developed by Lawrence Berkeley National Laboratory.
  
  [simulationresearch.lbl.gov/](simulationresearch.lbl.gov/)

ECOTECT

- Includes 3-D modeling interface.
- Allows for testing implications of design decisions at a conceptual level.
- Includes simulation of energy, shadows, solar, lighting, ventilation, and acoustics.
- Developed by Square One research.
  
  [www.squ1.com/site.html](www.squ1.com/site.html)

Energy-10:

- Hourly simulations.
- Widely used for smaller buildings (less than 10,000 SF).
- Evaluates whole-building tradeoffs during early design phases.
- Includes thermal and daylighting calculations.
- Developed by the National Renewable Energy Laboratory.
  
  [www.nrel.gov/buildings/energy10/](www.nrel.gov/buildings/energy10/)

EnergyPlus:

- Hourly simulations – capable of time steps of less than an hour.
- Built on popular features of BLAST and DOE-2.
- Includes many innovative simulation capabilities including heat balance-based zone simulation, multizone airflow, thermal comfort, and photovoltaic systems.
- User-friendly graphical interfaces are currently under development at the time of this writing.
- Developed by U.S. Department of Energy.
  
  [www.eere.energy.gov/buildings/energyplus/](www.eere.energy.gov/buildings/energyplus/)

Other Computer Simulation Tools

Cool Roof Calculator:

- Estimates energy saved by employing a cool roof strategy.
- User inputs location and details on the roof system.
- Free web based calculator.
- Developed by Oak Ridge National Laboratory.
Moist:

- Estimates combined heat transfer and moisture in a multi-layer building assembly.
- Used to test designs for moisture control.
- Free – available for download on the web.
- Developed by the National Institute of Standards and Technology.

Opaque

- Calculates U-value through a construction assembly section.
- Free – available for download on the web.
- Developed by the Department of Architecture and Urban Design, University of California at Los Angeles.
- [www2.aud.ucla.edu/energy-design-tools/](http://www2.aud.ucla.edu/energy-design-tools/)

R-value Calculators:

- Several types available
- Free – web based.
- Developed by Oak Ridge National Laboratory.

Introduction

Through thoughtful design, one which allows the building to take advantage of climatic and site conditions, windows and doors can provide daylighting, natural ventilation, view, and solar heating. These building elements can also cause discomfort due to excess solar gain from lack of adequate shading, and infiltration through and around poorly sealed windows and doors.

ENERGY PERFORMANCE
Energy performance can be characterized by U-value, Solar Heat Gain Coefficient (SHGC), visible transmittance (Tvis), and air infiltration (cfm/lf). Look for total window and door U-values which account for glazing and framing effects. The most cost-effective, energy-efficient windows have U-values of 0.3 Btu/hr-ft²-F (R-3.3), although window U-values of 0.2 (R-5) are possible. Steel, fiberglass, and composite doors have total U-values between 0.20 and 0.25, depending on the type of insulation used for the core. Glazed door U-values vary widely depending on the glazing area and type of glass. There are two very good sources of window U-values available: ASHRAE 1993 Handbook of Fundamentals (Chapter 27, Table 5); and the National Fenestration Rating Council Certified Products Directory.

In Colorado, we have over 300 days of sunshine per year. Through proper placement, orientation, and sizing of windows, the solar heat gain through windows and glazed doors warms a space and lowers heating requirements. To prevent overheating, provide shading through landscaping, overhangs, and shading devices. By optimizing windows, there are also potential cost savings from downsizing heating and cooling equipment. While the lower the U-value the better, this is not necessarily true with solar heat gain. When solar heat gain is desired, for example in passive solar homes, you prefer a window or glazed door with a higher SHGC (greater than 0.6). For buildings which are dominated by cooling loads, such as most commercial buildings, products with lower SHGC's (less than 0.4) are recommended.

Lighting through natural light, referred to as daylighting, has been shown to promote more healthy and productive spaces when done correctly. For example, direct beam radiation can be redirected toward the ceiling by venetian blinds or light shelves. The visible transmittance indicates the fraction of visible light incident on a surface that is transmitted into a space. This is a key parameter for daylighting design. For daylighting, a visible transmittance of greater than 0.5 is often required, although this is strongly dependent on the amount of glazing area, availability of daylight, and the quality of light transmitted through the glazing. See Divisions 13 and 16 for more detail on daylighting.

Most windows test below 0.35 cfm/ft² for air leakage, and this accounts for less than 10% of the energy loss through a window. However, air infiltration can increase dramatically if the window is poorly installed. Caulking or insulation should be used to fill gaps between rough framing and the window unit prior to the installation of window trim. Expansive foams are not recommended due to window frame distortion.

**MATERIALS**

**Glazing**

The primary ingredients in glass are silica, soda ash, limestone, and cullet. Cullet is post-industrial glass waste that is fed back into the float process. Although the other raw materials are abundant, the mining of them has significant land, water and air pollution impacts.

The most exciting change in windows over the last ten years is the addition of low-E (low emissivity) glazing. A low-E glazing is a thin, metallic coating applied to either glass or plastic.
It is essentially invisible to the human eye. There are two types of low-E coatings: hard coats (pyrolytics) and soft coats (sputtered). Generally, coatings with an emissivity of 0.15 or higher are hard coats and those with an emissivity of less than 0.15 are soft coats. The lower the emissivity, the lower the U-value and the lower the heat loss through a window. However, hard coats transmit more solar energy and therefore have a higher SHGC, so the difference between hard coats and soft coats relative to heating impacts are negligible.

One of the newest products on the market is the "twin-coated" Heat Mirror film from Southwall Technologies. This is the first suspended film with low-E coatings on both sides of the film. Two low-E coatings give optimum thermal performance in a triple-pane window, and with the twin coated product improved material efficiencies and greater recyclability of the glass is realizable. Expect low-E glazing to add 10% to the cost of a window and suspended films to add 25% to 50% to the cost.

Glazing systems with plastic films suspended between two glass panes or with a film laminated between the glass layers have the advantage that plastic blocks all invisible ultra-violet radiation, which can cause materials to fade. Visible light also causes colors to fade and the amount of fading depends on the material.

Manufacturers offer coated and tinted window products which control the amount of total solar energy transmitted and the amount of visible light transmitted. Through recent technological advances, including changes to low-E coatings, manufacturers have produced glazing with a high visible transmittance and a low Solar Heat Gain Coefficient. These glazings are ideally suited for commercial applications. The glazings are sometimes referred to as selective glazing, spectrally selective glazing, or cool glazing. Tinted glass does not affect the U-value; only coatings on the glass can affect the U-value.

**Between the Glass**

The optimum spacing between the glazing layers is 1/2" for energy efficiency. The thermal performance of a units starts to drop off considerably at less than 7/16" spacing. Wider spacings also have acoustic benefits. Manufacturers are filling the space between the glass panes with argon and sometimes krypton to reduce the heat loss through a window. Both gases are inert, transparent, and present in small quantities in the air. It is important that the glazing unit be filled within 2000' elevation of the installation to ensure that the unit retains the gas. Units shipped to different altitudes can leak which only means you lose the benefits of the argon.

**Spacers**

The spacer separates the glass in multi-pane windows. Aluminum spacers have been standard in double-pane windows for years and dual seal units have shown to be more durable. Many window manufacturers are now offering "warm-edges". Such spacers reduce condensation around window edges and slightly improve the thermal performance of the window.

**Wood Frames**
Wood, a renewable resource with low embodied energy and good thermal performance, has been traditionally used to construct doors and window frames. The wood is pretreated to protect against rot and infestation. The treatments typically contain mineral spirits, paraffin wax, and propynyl butyl carbamate. The lumber cut and available in the Rocky Mountain region is not of high enough quality, so all higher grade lumbers are imported into the region. The recent decline of available, clear and old growth lumber has forced the industry to look at alternatives: Using wood more efficiently, using finger-jointed wood and composite wood products that utilize poorer grades of lumber and some recycled wood. Composite products require a surface finish to meet quality standards.

**Metal Frames**

Metal has the advantages of strength, stability, availability and ease of maintenance; and the disadvantages of being energy inefficient and having a high embodied energy. The addition of a thermal break within the frame profile of aluminum windows improves the thermal performance but makes recycling more difficult. The metal industry is recycling and the use of recycled metals in windows is increasing. The manufacturing of recycled aluminum takes only 11% of the energy of producing virgin aluminum. Insulated metal doors are an exception in that they are relatively energy efficient and cost effective. The 1 3/4” core of foam or rigid board insulation makes them far superior to solid wood doors in terms of energy loss. We recommend metal doors with an insulating core made from expanded polystyrene (EPS), rather than the urethane or polyisocyanurate foams which are blown with CFC's or HCFC's. (See Division 7 on insulation materials.)

**Vinyl Frames**

Vinyl has been used in window frames for many years in Europe and Canada. Its thermal performance, cost competitiveness, and maintenance-free characteristics make it a viable material. The strong western sun can deteriorate some types of vinyl, so be sure to confirm UV resistance and warranties with the manufacturer and do not paint the exterior of the product. Local fabricators are popping up all over Colorado. They purchase the frame material from elsewhere and build the windows here. Some vinyl extruders accept cut-offs from the fabricator for recycling, but this is not yet the norm in the industry.

**Fiberglass Frames**

Fiberglass frames have a low embodied energy, their thermal performance is comparable to wood and vinyl, and it is durable and maintenance free. The cost is presently comparable to a good wood window. More common are fiberglass doors with insulating cores which perform as well thermally as steel insulating doors.

**APPLIED FILMS**

Applied films are plastic films which can be adhered to existing glazing. The primary benefit
from the films is to reduce solar gains. They are very cost effective in commercial retrofits. Be sure to consult manufacture's warranty as applied films may void the warranty.

CURTAIN WALLS

Silicone structural glazing and structural gasket glazing are two of the most energy-efficient curtain wall systems relative to reducing heat loss. When using metal frames, thermally-broken metal frames should be specified to reduce heat loss and avoid condensation problems. In commercial buildings, which are dominated by cooling and lighting loads, glazing selection emphasizing solar control and daylighting is more important than reducing heat loss. Glazing systems with the new spectrally selective products can provide superior energy performance. SHGC's less than 0.4 are recommended.

WEATHERIZING

Weatherizing existing windows can be done using several methods such as caulking, installing weatherstripping and/or plastic inserts, all of which are available at hardware stores. Installing storm panels is also an excellent alternative in improving the efficiency of existing windows without replacing the entire unit, and the cost is much less (approx. $10/sq ft). Storm windows are also available with hard coat low-E glass.

SUMMARY

- Specify low-E glass and an 1/2" air space for residential windows.
- Specify total window and door U-values of less than 0.4 Btu/hr-ft2-F. For solid doors, select products with U-values of less than 0.25 Btu/hr-ft2-F.
- Specify commercial glazing with a SHGC of less than 0.4.
- Use natural light (daylighting) for lighting.
- Provide adequate shading through landscaping, overhangs, and shading devices.
- Provide interior thermal mass to store solar heat gain and temper living space.
- Ensure proper installation through weatherstripping and caulking opening.
- Compare NFRC numbers for any product used.

RESOURCES

National Fenestration Rating Council Certified Products Directory Provides a non-biased source of U-value. Most manufacturers are including NFRC U-Value ratings on their labels. NFRC, 1300 Spring Street, Suite 120, Silver Spring, MD 20910, (301) 589-6372

ASHRAE 1993 Handbook of Fundamentals, Chapter 27, Table 5 Comprehensive List of All Window Types. Provides a non-biased source of U-value. American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE), 1791 Tullie Circle NE, Atlanta, GA
Division 9: Finishes

Introduction

Division 9 includes all materials used in interior finishes particularly on ceilings, walls and floors.

INDOOR AIR QUALITY

The choice of interior finishes has a particularly acute impact on Indoor Air Quality (IAQ). Many interior materials involve the use of toxins, which are frequently found in adhesives, paints, binders, finishing products, or even in the cleaners used for a product's maintenance. These toxins, referred to as Volatile Organic Compounds (VOCs), include solvents and urea-formaldehyde, which emit gasses over a long period of time. Other indoor pollutants include molds, bacteria, fibers, and dusts. Accumulation of pollutants can cause Building Related Illness (BRI), which includes eye, nose, or throat irritation, asthma, headaches, nausea, and liver, kidney, and nervous system damage. BRI may also involve drowsiness and suppression of the immune system. Buildings that repeatedly trigger building related illness are referred to as having Sick Building Syndrome (SBS). While ventilation systems are intended to exhaust pollutants, the systems often fail to perform this task effectively and often reduce the energy efficiency of the building. The best method to control the quality of indoor air is to reduce or eliminate pollutants at their source through informed material selections.
EMBODIED ENERGY

It is important to consider the energy consumed in creating an interior finish material. The embodied energy is the energy consumed during the entire life cycle of a product, from the processes of resource extraction, manufacturing, packaging, and transportation, down to the energy consumed during installation, use, maintenance, and disposal.

Many of the products in this section use renewable resources or are recycled from sustainable raw materials. For example, wood can be harvested from a sustainable managed forest instead of clear-cut from old growth forests. Floor tiles can be reground from broken glass. Carpet manufacturers are now recycling old nylon carpet directly into new carpet.

INSTALLATION, USE AND MAINTENANCE

Considering the environmental impacts of a product during its installation, use, and maintenance is also important. Installation of an interior finish often involves solvents, adhesives, and the generation of dusts, which are harmful both to the installer and to the future inhabitants. During use, many products continue to release volatile organic compounds (VOCs). Furthermore, some products such as carpets may trap dusts and toxins, lowering the quality of indoor air. The application of a finish may also improve or impair the energy efficiency of a space over time. During maintenance, gaseous and toxic chemicals may be required for cleaning. Careful consideration should be given to the maintenance process and its environmental impact. Selecting natural or bio-based products are preferable and are available for both commercial and residential use.

DURABILITY AND DISPOSAL

Products that are long lasting vastly reduce resource consumption, as well as reduce all of the other environmental impacts associated with future construction and remodeling. We are beginning to see a new movement towards truly recycling or reinventing products into reusable materials. It is important to consider whether a product is recyclable, salvageable, or biodegradable at the end of its use, as when a product must be disposed of in a landfill, there may be dangers of toxic hazards as the material degrades.

WALLS AND CEILINGS

Drywall is most commonly used as a wall and/or ceiling finish. Virgin gypsum still accounts for most produced but recycled and synthetic gypsum are increasingly available. Recycled gypsum board is derived from in-plant scrap & clean construction waste. Synthetic, or flue-gas, gypsum is a waste product taken from stack scrubbers that are used for removing sulfur from coal-fired power plant emissions. In these scrubbers, calcium carbonate is converted to calcium sulfate, or gypsum. Synthetic gypsum can replace up to 100% of the natural gypsum in drywall, if locally available. Some manufacturers are producing 54” wide sheets for more efficient wall coverage in
rooms with 9’ ceilings. There are several drawbacks: mining contributes to dust, soil erosion, and destruction of habitats. It has a relatively high-embodyed energy and it is difficult to recycle and therefore contributes to landfill problems. There are some advances in recycling technology that allows separation of the paper from the core so that each can be recycled separately.

Plaster is an alternative that is durable, conserves resources, and is low-maintenance, made from abundant resources and there is less job-site waste than from sheet materials. Integral pigment color can be added to the dry mix and it can be left untreated or finished with a wax or water based sealant.

When using wood wall finishes, woods should be selected which do not come from old-growth forests, but rather from sustainably managed forests. Further, it is best to choose woods grown in regional forests rather than in another part of the country or on another continent (Refer to Division 6). Woods common to the western area include pine, aspen, spruce, fir, and hemlock. Specifying regionally available wood products reduces the energy consumption involved in transportation. The most resource-efficient option is to use salvaged wood.

Wall coverings are covered in Division 12.

Acoustical tile ceilings are often less expensive than gypsum board ceilings. They also do not require painting or other finish materials to complete the installation. Some ceiling tiles are made from recycled newspaper, mineral wool, perlite and clay. Due to the grid organization, acoustical tile ceilings may not be as adaptable to renovations as a gypsum board ceiling, though they are easier to reuse.

Be cautious of ceiling tile and sprayed-on ceiling finishes containing asbestos, formaldehyde, or crystalline silica, as these items are possible cancer and respiratory tract hazards. According to a Cornell University study, one cause of SBS (sick building syndrome) is from mineral fibers (rock wool or fiberglass); these fibers do not decompose in a landfill.

FLOORING

While ceramic and porcelain tile have high-embodyed energy, it is potentially a very durable product. Some tile products are now made from recycled products such as fluorescent light bulbs, car windshields and agricultural waste. In addition, stone also has high-embodyed energy but has many beneficial qualities, least of which is the ability to reuse it. Stone should be used wisely and with care, a non-renewable resource in our lifetime, its beauty and durability adds to it’s as thermal mass properties in a building when used as flooring near windows or as a trombe wall. The environmental impact of mining any stone or mineral depends on the methods used to extract, transport and finish the stone. Regional stone has a lower embodied energy than imported stones such as marble that is polished or hones and transported long distances.

For wood flooring, it is again important to consider the management practices of the source, the local availability of the wood, and to avoid formaldehyde used in processed wood. Salvaged flooring, or flooring manufactured using salvaged woods conserve resources. It may be
necessary to plan ahead if large quantities are needed because availability can sometimes be
difficult. Engineered-wood can also be used successfully, especially if the product has a thick
veneer (more than 1/8 inch thick) that allow for refinishing. Using shorter planks or parquet style
flooring makes use of leftover pieces.

Bamboo, a recent addition to our market, is now widely available for flooring. A fast growing
grass from China, bamboo is a renewable resource that is harvested every 3-5 years. It is durable
and a dimensionally stable material, but one should be certain it is from a certified source and
manufactured with environmentally safe adhesives.

For resilient flooring, linoleum is recommended over vinyl flooring. It is a natural product,
biodegradable, and emits very low VOCs. Cork tile is another natural, sustainable choice that is
durable and naturally moisture resistant. Vinyl tile and sheet is made from PVC, off-gases
VOCs, and is not biodegradable. Solid vinyl tiles can be recycled, but sheet vinyl has a backing
that makes it difficult to recycle. Vinyl products have been linked with health risks and are
therefore not recommended. Toxic VOCs are produced during production, continuing throughout
installation and beyond. Rubber flooring in tiles and sheets are frequently available with recycled
content, but be aware that there are also VOCs being emitted and care should be taken to use
appropriately.

Carpet may contain many chemicals, such as flame retardants and biocides. Natural fibers, (such
as jute, cotton, wool) or fibers containing recycled materials carry a lower embodied energy than
carpet made from nylon or virgin plastics. Carpets can collect high amounts of dust, which can
cause allergic reactions in sensitive people, especially when combined with forced-air heating.
Vacuuming stirs up this dust, thereby contributing to indoor air quality problems. Several carpet
manufacturers have started recycling programs with their carpet products. At the end of the
carpet's useful life, the manufacturer takes the product back and fabricates it into new carpet.
Carpet backings of styrene butadiene rubber (SBR) latex should not be used when considering
healthy environments.

PAINTS, STAINS, AND ADHESIVES

Paints, stains, transparent finishes, and adhesives contain many toxins including urea
formaldehyde and other VOCs. VOCs are used to increase finish level, durability, and
convenience of application. Numerous non-toxic, or low-toxic versions are available and are
preferable. In general, alkyd-based, or alcohol-based paints contain higher levels of VOCs than
do latex or water based paints. Use adhesives with low VOC levels, or better yet, do not use
adhesives where at all possible. The non-solvent adhesives have 99% less hazardous emissions
than solvent adhesives. Yellow and white glues are recommended. When specifying sealants,
consider using only silicone sealants in interior areas. All other sealant types, especially the butyl
sealants, emit VOCs and other toxic compounds. Factory-applied finishes generally contribute
less VOCs than field applied finishes.
SUMMARY

Interior finishes, more than any other category of building materials, have a dramatic effect on indoor air quality and resource consumption. When specifying interior finish materials, keep the following things in mind:

- Use products with low or no VOC content.
- Use precious materials, like tropical hardwood, sparingly and only when certified to be from a sustainably managed forest.
- Specify wood harvested from sustainably managed forests.
- Choose products such as woods and stones that are regionally available.
- Choose products based on their total life-cycle cost, including durability and embodied energy.
- Use products with a high-recycled material content.
- Specify products that can be recycled or reused.
- Choose water-based finishes whenever possible.

SOURCES


Division 10: Specialties

Introduction

Division 10 includes a number of categories that provide specialized materials or fabricated items. Sections include everything from Visual Display Boards to Wardrobe and Closet Specialties. Although the Sections within this Division are diverse, a number of general environmental considerations apply to most of the materials used to manufacture the broad range
of products.

**PEST CONTROL**

Pesticides are designed to kill a certain species of insect. Many can be highly toxic, not only to insects, but also to humans, pets and wildlife. The health risk from pesticides stems both from the toxicity of the chemicals and the degree and duration of an individual's exposure. Since we cannot change the inherent toxicity of pesticide products, we can minimize the risk by limiting exposure to the products and possible selection of biologically friendly or organic materials. Web searches for “safe pest control products” provides numerous listings for suppliers and environmentally safe products in addition to sources of organic pest control. With products constantly changing and environmental regulations and concerns also in constant change, web research provides a source for information in selecting and evaluating products.

**FIREPLACES AND STOVES**

In the Rocky Mountain region, especially in the heavily settled Front Range corridor, a weather condition called inversion traps polluted air creating a cloud of noxious gas. As a result, many of the Front Range communities monitor air quality and on high (called "red") pollution days, wood burning is banned except in the cleaner burning woodstoves that comply with EPA Phase III stoves. Evaluating and selecting a wood-burning stove will require coordination with the planning and zoning department to determine what regulations apply where the stove will be installed. Stoves may also be fueled by natural gas or propane that burn more cleanly than wood, although wood has the advantage of being a renewable energy source. Keep in mind that rated efficiency is established under laboratory conditions and that actual performance may have a lower efficiency.

**Woodburning**

Open fireplaces, even the Rumford design, are the least efficient space heaters. Also, due to incomplete combustion, open fires add greatly to pollution. One step in the right direction is the use of tight fitting fire doors and outside combustion air, but this will only lessen the amount of warm air wasted and will not affect emissions. Airtight woodstoves work by radiating heat from a cast iron casing. Efficiency is far higher than open fires and emissions are considerably reduced. Advanced combustion systems for wood stoves do not use any air from the house and are far more efficient than previous models. Due to an elaborate burner arrangement exhaust gases are reignited so that emissions are greatly reduced. Electric fans supply air and circulate heat. Efficiency may reach 78% making them competitive with gas furnaces.

**Natural Gas Appliances**

Gas logs eliminate most of the emissions of wood burning, but even with glass doors they add little heat. There are also safety concerns when used in a retrofit unless the chimney is relined. Gas fireplaces are a more efficient source of heat. Units are sealed and supplied by outside
combustion air and may achieve 70% efficiency (lower than conventional gas furnaces).

Additional Information

1. Metro Denver Clean Air Hot line, Call 303-758-4848 (recorded message); 303-692-3106 (person).
2. For information on air quality, Colorado Phase III, and government regulations, contact Air Pollution Control, City and County of Denver, 303-436-7305. (You need to call your local government office to get information outside of Metro Denver).
3. For more information on air quality issues and government regulations contact: Hearth Products Association 2150 River Plaza Dr., Suite 315 Sacramento, CA. 95833 (CONFIRM INFORMATION)

They will also provide access to specific fireplace manufactures and products that will be helpful for your projects. For information about the Hearth Products Association's Annual Trade show, call the national office in Washington, D.C., at (202) 857-1181

SOURCES

2. Eclair and Rousseau. Environmental by Design. 1992
4. Orkin Pest Control, Mr. Ray Styles, 4251 S. Notches Ct., Sheridan, Co. 80110 (303) 761-2620.
5. Fireplace Equipment of Colorado, Mr. Robert Nuzzle, 7003 Lowell Blvd., Westminster, Co. 80030 (303) 428-6576.

Introduction

Division 11 covers equipment used for industrial, commercial, and residential processes. It does not include equipment for heating, ventilation, and air conditioning (Division 15), and lighting (Division 16). Because of the specialized nature of process equipment, this division's focus is
primarily on recycling equipment and receptacles, commercial laundry equipment, home appliances, and office equipment.

Generally speaking, high-performance motors are recommended for all types of equipment. In addition, all equipment operated indoors affects indoor air quality. Care should be taken to provide sufficient fresh air for the occupants and to vent equipment and appliances to the outdoors. ANSI/ASHRAE Standard 62-1989 published by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) specifies minimum ventilation rates and indoor air quality for indoor human environments.

Check with your local utility company concerning their rebate programs for energy-efficient appliances. The Energy Policy Act of 2003 recently added vending machines and commercial freezers and refrigerators to the list of equipment with required minimum efficiencies.

**RESIDENTIAL EQUIPMENT**

The U.S. Department of Energy has established minimum efficiency standards for the energy consumption of refrigerators and other appliances. Almost all of the major appliance manufacturers produce models that out-perform the minimum standards at no additional cost to the consumer.

Gas-fired appliances are often less expensive to operate than their electric counterparts. However, indoor air pollutants, such as carbon monoxide from incomplete gas combustion can be a problem. When available, sealed-combustion appliances are recommended for equipment located in living spaces.

**Refrigerators and Freezers**

Refrigerators are much more efficient today than in the past. However, there are still large variations between the efficiencies of similar models. A modern refrigerator uses less than 500 kWh per year. The current minimum efficiency standards for refrigerators and freezers were last updated in 2001. The Energystar program was expanded in 2003 to include compact, full size refrigerators, and freezers. A compact Energystar refrigerator will be 20% more efficient than the minimum federal standards for a full size refrigerator. The most energy-efficient models are those with separate compressors for the refrigerator and freezer but these are difficult to find in the United States. The next best option is two separate units. Failing that, combined models with the freezer positioned above or below the refrigerator use less energy than side-by-side models. The most efficient stand alone freezer models are top loading. The Consumer Guide to Home Energy Savings lists models which are at least 15% more efficient than required by law. Convenience features such as automatic ice makers and through-the-door water dispensers increase energy use by 10-20%. Manual defrost can save money in stand alone freezers by saving energy and contributing less to freezer burn than automatic defrost. Since this type of freezer is opened less frequently, frost will not build up as quickly compared with a manual defrost refrigerator. Refrigerators can be compared by their EnergyGuide. CFC's are destroying the ozone and are recognized as one of the primary causes of global warming. For these reasons,
companies were required to eliminate CFC’s by January 1, 1996. Replacement gases include HCFCs and HFCs and refrigerators using these alternatives are expected to have the same energy use. Finally, location of equipment will affect the efficiency. Try to locate equipment away from heat sources and direct sunlight, as these will make your equipment work harder. Also, do not locate equipment in areas that frequently reach temperatures below 45 degrees. Below 45 degrees the refrigerants do not work properly.

**Dishwashers**

80 percent of the energy use associated with automatic dishwashers is for heating the water. Dishwashers require a higher temperature of water than that required by other household appliances to ensure sanitization. Therefore a built-in heater in the dishwasher allows the household hot water heater to be set at a lower temperature. Look for models with a normal cycle water usage of less than 8 gallons and energy saving options such as a built-in heater, "no-heat" dry, and low water use cycle for less dirty dishes. Currently, “soil sensing” technology in dishwashers has not been shown to significantly reduce energy and water use. Consumer Reports, [www.consumerreports.org](http://www.consumerreports.org), lists various models, their water use, cost, features, and maintenance history.

**Washing Machines**

Energystar guides can be misleading when comparing between various machine styles. A new metric for comparison, MEF, has been developed to correct this situation. Currently, not all manufacturers provide MEF values for their equipment. Federally mandated energy efficiency standards incorporate MEF values. Federal law mandates increased efficiency levels for washers in 2004 and 2007.

Like dishwashers, the majority of energy use associated with washing machines is for heating water. Thus, equipment that minimizes water use creates savings from water and energy use. Traditionally, front-loading models have had the greatest efficiency. However, recent advances in top-loading models have lead to the development of top-loading models that equal front-loading models in efficiency. Front loaders remove more of the water during spinning thus reducing drying time. Top loaders are also typically less expensive. In selecting a top-loader, choose one with many water level and temperature settings. Also look for a feature called "suds-saver" which enables reuse of rinse water for the next load. Similarly, use of the presoak cycle will generally produce the same results as a typical wash cycle at a higher temperature. Consumer Reports, [www.consumerreports.org](http://www.consumerreports.org), compares various front-loading and top-loading machines. There is an electric washer/dryer unit that is a single unit horizontal-axis washer and electric dryer. Even though the dryer is electric, less drying time is required because the washer extracts more of the water. The unit is more resource efficient in terms of the materials used for the product, requires less space, and has the advantage that clothes do not need to be transferred between the washer and dryer (see Equator entry). Commercially, there are batch style washers that allow for significant water savings by using a scoop to transfer laundry from one wash bay to the next.
Dryers

Gas-fired models are less expensive to operate than electric models and are also more efficient in terms of energy use and pollution emissions. However, the units must be vented to the outdoors because of their adverse affect on indoor air quality. A moisture or temperature sensing control feature, as an alternative to a timer, can save energy and extra wear on clothes by avoiding over-drying. Moisture sensors located in the drum are more effective than temperature sensors in the exhaust air at accurately ending the drying cycle for all types of clothes. There are also features available that reduce the need for ironing such as a cool down cycle and periodic tumbling until clothes are removed.

Ovens/Stoves

The same comments concerning gas-fired dryers apply to ovens and stoves. In addition, convection ovens use less energy than conventional ones. Halogen element stoves are more energy efficient than conventional coil units, but are very expensive to purchase.5 Similar to Halogen stoves, radiant ceramic glass stoves heat up slower than coil units, but offer better cleanup. A new technology, induction elements, uses half the energy of coil units and has very little residual heat once the pan is removed. However, these units only work with iron or steel cookware and are very expensive. A new product category has emerged as “Professional” cooking equipment for the home. The quality and performance of this new category should be considered, as most are gas fired and the potential product longevity should reduce natural resource consumption.

OFFICE EQUIPMENT

Office equipment such as copiers, fax machines, printers and computers can have a significant impact on cooling loads, electricity demand, and indoor air quality. The Guide to Energy Efficient Office Equipment contains useful information on office equipment energy use. When buying new computer equipment, look for EPA's ENERGY STAR logo indicating a power-down feature during periods of inactivity. Over 70% of the computers and monitors on the market today offer the power-down feature, and over 90% of the printers have this feature.

Other common wastes of electricity are all those little transformers that power equipment like adding machines, fax machines, cordless telephones and peripherals for computers. Touch the little box that plugs into the wall--it’s warm because it is transforming higher voltage to lower voltage and heat whether the equipment is being used or not. Although this is a small loss, it does add up. The only way to avoid it is to buy equipment that uses line voltage or to disconnect the transformers when not in use.

"In 1991, office equipment directly consumed 26 billion kilowatt hours or 3% of total commercial building energy consumption; this translates into approx. $2.1 billion in electricity costs. This figure increases to approximately 36 billion kWh if cost of space conditioning to offset waste heat generated by the office equipment is included. ... If reduced this by 50%, it is equivalent to removing 6 million cars from U.S. passenger vehicle stock in terms of the
reduction in CO2 emissions."

Copiers emit gasses such as ethanol, methanol, and other VOCs; printers and copier supplies emit ammonia, benzene, carbon black, ozone, terpene, and many others; computers and VDT's emit cresol, ozone, phenol, toluene, and many others; and copy paper emits formaldehyde and other chemicals (VOCs). VOC emissions from the equipment itself diminish over time, but emissions from supplies reach a constant level related to the use of the supplies.

We also highly recommend purchasing refurbished office equipment. It is widely available (see the Yellow Pages) at significant savings. Use recyclable, reusable toner cartridges and refillable inkjet cartridges for computer printing.

SUMMARY

In selecting equipment for a home or business, consider the following:

- Energy requirements.
- Water use.
- Impact on indoor air quality.
- Specify high-performance motors.
- Specify refurbished equipment where appropriate.
- Provide direct ventilation to the outdoors for gas-fired equipment located in living spaces.
- Product longevity based upon manufacturers warranty.

SOURCES

3. Ibid.
4. Ibid.
5. not used
6. Ibid
Introduction

This division covers furniture, fabrics, upholstery, casework, window treatments and hardware, rugs and mats, accessories and artwork. Issues involved with these products are source materials and manufacturing processes. Many of the following items can be used for both commercial (which includes office, institutional, retail, hospitality, etc.) and residential applications.

TOXICITY IN FURNISHINGS

In recent years government regulations and entities (such as OSHA) have increased restrictions on the manufacturing process, which have forced many manufacturers to use less toxic products in their processes. Material Safety Data Sheets (MSDS) are available for all products from the manufacturer and supplier. The data sheets list all toxic and hazardous substances. However, fire safety regulations, product quality standards, health and accessibility codes, which were implemented for the good of the public, sometimes conflict with specification of sustainable or healthy products.

The addition of formaldehyde was initially considered a breakthrough for many products because it lessened the drying time for adhesives and allowed fabric to become "permanent press". Now we realize that VOC's (volatile organic compounds) off-gas from chemicals such as formaldehyde emitted from furniture, finishes, equipment, etc. and can have negative physical consequences, especially for the upper respiratory and immune systems. While off-gassing primarily occurs during installation and initial occupancy, certain materials can emit VOC's for years.

FABRICS

Both natural and synthetic fibers have advantages as well as drawbacks. Examples of natural fibers derived from natural sources include cotton, wool, silk, linen, hemp, coir, ramie and jute. Ideally these can be grown "organically", free of insecticides and pesticides, and minimally processed. Look for how they are treated, whether with bleaches, dyes, fabric protectors and fire retardants, as these can all contribute to poor Indoor Air Quality (IAQ) emitting VOC’s, and interfere with the long term goal of creating “cradle to cradle” products.

Synthetic fibers are artificial fibers produced by combining chemicals or by altering natural fibers. Examples include rayon, acrylic, nylon, polyester, spandex and viscose. Synthetics are long lasting and are sometimes an appropriate choice and can be made with recycled content as well as renewable content or bio-based fibers such as corn, maize or rice. They are often solution dyed, resulting in color fastness and reducing the risk to water pollution.

WINDOW TREATMENTS

Window coverings can aid in temperature control as well act as effective thermal barriers.
Options to consider include wood and fabric blinds, natural fiber shades, and cellular shades. Components to look for are anticipated lifespan of the materials, adhesives, stains, finishes or dyes used, as well as R-values to determine the appropriateness of your selection. Many solar shade companies offer versatile control systems for any kind of window treatments that can be either manually or automatically operated. Motorized systems offer a greater degree of responsiveness to climate and light conditions, including sun sensor keypads and switches.

**FURNITURE: NEW - COMMERCIAL**

The materials used for commercial furniture may be from a natural source, but manufacturers have to contend with multiple environmental concerns, as well as comply with local, state and national codes. In the case of wood, for example, eliminate exotic species of wood, or purchase from sustainable forestry operations. Although it can increase the cost of wood casework from conscientious manufacturers, the long-term ramifications far outweigh the initial price increase. Awareness of how CFC’s are affecting the ozone layer is another problem, which has led to formulations of alternative foam products and should be available. All aspects of making furniture should be examined, from fabrics, hardware, stains, adhesives, finish coating material, particle board, solid wood or veneers, plastic, metals, to waste disposal, packaging, and even shipping.

Numerous sources exist to recover and recycle office systems, including work surfaces, panels, storage and seating. Manufacturers themselves provide some, and these systems can be reused over and over, promoting less use of virgin resources.

**FURNITURE: NEW - RESIDENTIAL**

A variety of furnishings fit under this category, including mattresses, bedding and linens, light fixtures, upholstery and cabinetry case pieces. Furnishings impact our health especially through our respiratory systems.

Again, all aspects of making furniture should be examined closely to determine the most appropriate materials and application. Mattresses, sheets, pillows and blankets are now being offered in organic fibers, unbleached and undyed. Light fixtures can be made from recycled content materials and light bulbs that are energy efficiency should always be used. Local workrooms can always be found to custom make upholstery or case pieces, and there are manufacturers who fabricate lines that are designed wisely using organic or inert materials, sustainably harvested woods, and low VOC adhesives, stains and finishes.

**FURNITURE: ANTIQUE AND REFURBISHED**

Second hand furniture is available that can be refinished and reupholstered. Some office product dealers carry an inventory of used office furniture. A number of specialty companies stock refurbished components for modular panel systems. Check to make sure that older modular
systems will meet modern cabling demands.

Antiques such as desks should be considered if they meet the office demands. There are so many vendors of antiques that we are not listing them in this directory (see telephone yellow pages). Along with salvaged products, they provide wonderful opportunities to utilize "recycled" items.

RUGS AND MATS

Currently the most common materials used for mats are petrochemical based. However, both carpeting and rugs are available that are made from natural fibers and colored with natural dyes. There are now some mats that are made from recycled materials, such as recycled tires and old rag rugs.

SUMMARY

- Use untreated natural fabrics whenever possible.
- Use fabrics that are dyed with organic or natural pigments, free of toxins, carcinogens, and heavy metals
- Use fabrics that are solution dyed verses conventional dyeing
- Use fabrics that are naturally fire retardant and stain resistant verses needing chemical treatments.
- Consider the balance between sustainable construction and energy conservation.
- Whenever possible, use refurbished systems.
- Use regional woods for new furniture whenever possible, harvested from sustainable forestry operations.
- Avoid using exotic woods for new furniture unless you are assured they are harvested from sustainable forestry operations.
- Solicit MSDS information from manufacturers and become more aware of toxic and hazardous material content.

Division 13: Special Construction

Introduction

This division contains information on some of the forms of solar energy that relate to heating,
lighting, and powering buildings; passive solar systems, glazing, daylighting, solar hot water heating, active solar space heating, photovoltaics, and wind energy systems.

Passive solar systems involve no moving parts and are used to heat buildings. Some of the strategies include proper building orientation with respect to the sun; appropriate types, sizes and locations of windows; overhangs sized to prevent summer overheating; and the incorporation of thermal mass to store heat.

Solar-thermal systems are most often used for space heating or to heat water. These systems require mechanical circulation of the working fluid - typically air or water, or a glycol/water mixture.

Photovoltaics convert sunlight into electricity and can be used to power lights, appliances, and any other equipment that uses electricity. Photovoltaics can either be connected directly to the electrical grid or to batteries for storage.

Wind energy systems convert wind into electricity. Wind turbines can be used without storage for things like water pumping, connected to batteries for supplying electricity for off-grid homes, or grid-tied in larger scale utility operations. Building owners can specify wind power as the source for their building’s electricity in many utility company territories.

Solar energy systems are very effective in the Rocky Mountain Region because of the sunny climate. Some solar strategies must be implemented as an integral part of the building (e.g., daylighting and passive solar design with appropriate building massing and glazing design), and should be considered at the earliest stage of the design process. Others, such as solar hot water systems, active solar heating, and photovoltaics can be added later, but are best integrated at the start for aesthetic and cost reasons.

**PASSIVE SOLAR DESIGN**

Always consider passive solar strategies in building design. Five basic passive solar strategies include 1) proper building orientation with the long axis of the building oriented east-west to maximize southern solar exposure; 2) number of windows and placement appropriate for regional climate 3) use of energy-efficient glazing and careful window sizing to reduce heating costs in the winter, avoid overheating in summer and promote thermal comfort year round; 4) proper sizing and locating of building overhangs and shading elements to avoid overheating in the summer; and 5) incorporation of thermal mass into the building to store heat.

Energy efficiency is also a key component of passive solar design a building should be well insulated, tightly constructed, and have high quality windows and doors. Proper ventilation is needed: consider operable windows on the east and west sides of the building. The more efficient the building is, the larger the fraction of the heating that will be satisfied by the passive solar gains.

Buildings under 10,000 ft$^2$ in the Rocky Mountain Region, commercial or residential, are ideal
targets for passive solar heating in winter and shading in summer. One computer simulation program available for these calculations is ENERGY-10. The ENERGY-10 software tool was specifically designed to analyze passive solar and energy-efficient strategies in buildings under 10,000 ft². Buildings between 10,000 ft² and 50,000 ft² are good candidates for passive solar heating and daylighting. Daylighting reduces electricity use and cooling energy, lessening direct solar gain through glazing selection, orientation, and external shading devices.

**Glazing**

Division 8 includes a more comprehensive discussion on windows. The energy performance of glazing and windows is characterized by U-Factor, solar heat gain coefficient (SHGC), visible transmittance (Tvis), and air infiltration (cfm/lf). Look for total window and door U-Factors that account for glazing and framing effects. There are two very good sources of window U-Factors and SHGCs available: ASHRAE 1997 Handbook of Fundamentals (Chapter 29, table 5 and Table 11); and the National Fenestration Rating Council Certified Products Directory.

In Colorado, we have over 300 days of sunshine per year. Through proper placement, orientation, and sizing of windows, the solar heat gain through windows and glazed doors warms a space and lowers heating requirements. To prevent overheating, provide shading through landscaping, overhangs, and shading devices. Optimization can potentially lead to downsizing of heating and cooling equipment, resulting in cost savings. The most cost-effective, energy-efficient windows have U-Factors less than 0.4 Btu/hr-ft²°F (R-2.5). While the lower the U-Factor the better, this is not necessarily true with solar heat gain. When solar heat gain is desired, such as in passive solar homes, a window or glazed door with a higher SHGC (greater than 0.5) is preferred. For buildings that are dominated by cooling loads, such as most commercial buildings, products with lower SHGCs (less than 0.4) are recommended.

The most exciting change in windows is the addition of low-E (low emittance) glazing. Low-E glazing reduces the U-Factor of a window that results in lower heat loss. In the winter, the interior surface of the glass will also be 500°F to 1000°F warmer than that of a standard double-glazed window. The biggest difference between different low-E products is in how much solar heat gain they allow. Many residential products with low-E glazing have an SHGC less than 0.5. For passive solar heating applications, be careful to specify windows with low-E glazing and an SHGC greater than 0.5.

**Daylighting**

Designing a building to take advantage of plentiful daylight greatly improves the comfort and aesthetic appeal of interior spaces. If done correctly, the use of daylight can dramatically reduce the energy consumption of the building by reducing the time the lights are on. Reducing the electric light use also reduces cooling requirements. Studies have also shown that the occupant's psychological and physiological comfort can be improved by natural light.

A successful daylighting plan can introduce an ample amount of daylight and prevent overheating. This is accomplished by using daylighting strategies that minimize direct solar gain
through shading, use of north light and reflected light, and glazing selection that minimizes heat gain but maximizes visible light transmission. Daylighting can be as simple as using proper glazing with Venetian blinds and lighting controls that respond to ambient light levels. Effective daylighting strategies often include clerestories, light shelves on the east, west, and south walls, atria, and cupola structures. Light interior colors work best for reflecting daylight deep into the buildings. Light pipes can also be used to bring light deep into the inner areas of the building with very little impact on the design.

Automatic lighting controls are necessary for maximum electric light energy savings and peak load reduction from daylighting. These controls can either dim or turn off lights when the natural light level from windows, skylights, or clerestories is adequate for the occupants. Unless the space has been specifically designed to bring daylight deep into the building, daylighting controls are only effective on fixtures within about 12 feet of the perimeter windows. The different types of daylighting controls include on/off, step dimming, and continuous-dimming. Controls are also available that combine daylighting and occupancy sensors. They are available as light switches and ceiling-mounted devices.

Step-dimming and continuous-dimming controls require dimming ballasts, so the initial cost for the lighting system is higher than with on/off daylighting controls. Step-dimming ballasts vary in the number of steps they offer and their energy savings potential. For example, some products only offer two light levels (e.g. 50% and 100%), while others offer up to five light levels, ranging from 10% to 100%. Two-step ballasts are also available for HID lights, which are often used in industrial or warehouse applications. Continuously dimming ballasts allow the lights to respond to the changing natural light levels without making discreet steps. Continuously dimming ballasts are available for fluorescent lamps, HID lamps, compact fluorescent lamps, and incandescent lamps.

Detailed calculations can optimize the daylighting design for minimum energy consumption for heating, cooling and lighting by comparing different glazing types, sizes, and configurations. Several computer simulation programs are available for these calculations, including ENERGY-10. Professional daylighting or energy consultants can assist in detailed designs and calculations.

**SOLAR THERMAL SYSTEMS**

**Solar Domestic Water Heating**

Domestic hot water systems are often the least expensive and easiest solar application. When designing a residence, two simple features can allow for easy and less expensive installation: south facing roof on which to flush mount the collectors and a slightly larger mechanical room to allow for the additional solar equipment. The optimum roof slope is that equal to the latitude of the location (e.g. 400 in Denver), but lower angles are also adequate for solar hot water collection. In many cases building owners would prefer to have the collectors flush mounted on the roof, than to have them tilted at the optimal angle.

Rule of Thumb: In the Rocky Mountain Region, 60-70 ft² of flat plate solar collector can provide
50-75% of the hot water needs for a typical residence.

Freeze protection is an important feature for solar hot water systems in cold climates. The most common types of systems installed in Colorado use antifreeze in the collectors. A second strategy uses water (a better heat transport fluid) in the collectors but drains the collectors when the system shuts off. Some pumped systems utilize a small photovoltaic panel to power a DC pump. This eliminates the controller and enhances efficiency since the fluid flow rates are consistent with available sun.

**Active Solar Space Heating**

Solar hot water can be effectively used to heat a residence or small commercial buildings via radiant floor heating or a fan coil unit. These systems use low temperature water (900F to 1200F), which is optimal for collector efficiency.

For commercial buildings, the Solarwall product offers a cost-effective alternative for ventilation air preheating. In this system, “transpired solar collectors” warm the outside air as it flows through tiny holes in a dark-colored, south-facing, unglazed sheet-metal solar collector. The solar collector is mounted several inches from the building’s outer wall. Air that is drawn in the holes in the collectors is warmed and rises in this space to where it is drawn into the building’s air duct system. Additional heating required to bring the preheated air to the desired interior temperature is supplied by the building heating system. During the cooling months, the intake air bypasses the collector to prevent the air from being warmed. These systems reduce annual heating cost and require virtually no maintenance. Good applications for the solar wall are those that require significant ventilation air such as manufacturing plants, chemical storage buildings, laboratory facilities, animal-care facilities, and school gymnasiums.

**PHOTOVOLTAICS**

Photovoltaic (PV) systems convert sunlight to electricity through the use of specially designed silicon cells. The cells are assembled together into modules and the modules are connected together to form an array. An inverter is used to convert the DC electrical current output of the array to AC current that can be used to power standard electrical equipment. For off-grid or grid backup applications, the photovoltaic array is hooked up to battery storage. However, in many locations in Colorado the array can be connected to the electrical grid (a grid-tied system). The building uses the solar electricity when needed and sends excess energy to the grid for a credit on the electric bill.

Battery storage systems can be cost effective in locations that are not connected to the existing power grid because of the high cost of power-line extension. Battery systems are also used to ensure an uninterruptible power supply (UPS) on commercial and residential buildings. Some utility companies in the Rocky Mountain Region have simplified the process for tying residential PV systems to the electrical grid. In these systems the occupant can buy electricity from the grid when the PVs don’t produce enough for the building needs or sell electricity to the utility.
company when the PV power exceeds the building needs.

One of the most exciting PV applications for architects is “building-integrated photovoltaics (BIPVs). The integration of PVs into the architectural design is accomplished through the use of products such as roof shingles, exterior cladding, or skylights that have photovoltaics laminated to the exterior surface (known as thin-film technology). Using these products, some of the cost of the PVs is offset by the displacement of the traditional building material. Many large BIPV projects have been installed in Europe. There are some BIPV projects in the USA including the Rocky Mountain Region.

Costs of photovoltaic systems have dropped significantly over the last 20 years. Future incremental cost reductions will be accomplished through manufacturing innovations and higher production of panels and associated equipment. Some utility companies and governmental agencies offer rebates or buy-downs that reduce the cost as much as 25%. In some situations, the marketing benefits and the savings over time (lifecycle cost analysis) provide justification for the high initial cost.

Rule of Thumb: In the Rocky Mountain region, a 1 kilowatt system (electric demand of small home) costs $6-$7/watt or $6,000-$7,000 installed.

**WIND ENERGY SYSTEMS**

As with photovoltaic systems, wind turbines can be connected to batteries for off-grid applications or they can be connected to the electricity grid. Grid-tied systems are typically large wind turbines that are owned or contracted by the utility company.

Careful consideration should be taken to site selection due to zoning restrictions that may affect the use or application of wind turbines in certain residential or commercial communities. It is simplest for buildings in more urban setting to utilize wind through utility grid-tied programs if available. Fort Collins Light and Power Company, Colorado Springs Utility Company, Xcel Energy and the Holy Cross Electric Association are a few of the Colorado Utility Companies that offer a wind power option for customers.

The recommended average wind velocity to produce power reasonably is eight to fourteen miles per hour or greater. The state of Colorado is located in wind regions varying from five to thirteen mph average (non-mountains) to thirteen to fifteen mph average (mountains) Consequently, wind velocities in the non-mountain areas of the state of Colorado are marginal for the application of wind turbine technology. However, it is important to understand that wind is often a function of microclimate. While the average numbers do not look ideal for wind, a specific site might be very windy due to topography.

Rule of Thumb: A 5 to 10 kW wind generator would be appropriate for a residence consuming 500 to 2000 KWH per month.
SUMMARY

- Passive solar strategies for heating and cooling should be a cornerstone of every building design.
- For residential applications, windows with U-Factors less than 0.4 Btu/h·ft²·F, solar heat gain coefficients greater than 0.5 are the most energy efficient.
- For commercial application, windows with U Factors less than 0.7 Btu/ht·ft²·F, solar heat gain coefficients less than 0.4 and visible transmittances greater than 0.5 are recommended.
- Daylighting design should be considered for all commercial buildings to reduce lighting and cooling energy use.
- Solar hot water systems are proven effective for providing domestic hot water.
- Large solar hot water systems are applicable for buildings with high water usage, like prisons and recreation centers. Why not hotels??
- Solar hot water systems can be successfully used to heat homes or small offices that utilize a radiant floor or a fan-coil forced-air system.
- Transpired solar collectors offer a cost-effective option for solar preheat of ventilation air.
- Photovoltaic systems can be grid-connected, eliminating the need for batteries.
- Building-integrated photovoltaic products allow designers to specify PVs that are integral to building materials (such as a roof or skylight).
- In some areas of the Rocky Mountain Region, an electricity customer can pay a small fee to utilize the wind power from grid-connected wind farms.

Introduction

Division 15 includes heating, cooling, ventilation, refrigeration, and plumbing. The selection of mechanical systems has a major impact on consumption of three of the most critical resources we use: water, air, and fuel. Mechanical systems also impact pollution, both local and remote (a power plant, for example). Movement toward sustainable design is occurring in mechanical systems due to increasing public awareness, high profile organizations (see USGBC – LEED below), building code advancement (energy codes, ventilation, indoor air quality, etc.), and government agencies (DOE, EPA) and regulations (CFCs, Federal Energy Policy Act of 1992, etc.). However, economics continue to drive many mechanical design decisions, not necessarily environmental factors.

The USGBC LEED rating system for sustainable design has become a strong force in the
building construction industry. The primary focus of LEED with respect to mechanical systems has been energy consumption. Little information seems to be available on other sustainability aspects such as material selection and there are often few, if any, alternative materials available. We fully expect this to change in the near future, and encourage sending such information to the SDRG (Sustainable Design Resource Guide) update committee for addition to this guide.

**INTEGRATED DESIGN**

The most important paradigm shift that is necessary (at least for most parts of the market) for successful sustainable design is the use of an integrated design process. As much of the community and design team as possible should be involved in the planning and design process, as well as through construction, commissioning, and acceptance. Another paradigm shift that is necessary is the inclusion of the building purpose, function, and success in the overall process. This means including the impact of the indoor environment and comfort on the productivity and health of the occupants. A building that is built for the lowest cost, but results in lower occupant productivity, or high employee turnover, or tarnishes the reputation of the design team, has not met these goals.

The full integration of daylighting is an excellent example of the need for integrated design involving all team players. A design utilizing daylighting can and should result in dramatically reduced mechanical loads. If, however, the daylighting does not work (perhaps because of control inadequacies or insufficient zoning) and as a result more lights are left on or worse, added later, then the mechanical system will be deemed “undersized” likely resulting in numerous adverse impacts and costs. It is therefore important that the entire design team shares in the responsibility and the risk and assure themselves that the daylighting design will work, including full integration with other building systems. The eventual occupants need to understand how to use the system, and also have sufficient input to assure that the systems is tailored to how they will use the building.

Another important example is the selection of building characteristics, such as building material R-values and window shade coefficients. Similar to the example with daylighting, if the building R-values are reduced or window shade coefficients are increased from the values given to the engineer during initial design phases (most often due to budget reasons), then the mechanical and electrical engineers are often stuck with trying to re-design a larger system into a space that is no longer large enough and for no additional fee. An even worse scenario would be that the engineers are never told that these changes have been made. It is therefore critical to the integrated design process that these decisions be made and finalized early in the design with the entire team responsible and at risk, so that the entire team, including the owner, must find a solution to any subsequent budget issues and share in the cost implications of the solution. One solution becomes better cost estimating earlier in the process, perhaps putting the cost estimators on the team and at risk as well.

**MECHANICAL SYSTEM DESIGN**
Residential, commercial, and institutional buildings should be designed to conserve resources and reduce pollution. The mechanical systems in a building should keep the building's occupants comfortable; provide ventilation air, hot and cold water. The mechanical systems can be powered by common sources such as natural gas or electric energy. The building may be designed to use renewable energy sources, like solar, geothermal, biomass, wind, etc. (See Division 13 for renewable energy systems that should receive first consideration). Good building design will reduce the heating and cooling requirements.

Specify the mechanical systems and components as close to the building energy loads as possible. Keep in mind design safety factors and future expansions to the building. Building energy simulation programs are useful in estimating the energy load of a building, but beware of manufacturer claims, and view with caution even the best computer calculations by a non-biased expert. Use life cycle costing methods to compare first cost against future energy cost and operational and maintenance expenses.

Because there are so many possible issues to consider in Division 15, the reader is encouraged to find other sources for in-depth analysis of each issue. Some of the sources are listed at the end of this section; others are listed with the other divisions. Pitfalls include new product “bugs”, overlooked considerations, or less-than-hoped-for energy savings due to the interaction between energy conservation measures. For example, a reduction in lighting watts can decrease cooling loads and increase heating loads.

**ENERGY SOURCE SELECTION**

The two most common fossil fuels used by buildings in this region are coal-fired electricity and natural gas. The environmental considerations for using these fuels are shown in Table 15-1 (See Graphic). The trade offs between the fuels depends on these factors as well as an electric utility's generating capacity mix (coal, hydroelectric, nuclear, oil, and gas), the efficiency of the equipment using the fuel, the availability of the fuel, and cost for the fuel. Environmental Building News is an excellent resource for information on the environmental impacts of energy sources.

The most common sources of fuel for the production of electricity are biomass material such as oil, natural gas and coal. Biomass is technically a renewable resource, but the time required to replace it is measured in millions of years making it effectively, a finite resource. For this reason the use of this limited supply of a natural resource deserves careful thought and consideration, and certainly burning it as a fuel should be minimized as much as possible and eventually the practice ended.

These fuels are typically the first choice after renewable energy sources, because they are considered to have the least environmental problems. However, due to limited supply these fuels should be conserved. Direct consumption of one of these fossil fuels at a building for heating and/or cooling is apt to be the environmental choice versus electricity.
ELECTRICITY

Power plants generate electricity by burning coal, natural gas, or fuel oil. Other electric plants are hydroelectric or nuclear powered. Wind energy and solar electric (photovoltaics) are gaining popularity as supplementary power in utility power grids. Due to power plant inefficiencies, electricity is not the most appropriate heating energy source. Instead, electricity is a high quality power source that is best suited to functions such as lighting and running motors.

Geothermal (Renewable)

True geothermal energy sources (underground steam or hot water) are uncommon in Colorado. Ground-coupled heat pumps with buried piping that use the earth as a heat source (heating mode) and heat sink (cooling mode) are at times called “geothermal” energy sources. They are discussed below.

Wind Energy (Renewable, See Division 13)

Hydroelectric (Renewable, See Division 16)

Biofuel (Renewable)

“Biomass” fuels made entirely or partially from organic materials (excluding fossil fuels such as oil, natural gas, gasoline, coal, etc.) are becoming available. Examples are soy-diesel, methane from organic waste, ethanol, and methanol. They have environmental and national security benefits, but many are still in the demonstration stage. Few manufacturers of energy consuming heating or cooling equipment presently offer systems that operate on biofuels.

Solar Thermal & Solar Electric Systems, Daylighting: (Renewable, See Division 13)

Wood Burning (Renewable)

In rural areas with adequate wood resources and weather patterns that do not cause frequent temperature inversions, wood may be an acceptable heating fuel. Verify local community ordinances such as in Vail or Denver where wood burning is restricted to maintain air quality. Make sure the wood is produced on sustainability-managed wood lots. Use only low emissions wood stoves, pellet stoves, or masonry heaters. Never use pre-EPA-certified wood stoves.3 Open fireplaces should be discouraged because of their very low operating efficiency. Provide a controllable outside air supply to any wood-burning appliance or fireplace.
ENERGY SYSTEMS AND EQUIPMENT

General

Mechanical systems suitable for residential and commercial buildings are sufficiently different that they will be dealt with in this section separately where appropriate. Energy use in the residential sector is primarily for heating and is dependent on the envelope of walls, roof, windows, and doors. Commercial buildings are primarily cooling load dominated due to concentrations of people, lights, and heat releasing equipment. In small strip malls and commercial facilities the heating and cooling loads can be equal. Insulation for piping and ductwork, as well as sealing ductwork against leaks, is essential to reduce unwanted heat losses or heat gains. ASHRAE publishes recommendations for types, thicknesses, etc. Non-toxic mastic or sealant should be used for ductwork sealing. Although fiberglass is the common material, there are concerns regarding its high embodied energy and the negative health effects of airborne fibers. Non-fiberglass materials may be available in some areas. (Refer to Division 7)

Residential Heating, Cooling and Hot Water

Heating and cooling requirements can be minimized through passive or active solar design (Refer to Division 13), tight construction, and superior insulation and window systems (Refer to Division 7). External window shading devices and overhangs on east, south, and west orientations can reduce cooling requirements. But, in the winter, the same external shading devices can reduce desired solar gains. A whole-house (attic) fan or ceiling paddle fans can provide cooling at moderate first cost and low energy-environmental cost. Ceiling fans can also enhance heating comfort by returning hot air from high ceiling areas down to occupied levels. Natural ventilation can be used by the careful location of operable windows with respect to prevailing summer winds. Automatic controls, including programmable thermostats, are available to assure that spaces are heated or cooled only during occupied periods.

When cooling requirements are beyond natural ventilation and fans, evaporative cooling or "swamp coolers" should be considered. Such systems require far less energy than conventional refrigerated type cooling and required no CFCs or HCFCs, but freeze-proofing is required, and maintenance/health issues are significant. (See Evaporative Cooling section.) If typical electric refrigerated cooling is used, equipment that uses more benign HCFCs is now available. Gas cooling can be used in place of electric cooling for small residential applications. (See Gas Cooling section.)

In-floor radiant heating systems are becoming more popular. In a radiant system, the heating pipes are embedded within a concrete slab or under a wood floor and hot water is circulated to heat a space. The hot water can be generated with a solar system (Refer to Division 13). By heating people and objects rather than space/air, these heating systems can have lower energy requirements than forced-air systems and greater comfort claims are common. The "cold floor" is eliminated. For “spot-heating,” ceiling mounted electric panels or hot water panels are available.

For service water heating, solar and instantaneous water heaters offer alternatives to standard
water heaters (Refer to Division 13). Instantaneous water heaters (electric or gas) heat the water on demand so there is no need for a storage tank and stand-by heat losses from the tank or flue. However, capacity must be checked against any need for simultaneous use of fixtures (for example, dishwasher and shower).

Specify sealed-combustion appliances for fuel-burning appliances (e.g. natural gas appliances) to avoid indoor air quality problems. These appliances are vented to the outdoors and draw air from the outdoors. The appliances are completely decoupled from building pressure variations caused by exhaust fans, wind, etc. (Refer to Division 11).

There is a significant range in efficiency available in space heating and water heating equipment. The best efficiencies by type of appliance for gas, oil, and electric appliances are listed in the “Consumer’s Directory of Certified Efficiency Ratings” available from ETL testing laboratories, (607) 753-6711. Using high efficiency equipment minimizes use of nonrenewable resources, reduces carbon dioxide emissions and acid rain, and reduces the amount of money spent on energy. A high efficiency appliance may have a higher first cost, but life cycle costs typically show them to be the better long-term choice. Refer to Consumer Guide to Home Energy Savings, the most recent edition.

VENTILATION/INDOOR AIR QUALITY/HEAT RECOVERY (RESIDENTIAL AND SMALL COMMERCIAL)

Indoor air quality (IAQ) is receiving considerable attention in both residential and commercial-institutional buildings. In standard residential construction, codes recognize that operable windows and infiltration satisfy residential ventilation needs. With tighter construction, in homes that have less than 0.35 air changes per hour (ACH), mechanical ventilation is necessary. A conventional built house is around 0.5 to 0.8 ACH. Have a blower door test done if concerned about the air change rate. Heat Recovery Ventilators to supply fresh air for homes are becoming more widely available but can be costly. Integrated systems that provide heating (and possibly ventilation) in connection with the domestic hot water system offer an efficient alternative to a gas furnace.

HEATING, COOLING AND VENTILATING (COMMERCIAL)

Commercial projects typically have substantial internal heat gain due to lights, people, and equipment, so heat loss through the building envelope is a less important consideration than in residential projects. In addition to the cooling requirements to offset the internal heat gains (and external solar heat gains), Commercial buildings use substantial amounts of energy for heating, cooling, and moving large volumes of ventilation air.

Minimum ventilation rates are required for health and comfort. Ventilation air quantities should
be no lower than those indicated in the American Society of Heating, Refrigeration, and Air-Conditioning Engineers' standard: ASHRAE 62-2001, VENTILATION FOR ACCEPTABLE INDOOR AIR QUALITY.5

**Energy Recovery Ventilators (ERVs)**

Indoor air quality can be affected negatively if building air intakes are too close to exhausts, standing vehicles or other odor-pollution sources. Codes require certain separations, but they may be insufficient. Radon gas can be an indoor air quality problem (Refer to Division 2). Indoor air quality concerns question the traditional use of duct lining (coated fiberglass inside the duct) for sound and thermal insulation. The concerns include fiberglass particles in the air stream as well as difficult cleaning of the lining. Substitutes include external duct wrap and double-wall duct with insulation between the duct walls.

**Heat Recovery**

Heat recovery systems should be considered to balance energy use and indoor air quality. Various devices are available to transfer heat from a warm exhaust air stream to preheat incoming cold ventilation air. Many manufacturers are now making packaged heat recovery units, sometimes called Energy Recovery Ventilators (ERVs). The cost effectiveness of heat recovery systems depends on initial cost, potential energy savings, and ease of integration into the HVAC system.

**High Efficiency Boilers**

There are many kinds of boilers and many factors involved in the actual efficiency in the use of fuel to produce usable heat. An instantaneous efficiency is only one factor. There are also standby losses to consider – those losses that occur even when no heat is being utilized. Then there are part-load efficiencies that are normally, but not necessarily, lower than full load efficiencies. The metric of AFUE (Annual Fuel Utilization Efficiency) is intended to take standby losses and part-load efficiencies into account for typical operating conditions. An energy analysis should consider these factors. A careful analysis is sometimes warranted to compare the project application to the conditions assumed for the rated AFUE.

It is beyond the scope of this document to discuss each type of boiler, so a few considerations will be mentioned. There are condensing and non-condensing boilers. Condensing boilers do not always condense, and their efficiency may be dramatically reduced under some non-condensing conditions. Non-condensing boilers can condense (in the flue) under some conditions (which are to be avoided). There are gravity burners, power burners, power vents, induced draft fan systems, draft hoods, engineered combustion air systems, and more. The gravity systems are the least efficient (annually) due to the standby losses, which in some cases can increase energy consumption by 40%. Low mass boilers (typical of copper finned-tube boilers) may have only a few percentage points higher efficiency, however the annual efficiency can be much higher, often almost equal to the instantaneous efficiency.
Combustion Efficiency

COMBUSTION EFFICIENCY is a bit of a misnomer, as it has little to do with the efficiency of the actual combustion process. Combustion efficiency really measures the percentage of total energy that is absorbed into the heating medium or escapes from the boiler jacket. The only input energy not accounted for by combustion efficiency is that energy which leaves via the vent as flue loss. Combustion efficiency can be readily calculated by using the following equation:

\[
\text{Combustion Efficiency} = 100\% - \text{Flue Loss Percentage (Equation 1)} *
\]

By inserting Battelle’s critical flue loss of 16.4\% into Equation 1*, we find that if a boiler has a combustion efficiency of 83.6\% or less, the flue gases will have enough energy to properly vent without condensing. Conversely, if a boiler has a combustion efficiency greater than 83.6\%, there is significant risk of condensing in the vent and therefore corrosion resistant vent material should be used.

Some manufacturers do not list combustion efficiency on their specification sheets. Instead, they list THERMAL EFFICIENCY. Thermal efficiency measures the percentage of energy created at the burner that is absorbed into the heating medium. Thermal efficiency is defined as the ratio of output to input at full fire and steady state conditions. Equation 2 shows the relationship between thermal and combustion efficiency:

\[
\text{Combustion Efficiency} = \text{Thermal Efficiency} + \text{Jacket Loss Percentage (Equation 2)}
\]

The National Fuel Gas Code (NFGC) divides gas appliances into four categories based on vent operating pressure and the likelihood of condensation occurring in the vent. The four categories, which are used to determine which type of vent is appropriate for a given appliance, are listed in Table 1. Most manufacturers specifically identify the appropriate appliance category in their operating and installation instructions. A word of caution: do not solely rely on the manufacturer’s installation instructions.

Table 1.

<table>
<thead>
<tr>
<th>Appliance Categories Per NFGC and ANSI Z21.13</th>
<th>Appliance Vent Condensing Category Pressure or Non-Condensing</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Non-Positive Non-Condensing</td>
</tr>
<tr>
<td>II</td>
<td>Non-Positive Condensing</td>
</tr>
<tr>
<td>II</td>
<td>Positive Non-Condensing</td>
</tr>
<tr>
<td>IV</td>
<td>Positive Condensing</td>
</tr>
</tbody>
</table>
Gas Cooling

Gas-driven cooling equipment has become a fast growth industry due to the comparatively high cost of electricity and some utility company incentives. The gas-driven chillers can replace the electric-driven chillers. Gas cooling has fewer environmental problems because of the lower emissions. In addition to the clean burning nature of natural gas, CFC's are avoided with “absorption” type cooling units, gas-fired or steam fired (steam typically generated by gas-fired boiler). CFCs are one of the primary causes of ozone depletion. It is possible to convert a chiller with CFCs to HCFCs or HCFCs that have less environmental problems. First cost for gas cooling is typically two to three times more than electric cooling. The efficiency of absorption systems is lower than electric, but energy cost savings and utility rebates/incentives are attractive.

Evaporative Cooling

Evaporative cooling is very effective in Colorado’s dry climate. It eliminates the CFCs used in mechanical cooling equipment. Compared to electric or gas driven cooling equipment, evaporative cooling requires a fraction of the energy costs. Both direct and indirect evaporative systems are available. Freeze protection can be manual or automatic. The water sump must be kept free of organic growth (by water bleed-off, etc.) that can enter the supply air and expose occupants to health risks.

Heat Pumps

Heat pumps provide heating and cooling (and, in some cases, domestic water heating) using electric energy. They are more efficient than other all-electric heating and cooling options. Air source heat pumps extract heat from, and reject heat to, the air. Since their heating capability below 40o F is poor, back-up heat is required in cold climates. This substantially lowers their energy cost savings. Water-source heat pumps extract heat from, and reject heat to, a water source. The water source is usually a pumped, closed system with the temperature maintained at approximately 60-90 degrees for maximum heat pump efficiency.

Ground source heat pumps can be the most efficient of the heat pump options. They use the stable ground temperature as a heat source/sink. Typical ground F for heating and loop fluid selection temperatures in this region are about 32 F for cooling. Note that in the sizing of ground-coupled heat pump systems in this climate, the heating requirement will generally govern partly due to the greater temperature difference between indoor loop temperature and ground temperature in the heating mode/season as compared to the cooling mode/season.

Radiant Heating & Cooling

Radiant heating and cooling has often been found to be a very efficient system. The panels or surfaces with tubing and a circulating fluid can be used for heating only, cooling only, or both.
Those systems can be two-pipe (only heating or cooling in the building or zone at any given time), or four-pipe (allowing heating and cooling simultaneously in different zones on the same system). Some of the common system types are described below:

**In-Floor Radiant Heating**

In a typical radiant-floor heating systems, warm water circulates through tubing (generally plastic) either embedded within a concrete slab, within a sub-floor system, or attached to the underside of a (wood) floor. The floor radiates heat to the heated space above. Radiant systems can be used in-floor or above grade in or attached to walls or ceilings, with water, air, or electricity.

In-floor radiant heating systems are best adapted to homes with conventional or higher levels of insulation and standard or better windows, as there are limitations to the rate of heating that can be provided from a radiant system. Radiant systems are generally more expensive than typical furnace systems. There may be advantages for occupants with acute chemical sensitivities or allergies in which they are concerned about dust distributed through forced-air systems.

The benefits of in-floor radiant heating include the following:

1. **Comfort:** Radiant systems can provide a high level of comfort. The large radiant surface means that most of the heat will be delivered by radiation, heating occupants directly, rather than by convection. Warmer surfaces in a living space result in a higher mean radiant temperature, (a measure of surface temperatures in a space that influences the rate of radiant heat loss from occupants). With higher mean radiant temperatures, comfort is achieved at lower air temperatures. This results in energy savings as well as less respiratory and skin irritation from low indoor humidity in dry winter climates. One common expectation of radiant-floor heat, a warm floor, won’t occur for most of the heating season. The reason is that for a concrete slab to feel warm, it needs to be about 80°F. Normally during the hating season, floor temperatures below 80°F are sufficient to heat the space. Also because the floor is insulated underneath, it will be more comfortable to walk on than most slab floors even when the heat is off, but the benefit will be from the insulation, not the radiant heat.

2. **Air quality:** Compared with a conventional forced-air distribution system, there may be less dust circulated around the house. There is no air system filter, however, so this will vary depending on factors such as house-cleaning practices or whether a re-circulating air-cleaner ("purifier") is used.

3. **Energy savings:** There is potential for saving energy with radiant-floor heating by lower thermostat settings, lower-temperature boiler (or other heat source) temperature settings. There may be reduced infiltration depending on the system to which radiant is being compared. There may also be increased energy consumption if slab or floor edge insulation and detailing, or below slab insulation, is insufficient.

4. **Potential for use with solar energy, high-efficiency condensing boilers, and water-to-water ground-source heat pump systems:** Radiant-floor heating systems typically use water temperatures of 85–140°F, compared with baseboard hydronic systems that typically operate at 130–180°F. At these operating temperatures, condensing boilers can be used which have higher efficiencies the lower their operating temperatures. These low temperatures also provide an
opportunity to utilize solar hot water or water-to-water ground-source heat pump systems. Caution is advised in that some boilers may have operational difficulties from operation as low water temperatures. Consultation with the manufacturer is recommended.

5. Acoustics: Radiant hydronic floor heating is normally very quiet. The sound from a fan or airflow through ducts in spaces of a typical furnace system is avoided, as well as the potential sound of expansion and contraction found in some baseboard radiation and piping systems.

For hydronic radiant-floor systems, most systems today use cross-linked polyethylene (PEX) tubing. Manufacturers can provide calculations, such as the length and size of tubing required, and packaged system solutions for radiant floor heating systems. Computer sizing programs can also be purchased.

Under-slab insulation:
Manufacturers recommendation insulation of at least R5 to over R20 (typically 1” to 4” of XPS or high density expanded polystyrene insulation) beneath a radiant slab, depending on the climate and construction details.

A high performance green home in a cold climate with high levels of insulation (at least R-25 walls and R-40 ceiling/roof), extremely low infiltration rates, high-performance glazing (unit U-factors below 0.3), and at least some passive solar gain would result in very low heating costs. This makes radiant heating more difficult to justify economically for high performance buildings since it the payback period would be long due to low heating costs and the much higher initial cost for radiant systems. There is also a potential conflict if radiant floor heating is used with passive solar design, which may result in reducing the contribution from the passive system.

To avoid overheating, many radiant-floor designers install control systems that also adjust the circulating water temperature based on outside air temperature and the temperature of the slab. Also, since it can take several hours to heat up a concrete slab, standard set-back thermostats are not recommended. If setback is used, the time to warm the slab must be considered in the design. Separate outside air temperature sensors, slab temperature sensors, and room thermostats can be used in a sophisticated controller to adjust the slab temperature for maximum comfort.

Gas-fired Radiant Tubes & Panels

Radiant heating systems of the gas-fired tube or panel type have been used for decades in commercial and industrial buildings where high air change rates are common, such a garages, fire stations, airplane hangers, and warehouses. These systems are capable of saving significant amounts of energy as they directly heat surfaces, including occupants, rather than heating the air that then transfers the heat to occupants and surfaces.

Electric Radiant Panels

Electric radiant heating panels have found extensive use in applications such as outdoor restaurant dining areas, outdoor shopping malls, and similar public spaces. These systems are capable of saving significant amounts of energy as they directly heat surfaces, including
occupants, rather than attempting to heat the outdoor air.

**Radiant Ceiling Panels - Heating**

Radiant ceiling panels have been used in buildings with large open spaces and tall ceilings; and where ceiling plenum heights are minimal such as in retrofit applications. The panels can be manufactured, such as metal panels with attached copper (typically) tubing, or they can be made of tubing embedded in a ceiling material such as plaster. Each has a different application. The embedded tubing will have a lower surface temperature for the same circulating fluid temperature due to the thermal resistance of the material in which it is embedded (the encasing material). This results in a lower output capacity. Care must also be taken not to allow too much temperature change that might crack or otherwise damage the encasing material. There may also be a higher risk of inadvertently drilling into a tube when suspending a fixture or making other modifications to the ceiling.

**Radiant Ceiling Panels - Cooling**

Radiant cooling panels can be used in conjunction with the ventilation system so that the dry, cooled outside air is used to regulate the latent load of the space to prevent risk of condensation. The same possibilities of metal panels or ceiling-embedded tubing as described above under Radiant Ceiling Panels – Heating, also apply. Radiant cooling also has output per square foot limitations, thus is best applied to spaces with tight envelopes and low loads. Radiant cooling panels can also be used to offset part of the cooling loads in spaces such as atriums with high solar radiation gains.

Radiant cooling with ceiling panels is used quite commonly in Europe, where humidity levels are generally not very high and where the comfort range of building occupants is believed to be wider than in the United States. A radiant system using copper tubing attached to metal panes in place of ceiling tiles and used for both heating and cooling is well adapted to retrofit office applications with tight ceiling spaces. Chilled and hot water is circulated through ceiling panels to provide radiant cooling and heating, depending on demand, with a make-up air unit to meet minimum ventilation requirements. The ventilation air can be dehumidified if the latent load in the space is high, thus eliminating the potential for condensation on the radiant ceiling panels. Some method of maintaining the space dew point below the panel surface temperature is a must. This type of system in a dry climate such as Denver, Colorado saves energy in two ways: because pumping water requires less energy than moving air, and because the chilled water has to remove only the sensible heat loads, not the latent loads. With the 100% outside-air supply, the total amount of circulated air is reduced by about 80%, compared with conventional recirculating systems.

**Radiant Wall Systems – Heating or Cooling**

Radiant systems can be applied to walls, just as with ceilings or floors. The embedded systems are quite similar. Manufactured panel systems are a little different and generally consist of stand-off panels, either metal or plastic, that are designed for radiant heating. Since they are designed
for heating, radiant cooling data is hard to come by (if at all), however the principles are the same as for radiant ceiling panels.

**Thermal Storage - Cooling**

There are a great many types of thermal storage systems used for cooling. Just to name a few: ice on coil with cooling and distribution system fluid in the coils; ice on coil with only the cooling generation fluid in the coils, and water in the “coil bath”; ice chip making machines; eutectic salts; ice balls; chilled water storage in tanks; and so on. For brevity, only the first system mentioned (ice on coil with cooling and distribution system fluid in the coils) will be used below to illustrate some of the principles.

Electric or gas cooling systems can reduce demand charges or take advantage of lower cost off-peak power when available from the utility by using ice or chilled water storage. The chiller is operated at night to cool the water storage or to make ice. The building’s chilled water requirements during the day are then met from storage, partially (partial shift system) or totally (full shift system). Optimization will normally require monitoring of building kW in real time and automatically reducing the kW used by the mechanical cooling system (generally a chiller) and increasing the amount of cooling provided from storage.

**Thermal Storage - Heating**

Hydronic heating systems using water for thermal storage are an option, or rock storage can be used for air systems. These are generally found in solar heating systems.

Thermal storage in water is generally applied to systems with hydronic distribution and heat release systems, such as radiant heating (baseboard, wall, ceiling, or floor), or air systems with coils in the equipment or ductwork. As a caution with solar hot water used for heating, generally speaking the system efficiency will be lower the higher the required thermal storage temperature. This is primarily due to the efficiency curve of the solar collector, which loses more heat the warmer it becomes. Thus larger radiant surfaces will lead to a higher efficiency system (at higher installation cost).

Thermal storage in a rock medium is normally directly coupled to an air system. As with water storage, the collector efficiency drops as the system temperature rises. In this case, larger air flow rates can be used to accommodate lower supply air temperatures. There are two other cautions worth mentioning here with rock storage (in large part because of the number of systems with problems in these areas). First is consideration of the air pressure drop across a rock bin. Flat rocks can easily have a pressure drop ten times that of rounded rocks. Thus flat rocks must not be used unless there is a very good reason and they are accommodated in the design (and the higher air movement energy is acceptable). The other is rock dust. The rocks must be thoroughly washed and dried, and this must be carefully inspected before the rocks are placed in the bin. Once the system is closed up, there is no practical way to remove the dust, which could provide a medium for growth.
Thermal Storage – Miscellaneous

Electric heating systems using thermal storage have been used (and utilize lower cost off-peak power when available from the utility). Packaged electric-ceramic storage furnaces may be another option.

The University of Alabama has studied a technology called Aquifer Thermal Energy Storage (ATES). Several buildings are currently operating with ATES. Wells are drilled to confined underground aquifers (possible in much of the USA) where water transfer allows storage for cooling. The system may be attractive to utilities as a Demand Side Management technique. (See DSM section.)

Chilled Water Systems - Chillers

There are many factors involved in the efficiency of a chiller. Fortunately the manufacturers provide net efficiency data in common units for easy comparison: kW per ton. Two basic chiller types are in use in commercial projects: air-cooled and water-cooled. As a general rule, the water-cooled chillers are more efficient. Air-cooled chiller maintenance is simpler (no condenser water treatment required) and air-cooled chiller systems are available in smaller sizes. Chillers are available at a number of efficiency ratings, with the more efficient chillers being a little more expensive. An analysis of efficiency vs. cost will help to determine the optimum point for each project.

Both water-cooled and air-cooled chillers use water (as does any electrical powered equipment where the electricity is provided by a traditional power plant). The use of electricity from a traditional power plant involves the use of water in cooling towers primarily for cooling of the engine generators. Typically this is on the order of ½ gallon of water per kwh of electricity, but this varies quite a bit depending on the type of plant and type of fuel. It is possible for a water-cooled chiller to use less water if a low-water use water treatment system (such as ozone or magnetic pulse, or possibly other products presently on the market) is utilized.

Chilled Water Systems – Cooling Towers

Cooling tower selection and sizing can have a large effect on the overall chilled water system efficiency. As a general rule, a larger tower (at least in dry climates) will provide very cost-effective efficiency improvement. This is true when the larger tower can deliver lower condenser water temperature to the chiller in a way that increases the chiller efficiency. Naturally there is a point of diminishing returns that must be found for each project. See below for “fee cooling” from a “water side economizer” when a chiller and a cooling tower are used.

As discussed above under “Chillers”, the water use of cooling towers is heavily dependent on the type of water treatment system used. It can also be addressed through the use of mist eliminators.

The energy use of cooling towers can be addressed through the use of fan speed controls – two speed or variable. Another way to save energy is to monitor the outdoor air temperature and wet
bulb temperature (indicator of moisture content) and adjust the tower water supply temperature based on what is F tower water supply possible. A lot of energy can be expended trying to make 60 when the wet bulb temperature is too high for that to be possible, or when too much energy will be expended in the effort.

**Chilled Water Systems - Distribution**

A large component of the chilled water system energy use is the distribution system – basically pumping power. See below for Variable Pumping.

A significant factor in pumping power is friction rate, normally expressed in ft. of water column per 100 ft. of pipe. Friction losses for fittings are expressed as equivalent ft. of pipe. While velocity is a factor, the friction rate is higher for smaller pipes at the same velocity due to larger pipe surface area per volume of water. Therefore larger pipes (within reason) will reduce pumping energy.

**Piping**

There is little data collected on the environmental impact of various piping materials, however they do have an impact. More research is needed into the various options. Normally the piping material is selected based on the needs of the particular application in terms of corrosion resistance, longevity, conductivity, chemical resistance, expansion characteristics, and others. PEX piping used in radiant heating/cooling systems is a good example. This piping material is selected for these factors in order to achieve an essential end result – avoidance of leaks. Any alternative material will need equivalent or better joining methods that reliably achieve that result. As a point of historical reference, steel and copper piping used to be common in under-floor radiant heating systems, however most have since been abandoned or replaced due to leaks (often the result of corrosion at joints).

**Variable Pumping**

Constant volume (rate) pumping consumes considerable energy even when the system load is light. Therefore variable pumping has the potential to save energy is systems with a variable load. One method of achieving variable pumping is with variable speed pumps, often through the use of variable frequency drives to control the pump although there are other technologies. Another possibility is through the use of multiple pumps in parallel. The pumps themselves are constant speed although their individual pumping rate may actually increase when other, parallel pumps are shut off. The system pumping rate, however, will decrease.

A necessary component in a variable pumping scheme is that the system be able to operate properly at lower system flow rates. In many systems, this means the use of two-way valves is necessary, although some valves may need to be three-way to maintain minimum pump flows or other minimum system flows. There are also minimum flow requirements on some equipment, although manufacturers are working on lowering those minimum flow requirements in some
Variable Air Volume (VAV)

VAV systems are commonly used to minimize energy use by reducing cooling and heating airflows to only the amount needed. This avoids reheat energy associated with constant volume systems and reduces fan motor energy. VAV systems can provide the required ventilation and cooling, but good balancing and controls are needed to maintain the minimum required airflows for good indoor air quality (see above). Reheat may be required with VAV in some rooms to avoid overcooling when minimum ventilation requirements are maintained. Spot reheating requires less energy than maintaining all the ventilation air at the required temperatures.

Air and Water Economizers

An air economizer saves cooling energy by cooling the building with outside air when possible, instead of using mechanically cooled air. A water economizer (normally called a “water-side economizer” or a “hydronic economizer”) saves cooling energy by using a cooling tower (or other evaporative cooling device) rather than a chiller, when the outdoor temperature and moisture content (humidity) allows. Typically a heat exchanger is used to avoid contamination of the chilled water system with water from an open system cooling tower. Note that a water economizer and air economizer are not generally used together. The term “free-cooling” is often used, however that is a misnomer as fan and/or pump energy is expended.

Sophisticated computer-based energy management and control systems (EMCS) utilizing direct digital controls (DDC) are the standard now for automatic control and monitoring of HVAC systems. Major energy cost savings is possible by utilizing strategies such as:

Night-temperature setback/set up, Optimized supply air temperature based on the zone calling for the most cooling, Night fans shut-off, and reset of heating water temperature (as low as possible) based on outside temperature.

Note that it is not essential to use EMCS/DDC systems to accomplish some of these control strategies. Electric and pneumatic controls with time clocks can be used, although in most commercial applications they are considered out-dated.

Service Water Heating

High efficiency gas water heaters are typically a better energy-environmental choice than electric water heaters, except for remote lavatories or sinks with low hot water usage. (See Residential Hot Water section.) Dedicated water heaters are usually a better energy choice than a heat exchanger that uses water heated from a large boiler; summer operation of a large boiler just for service water heating is typically inefficient. Another way to reduce the energy required for domestic water heating is to recover heat from the water used for dishwashers, showers, washing machines, etc. Such “gray water heat recovery” can be done with a simple heat exchanger-tank.
Commissioning

Building Commissioning in Division 15, and often Division 16, is a professional specialty that has been slowly gaining popularity since the mid-late-1980’s. This process seeks to avoid the frequent problem of HVAC (and electrical and other) building systems that do not perform as designed. Energy conservation is of particular concern (and frequently pays for the added cost of commissioning), as is indoor air quality and occupant comfort. An independent commissioning agent is hired to participate during construction (and design, optionally) to monitor and document the work of contractors for substantial compliance to design: equipment capacities and efficiencies, controls, air balance, etc. Commissioning of the building can be expanded to verify proper functioning and integration of all building systems, a process that ASHRAE, along with other professional societies, is now developing. The USGBC LEED process requires basic commissioning as well as offering an additional point for further commissioning.

Demand-Side Management (DSM)

DSM is a popular technique currently used by electric utilities to shift or reduce the demand for power from consumers during daily or seasonal peak loads. This is achieved by shifting the electric load to off-peak periods (typically 10 p.m. to 6 a.m.), or with long term thermal storage systems, to the next winter or summer season. Demand reduction is achieved by using more energy efficient equipment or converting to gas powered equipment. DSM avoids the need to build additional power plants. Typical DSM measures include efficient lighting systems; efficient motors; on-site cogeneration; heat pumps; thermal storage (daily and seasonal); and interruptible load shedding that reduces power consumption by using controls that “shed” loads by priority when a preset maximum demand is approached. Incentives also exist for electric-to-gas conversion for cooling and heating equipment. These measures are discussed in the following paragraph and in Division 16. Xcel and other electric utility companies have DSM programs through which they offer customers cash incentives to reduce electricity demand through the design and installation of energy-efficient systems. (See ESCO section.)

Energy Service Companies (ESCO)

Many companies exist today that provide financial assistance for energy conservation. They will actually pay the entire initial cost of energy conservation and DSM improvements. These firms recover their investment by contracting with the Owner to be repaid over an agreed upon period of time (usually less than 10 years) from the energy cost savings. This is also called Performance Contracting. If the energy cost savings are not realized, the ESCO loses, not the Owner. Contracts have become standardized, so conflicts characteristic of prior years have been reduced. ESCO firms typically work with existing buildings, but some will accept new buildings in design. Some ESCO firms also consider improvements that save water and/or maintenance costs. Architects and Engineers should start early in design with an ESCO (after base design and budget is set) to minimize redesign or delays. ESCO companies can be contacted through the Association of Energy Engineers (AEE)
WATER CONSERVATION

General

Water conservation opportunities beyond Division 15 items are addressed in Division 2 Sitework (xeriscape, rainwater harvesting, gray water irrigation, pervious materials).

Supply Water

To minimize the use of water and energy used to heat water, low flow toilets (1.6 gal/flush or less), showerheads, and faucets should be specified. Waterless urinals are new to the industry. See the product listings at the end of this section for a source of information and products. Consumer Report (February 1995) compares various low-flow showerheads and toilets. In public buildings, faucets with infrared sensors and self-closing faucets should be specified to reduce water use. Gray water from waste water plant effluent or building waste (excluding toilets and kitchen sinks) can be collected as supply water for toilets and landscape irrigation to minimize water use from municipal water treatment plants. Code authorities should be consulted.

Waste Water

Composting toilets can be used to conserve water and reduce chemical treatment of wastewater by municipal (or other) waste treatment plants, while simultaneously providing a fertilizer source.

Commercial and Institutional Domestic and Process Water

Reduce water consumption in commercial projects by specifying low-flow fixtures. Process water consumption should be minimized to both reduce the cost of chemically treating water and to reduce the environmental impact of water disposal. Eliminate all once through cooling. The most common use of process water is cooling another fluid by means of a heat exchanger. In a common system, such as a cooling tower, chemicals are added to prevent corrosion. Considerable attention to water chemistry is required, involving a variety of chemicals to control oxygen levels, alkalinity, scale, dissolved minerals, corrosion and biological growth. Consult a water specialist, not someone who makes living selling chemicals, for the chemical makeup of the process water.

SUMMARY

- Involve as much of the community and the design team as possible in the planning and design process.
- Design the most energy efficient building possible.
- Use renewable technologies as the first consideration.
- Use daylighting to improve productivity, comfort, and satisfaction and to reduce internal cooling loads in commercial buildings.
- Specify the mechanical equipment to match the required energy loads using a modular approach to address future loads.
- Design and install high-efficiency heating and cooling equipment.
- Select boilers for annual efficiency.
- Design and install water-efficient equipment.
- Reclaim, capture wasted heat energy for preheating cold incoming water/air.
- Avoid ozone-depleting chemicals in mechanical equipment (CFCs). Direct or indirect evaporative cooling is an excellent option in the Rocky Mountain Region.

**SOURCES**

Association of Energy Engineers
Rocky Mountain Chapter
Denver, Colorado
[www.rmaee.org](http://www.rmaee.org)

Environmental Building News
Building Green, Inc.
122 Birge St., Suite 30
Brattleboro, Vermont 05301
Phone: (802) 257-7300
Fax: (802) 257-7304
[www.buildinggreen.com](http://www.buildinggreen.com)

State of the World
2004 Worldwatch Institute
1776 Massachusetts Avenue, NW
Washington, DC 20036
Phone: (202) 452-1999
Fax: (202) 296-7365
[www.worldwatch.org](http://www.worldwatch.org)

Environmental Protection Agency
Regional Office - Denver
999 18th Street, Ste. 300
Denver, Colorado 80202
Phone:(303) 312-6312
[www.epa.gov/regionD8](http://www.epa.gov/regionD8)

American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)
Rocky Mountain Chapter
Denver, Colorado 80033
[www.rockymtnashrae.com](http://www.rockymtnashrae.com)

LEED (Leadership in Energy and Environmental Design)
Division 16: Electrical

Introduction

Division 16 includes the generation and distribution of electricity and electrically powered equipment. We discuss renewable energy sources for electricity generation, cogeneration, lighting, controls, motors and transformers. The thoughtful selection of electrical energy sources and equipment results in a positive environmental impact as well as a reduction in electrical use.

Colorado is a “home rule” state, which means codes are adopted on a local level. Check with
your local jurisdiction to determine the applicability of the following codes. ASHRAE/IES 90.1 is an energy guideline for non-residential construction adopted by many jurisdictions as a code. It sets maximum energy levels for lighting (as well as other building systems) in specific use areas. See Division 15 for non-electrical ASHRAE aspects. The International Energy Conservation Code (IECC) is similar to ASHRAE 90.1, with energy regulated on watts per square foot basis. However, IECC governs a broader list of construction types including residential. The IECC also has specific lighting controls requirements.

**ELECTROMAGNETIC FIELDS (EMFs)**

EMFs are radiated magnetic waves originating from electrical conductors and equipment. The waves are created anytime alternating electrical current is flowing. Health concerns have been raised about EMFs. Various U.S. governmental and private studies show ambiguous results and conclusions have only fueled more controversy. There has been a much broader movement in Europe to avoid EMF. Though we are not aware of definite guidance in addressing this issue, prudent avoidance is often suggested.

**RENEWABLE ENERGY SOURCES**

Xcel Energy has hydroelectric power plants that are used primarily as back up for their coal-fired plants. Xcel Energy also has wind power plants and, currently, users can specify that these wind plants provide their energy. Small residential hydroelectric systems that require a minimum of 10 feet vertical fall and 4 to 400 GPM flows are available. They provide DC power only that is then stored in batteries until used by the building.

- **Wind Power** (See Division 13)
- **Photovoltaics** (See Division 13)
- **Daylighting** (See below and Division 13)

**COGENERATION**

Cogeneration is an electricity generator and waste-heat recovery system that produces both electrical and thermal energy from a single fuel source. Usually a natural gas engine is used. The waste heat from the engine or turbine exhaust and engine-cooling water is used to heat or cool a building or provide hot water or process steam.

Cogeneration is typically more economical in larger buildings or building complexes with a relatively constant heating/cooling and electrical load. Buildings should be at least 50,000 square feet, have continuous operation, and balanced and concurrent thermal and electrical needs. Some utility companies offer financial incentives to install cogeneration systems. Natural gas generators can help reduce negative environmental effects by trimming the loads of public utility power plants that burn oil or coal. However, it is also possible that the gas cogeneration facility
is less efficient than the central utility plant under certain circumstances, so careful study is needed.

**LIGHTING**

Lighting design or retrofit affords building operators the easiest way to reduce electrical demand. The use of daylighting, energy-efficient lamps and ballasts, and lighting controls reduces electrical loads, quantity of luminaires, maintenance requirements, and cooling loads. The reduction in cooling loads may also translate into smaller cooling equipment on new installations as long as the lighting load reduction is assured during peak cooling times. Typical electric lighting in offices has been historically designed to over 2.5 W/sq. ft. Through more efficient design and improved luminaire technologies, providing illumination levels appropriate for the location and type of visual tasks, and more efficient luminaires, the lighting power consumption can be reduced to below 1 W/sq. ft. for most applications. Reducing the ambient illumination levels to reduce costs, providing accent lighting to improve user comfort and add interest, careful control of glare, and providing task lighting where it is needed improves the visual quality of a space. See the Illuminating Engineering Society (IES) "Recommended Practices Handbook" for design guidance.

Proper application of efficient lamps is at the heart of lighting energy conservation.

High intensity discharge (HID) lamps include: metal halide (MH), ceramic metal halide (CMH), pulse start metal halide (PSMH), mercury vapor, high-pressure sodium (HPS), and low-pressure sodium (LPS). LPS are the most efficacious (lumens output per watt input). Mercury vapor lamps have the lowest efficacy of the HID lamps due to their blue color. Ceramic metal halide lamps give the best overall color rendition of the HID lamps and are suitable for indoor and outdoor applications. CMH lamps still favors blue/green objects, though the light appears white. PSMH lamps offer similar lighting compared to MH, but with less energy consumption. HPS lamps are more efficacious than MH, favor red/yellow objects, and have greater lamp life. However, HPS typically renders overall color poorly compared to MH or CMH. Recent advances in HPS lamps have led to lamps with light that appears white and is suitable for indoor applications. These new HPS lamps with their warm tones and white light offer an HID alternative to incandescent or halogen sources. LPS lamps are effectively monochromatic; objects under this light appear drab. Electronic ballasts are now mainstream for lower wattage HID sources (less than 250W). Though still expensive, these ballast help to reduce several of the drawbacks to using HID such as power fluctuation sensitivities and large start-up currents.

Compact fluorescent (CF) lamps can replace incandescent lamps in many existing luminaires making retrofit applications practical. In addition to reducing energy consumption by approximately 75 percent, CF lamps last approximately 13 times longer than incandescent lamps. Recent advances in CF lamps have lead to high wattage lamps with light output that nears HID levels. Unlike metal halide lamps, which produce significantly less light near end-of-life, CF lamps loose little of their light output near end-of-life. CF lamps also have instant restriking, unlike HID lamps. As a result of these benefits CF lamps are starting to see more use in exterior
lighting.

Inductive lamps are a newer technology using high frequency, oscillating magnetic fields to excite phosphors in an incandescent shaped lamp. Currently, inductive lamps enjoy an extremely long lamp life, but suffer from poor lumen output compared to lamp size. They are fairly expensive at present and require special heat removal design in within the luminaires. The long life makes them useful for areas where relamping is difficult.

Fluorescent lamps require a ballast to raise voltage levels high enough to force a current down the length of the lamp and to control the amount of current. The current acts to excite phosphors as in the inductive lamp. Less efficient magnetic core and coil ballasts have been used since fluorescent lighting was invented. Core and coil ballasts operate at low frequencies typically 60 HZ. Energy efficient electronic ballasts now available can reduce luminaire power consumption up to 30 percent. Electronic ballasts operate at higher frequencies typically about 20 KHZ, exciting the lamp phosphors at a nearly continuous rate. The higher frequency has the effect of reducing the amount of current needed to get the same lumen output, and also reduces the "flicker" associated with fluorescent lamps. Electronic ballasts also have greater internal efficiencies, reducing electrical losses and producing less heat. Less heat results in reduced cooling demands and longer ballast life. It is important to consider harmonic distortion when selecting ballasts. Typically electronic ballasts have a maximum THD (total harmonic distortion) of less than 10-20 percent. Selection of a 10% maximum will add first cost, but increase the life of ballasts and solid-state electronics, i.e. computer power sources, on nearby circuits.

Recent advances in linear fluorescent technologies have provided lamp/ballast systems that produce traditional light output with about 10% less energy. These systems are called “Super T8” or “Next generation T8”. Currently these lamps are only available in 4ft lengths and operate poorly below 60 degrees Fahrenheit. T5HO (high output) lamps have higher lamp efficacies than the traditional T8. Luminaires that use T5 sources have greater light control and design flexibility due to the small size of the T5 compared to the T8. Most major lamp manufacturers have lamps with reduced mercury content or additives that allow for easier mercury collection at end of life with minimal light output losses. Several organizations including the USGBC and the IESNA are investigating appropriate levels of mercury in lamps for sustainable projects.

LEDs, light emitting diodes, are rapidly becoming the most promising light source of the future. In their current form LEDs still lack the light output required for general ambient lighting for many environments. However, they are being used successfully in decorative and special applications lighting. The low power usage of LEDs combined with the minimal space requirements for these systems makes them attractive for energy- or space-conscience applications. The greatest challenges for LED systems are replicating multi-wavelength lighting and maintaining their long life while increasing their light output. Each LED can only emit light at one wavelength (monochromatic) compared to the multi wavelength emissions of other electric light sources or the sun. This is important because the more wavelengths that are emitted, the greater the ability the source has to render all colors. Colored light is achieved in LEDs by mixing LEDs that emit light at different wavelengths. Placing a phosphor coating on the LED cover creates White LEDs, in effect making it a mini fluorescent lamp. Additionally, current
trends are showing a decrease in LED life as the LEDs get brighter. This is due to a combination of the heat sensitive electronics that LEDs rely on and the additional heat generated by brighter LEDs.

Incandescent sources have the highest energy consumption per light output of all mainstream light sources. However, these sources are still widely used due to their “warm” colored lighting, strong color rendering, and low first cost. Over the life of the luminaire, these sources will use significantly more energy and contribute heat (and additional mechanical load) to the spaces being lit. Incandescent lamps are the least desirable option to use in terms of energy-use. Halogen-incandescent lamps, which produce more light per energy consumed than incandescent, are available. New halogen sources largely known as “halogen IR” for the infrared reflective coatings within the lamp, are also available and can further reduce the energy use while maintaining the same light output as the traditional halogen sources. There are also PAR lamps that use silver instead of aluminum on the reflector to increase light output with the same energy as traditional PAR lamps.

Extra precautions are required when disposing of fluorescent and HID lamps, and old ballasts, as mercury and sodium are used in the lamps. Older ballasts may also contain PCBs (Polychlorinated biphenyls). While the manufacturing and distribution of PCB-containing ballasts was banned in the United States in 1978, they can still be found in old installations. A non-PCB ballast is labeled, “No PCBs”. PCB ballasts, fluorescent lamps and HID lamps must be disposed of in accordance with state and federal guidelines. The U.S. Environmental Protection Agency should be contacted for more information.

**LIGHTING CONTROLS**

The use of occupancy sensors and energy management systems to turn off lamps when not needed greatly reduces electrical demands. Occupancy sensor control systems detect a person within the space, turning on the lights automatically and turning off the lights at a preset time after the person leaves. Studies have shown that if a person leaves the office for longer than two minutes, it is cost effective to turn the lights off. Loss of lamp life due to switching on and off, as well as the sensor costs were considered. Energy management systems can turn off lights at preset times, i.e. one hour after the end of the work day, and one hour before the beginning of the work day. If one wishes to work during off-hours, switches for set interval override of the system can be used. Dimmable fixtures and dimming controls have become very reliable and offer increased savings and improved functionality over the on/off controls. Small-scale dimming systems have become affordable making dimming control possible for most projects. Some systems need little more than 10V ballasts and an occupancy sensor. Occupancy sensor manufacturers are beginning to publish information on spatial views (3-dimensional distances within which the sensor is effective) of various sensors. This information, similar to photometric reports for luminaires, will enable designers to select the appropriate sensor type based on the application and then a specific sensor based on required spatial view of that unit. Years ago lighting controls earned a reputation of being unreliable. Fortunately, newer technologies and the more wide spread use of controls since the late 1980’s and early 1990’s have resolved those issues. Recent research by the Heschong, Mahone Group has confirmed that lighting controls are
significantly more reliable than their old reputation.

**DAYLIGHTING**

Refer to Division 13 for discussion of daylighting.

**ELECTRIC MOTORS AND DRIVES**

Proper selection, application and purchase of motors can reduce power demands substantially. The definition of what constitutes a high efficiency motor is quite confusing. The term “high efficiency” is now standard, or code minimum, in many cases. The upgrade is efficiency is now called “premium efficiency” for many motor types. There are also “induction duty rated” motors that should be used when the motor will be controlled by a variable frequency drive (VFD). Premium efficiency motors save up to 30 percent in electrical costs as well as reduce heating loads. Payback periods for continuous running, premium efficiency versus standard “high” efficiency motors are commonly as short as 1-1/2 years and the economics are continuously changing. Providing a properly sized motor for the application allows the motor to run at nearly 100 percent efficiency levels. Under-loading and overloading motors decreases efficiency. Using variable speed drives for all but the smallest motors (currently over 5HP) allows the motor to slow to meet the demand thus reducing energy consumption.

**TRANSFORMERS**

Transformers are an integral part of almost all electrical installations. Transformers are used to change voltages between higher transmission voltages and lower common usage voltages. They generate heat and frequently create a humming noise. Higher quality transformers produce less heat and have an increased life expectancy. Some transformers can even greatly reduce harmonics in the electrical system, which can harm computers and other electronic devices. Recently, NEMA introduced a new rating, TP-1, for energy efficient transformers. While not inclusive of non-linear loads, the source of harmonics, this new standard is an excellent way to specify higher quality transformers.

See Division 15 (Section 15170) for motor suppliers.

**SUMMARY**

- Incorporate daylighting and energy-efficient lighting systems to improve visual quality, productivity, cooling load, and energy costs.
- Specify premium efficiency motors and variable speed drives with induction-duty rated motors.

**REFERENCES**
2. Ibid.
3. Ibid.
4. Ibid.

ADDITIONAL RESOURCES

The Rocky Mountain Institute 1739 Snowmass Creek Road Snowmass, CO 81654 (970) 927-3851 (970) 927-4510
The Six-Sigma Zone

by

Donald J. Wheeler

The objective of having a process operate with a capability index of 1.5 to 2.0 is a reasonable and economic objective. However, the arguments commonly used to explain the economics of this objective can only be described as statistical snake oil—a blend of tortured computations and incompatible, highly questionable assumptions, having a hypnotic effect and often resulting in a suspension of critical thinking.

Therefore, since the conclusion is right, but the argument used to support the conclusion is complete nonsense, this paper begins with a theoretically sound and rigorous justification for the economics of operating with capabilities in the 1.5 to 2.0 range. Furthermore, this justification allows you to convert capabilities into the one metric that all managers understand: the excess cost of production. This justification is more rigorous, more comprehensible, and more useful than the common arguments involving parts-per-million nonconforming.

Finally, in the interests of exorcism, this paper will conclude with an explanation of the fallacies contained in the common parts-per-million argument.

1. A Model for Excess Costs

The first step in an economic justification for operating with capabilities in excess of 1.5 is to develop a model for excess costs of production. So we begin with the three points with known costs.

If everything were always exactly on-target, and each part was exactly like the next part, then we should find that everything would fit together exactly, and assemblies would work exactly as intended. Measurements would not be needed, inspection would be a thing of the past, shutdowns would be unheard of, efficiencies would all be 100%, and life would be lovely. And there would be no excess costs of production. Thus, the first point on our excess cost curve will be a zero at the target.

Next consider what happens when we scrap an item. We have paid to produce the item, we have consumed resources, capacity, time, and effort, and now we have to throw all of this away, losing not only the item, but also the opportunity to profit from the item. Many of these real costs are easy to determine, and so we usually have a cost that we can attach to scrap. Thus, for all product values beyond the scrap point, there will be a fixed cost of scrap.

And what about rework? When an item is reworked we attempt to salvage the raw materials, resources, and effort contained in that item and to recover the opportunity to profit from that item by adding more effort and resources. Since this will only make sense when it is cheaper to rework the item than to scrap it, the cost of scrap will be an upper bound on the cost of rework. Thus, for all product values beyond the rework point, there will be a fixed cost of rework.

This means that we know the excess costs of production at three points, scrap, on-target, and rework.
The next step in developing a model for excess costs is to connect the three known excess costs. A traditional model has been a step-function where the zero cost was used for all values in between the scrap point and the rework point. As long as the part is inside the specifications the producer does not see any excess costs, but as soon as the part goes outside the specifications the producer has to face the excess costs of scrap or rework.

Unfortunately, the step-function model for excess costs in Figure 2 is incomplete. While it captures the producer’s perspective it completely ignores the consumer’s excess costs—the costs associated with using the conforming product. Think about the actions you have to take in order to use the stuff that your supplier sends to you—the adjustments that have to be made, the scrap and rework that you suffer, the testing, sorting, and complex control strategies that you have to use because all of your incoming material is not exactly on-target. These costs are costs of using conforming product, and they are usually substantial.

If you add to these costs of using conforming product the fact that your supplier’s scrap and rework costs will always get factored into their overhead costs, and that they have to recover their overhead costs from their customers in order to stay in business, then perhaps you can see that the traditional step-function model for excess costs does not begin to tell the whole story. From the perspective of the
customer, excess costs need a continuous model, and the simplest way to connect three points with a single continuous function is to use a quadratic curve.

Hence, a more realistic, macroeconomic model for the excess costs will look like the curve in Figure 3. Beyond the scrap point there is a fixed cost for scrap. Between the scrap point and the target there is a quadratic excess cost curve. Between the target and the rework point there is a second quadratic excess cost curve, and beyond the rework point there is a fixed cost of rework. This simple model provides a reasonable first order approximation to any realistic excess cost function. As the parts deviate from the target there are excess costs. The greater the deviation the greater the excess costs, until finally it is cheaper for the customer to have the part scrapped or reworked than it is to try to use it. This simple model incorporates the cost of scrap, the cost of rework, and the costs of using conforming product that is off-target.

While we usually think of scrap and rework costs as showing up at production, and the costs of using conforming product as showing up when the customer tries to use the product, the simple curve in Figure 3 provides the macroeconomic perspective needed for a realistic understanding of the consequences of our actions.

2. The Effective Cost of Production

The excess cost function defines an excess cost for each possible product value. A probability model, \( f(x) \), can be used to define the frequency with which each possible product value will occur. And so the excess costs can be written as the integral of the product of the excess cost function and the probability model, \( f(x) \).

\[
Excess\ Costs = \int excess\ cost\ function \times \ probability\ model\\
= \int L(x) f(x) \, dx
\]

Since our excess cost function in Figure 3 comes in four parts the expression above separates out into four separate integrals as shown below. There \( C_S \) will represent the cost of scrap and \( C_R \) will be the cost of rework.

![Figure 4: The Excess Cost Function and a Probability Model for Outcomes](image-url)
The Six-Sigma Zone

Excess Costs = $\int_{-\infty}^{\text{LSL}} f(x) \, dx$ 

excess costs due to scrap

$+$ $\int_{\text{LSL}}^{\text{target}} \frac{(x - \text{target})^2}{(\text{LSL} - \text{target})^2} f(x) \, dx$ 

due to deviations below target

$+$ $\int_{\text{target}}^{\text{USL}} \frac{(x - \text{target})^2}{(\text{USL} - \text{target})^2} f(x) \, dx$ 

due to deviations above target

$+$ $\int_{\text{USL}}^{\infty} f(x) \, dx$ 

excess costs due to rework

$= C_S \, \text{ISP} + C_S \, \text{IBT} + C_R \, \text{IAT} + C_R \, \text{IRP}$

$= C_S \left\{ \text{ISP} + \text{IBT} + \frac{C_R}{C_S} \left[ \text{IAT} + \text{IRP} \right] \right\}$

where ISP represents the integral for scrap portion, IBT is the integral below the target, IAT is the integral above the target, and IRP is the integral for the rework portion.

If we assume that the Cost of Scrap is approximately the same as the nominal cost per unit, we end up with:

$\text{Excess Cost} = \text{Nominal Cost per Unit} \times \text{Curly Brackets}$

The Excess Cost defines the amount by which the actual cost will exceed the nominal cost. In fact, if we add the [cost of the units shipped] to the Excess Cost, and divide by the number of units shipped, we get the Actual Cost of Production (ACP):

$\text{Actual Cost of Production} = \frac{\text{nominal cost of units shipped} + \text{excess costs of units produced}}{\text{units shipped}}$

With some rearranging this becomes:

$\text{Actual Cost of Production} = \text{nominal cost per unit} \times \frac{1.0 - \text{proportion scrapped} + \text{Curly Brackets}}{1.0 - \text{proportion scrapped}}$

$= \text{nominal cost per unit} \times \text{Effective Cost of Production}$

The Effective Cost of Production combines the excess costs of fabrication and the excess costs of using conforming product into a simple multiplier which can be used to characterize the excess costs associated with a particular characteristic.

Inspection of the formulas above will show that the Effective Cost of Production will depend upon three things:

1. The relationship between the distribution of process outcomes $f(x)$ and the specifications, which is
fully characterized by the capability indexes, $C_p$ and $C_{pk}$.

2. The ratio of the cost of rework to the cost of scrap, which will generally be known for any specific situation.

3. Whether the process mean is on the rework side or the scrap side of the target value.

Extensive tables of the Effective Cost of Production are available in *The Process Evaluation Handbook* by this author. In the next section we shall use one of these tables to look at the relationship between the Effective Cost of Production and the Capability Indexes in one situation.

3. The Effective Cost of Production Curves

In the case where all nonconforming product is reworked, the excess cost function becomes symmetric and the Effective Cost of Production depends solely upon the capability indexes and the probability model. Using a normal probability model, Figure 5 shows the relation between the Effective Cost of Production and the Capability Index for the case where the process is perfectly centered (so that $C_{pk} = C_p$). Inspection of the way this curve flattens out as we move to the right will suggest that a reasonable definition of economic production would be an Effective Cost of Production of 1.10 or less. When a process is perfectly centered you will enter this zone of economic production only when you have a $C_p$ value greater than 1.05.

![Figure 5: The Effective Cost of Production Curve When $C_{pk} = C_p$](image)

The curve in Figure 5 is the best you can do. Values below this curve are impossible. However, if the process drifts off-target then this curve will no longer apply.

When a process is not perfectly centered the centered capability index $C_{pk}$ will be less than the capability index $C_p$. This will be represented on the graph in Figure 6 by a vertical shift. A $C_{pk}$ that is 0.3 units smaller than $C_p$ will represent a process average 0.9 standard deviations off target. The Effective Cost of Production Curve for this situation is shown in Figure 6.
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Figure 6: The Effective Cost of Production Curve When $C_{pk} = [C_p - 0.3]$

The effect of being 0.9 standard deviations off target is represented by the vertical displacement between the two curves in Figure 6, and the zone of economic production has shifted to those situations where $C_p$ exceeds 1.42. Since no technique for analyzing small amounts of data will be very sensitive to shifts in the process average that amount to 0.9 standard deviations or less, the curves in Figure 6 have serious implications for production. In particular, for you and your supplier to achieve the desirable goal of economic production, your supplier will need to have a capability index in the neighborhood of 1.5 or larger, and he will also need to have a way to monitor his process to keep it operating near the target value.

When the centered capability index $C_{pk}$ is 0.5 units smaller than $C_p$, the process average will be 1.5 standard deviations off center. The Effective Cost of Production Curve for this situation is shown in Figure 7. There we see that the effect of being up to 1.5 standard deviations off target will move the zone of economic production out to $C_p$ values in excess of 1.87.

Figure 7: The Effective Cost of Production Curve When $C_{pk} = [C_p - 0.5]$
Techniques for analyzing small amounts of data will tend to be slow to detect shifts in the process average that amount to less than 1.5 standard deviations. As a result, even when your supplier is monitoring his process to keep it centered, there may be periods of time when you operate in the zone between the top two curves in Figure 7.

Continuing in the manner above, we could look at the curves for processes that are off-center by 3.0, 4.5, and 6.0 standard deviations. These curves are shown in Figure 8. Fortunately it is easy to detect when a process is this far off target. Any reasonable monitoring procedure will quickly let your supplier know when the process average has drifted by this amount. Therefore, while the zone of economic production for these last three curves is completely off the graph, it is of little interest to those who have an effective mechanism for maintaining a process on target.

Of course, if your supplier does not have an effective mechanism for maintaining a process on target, then you will suffer the consequences of an Effective Cost of Production that is much larger than it needs to be.

Shifts of 3.0, 4.5, and 6.0 standard deviations were used in Figure 8 simply because shifts of this size are quite common in virtually all production processes. Moreover, as will be illustrated in the next section, even larger shifts are not uncommon. Thus, the consequences shown in Figure 8 do not exaggerate or overstate the situation in the least.

Now that we have constructed the Effective Cost of Production Curves, what do they tell us about economic production? By taking into account the fact that small shifts (one sigma or less) are hard to detect, and shifts of up to 1.5 sigma will not be detected quickly, we can use Figure 9 to make some statements about the relationship between capability and the Effective Costs of Production we will actually experience in practice. In Figure 9 the vertical arrows represent the range of values for the Effective Cost of Production that are likely to occur when your supplier operates at various capabilities.
The first vertical line in Figure 9 shows that if we have a $C_p$ of 1.05, and if we also have an effective mechanism for keeping the process centered within the specifications, then most of the time we will have an Effective Cost of Production between 1.10 and 1.18, with occasional periods where the Effective Cost of Production may fall between 1.18 and 1.30.

The second vertical line in Figure 9 shows that if we have a $C_p$ of 1.42, and if we also have an effective mechanism for keeping the process centered within the specifications, then most of the time we will have an Effective Cost of Production between 1.05 and 1.10, with occasional periods where the Effective Cost of Production may fall between 1.10 and 1.17.

The third vertical line in Figure 9 shows that if we have a $C_p$ of 1.87, and if we also have an effective mechanism for keeping the process centered within the specifications, then most of the time we will have an Effective Cost of Production between 1.03 and 1.05, with occasional periods where the Effective Cost of Production may fall between 1.05 and 1.10.

Thus, in combination with an effective mechanism for keeping the process on target, a process will operate in or near the economic zone most of the time only when it has a capability index in the neighborhood of 1.5 to 2.0 or larger.

All three lines above show that in the absence of an effective mechanism for detecting shifts in the process average, no capability index value can guarantee that you will operate in the economic zone.

In the simple model used above, where all rework was assumed to be completely effective, the limit on the Effective Cost of Production was 2.0. However, in those situations where some product is scrapped there will be no upper bound on the Effective Cost of Production. The only way to realize the benefits of having a comfortably large capability index is to have an effective mechanism for detecting shifts in the process average. If you do not have a mechanism for detecting process changes there is no capability index value large enough to guarantee that you will always operate in the economic zone.

Thus, while it is desirable to have a capability index of 1.5 to 2.0, there is more to economic operation than achieving a good capability number. You will have to be able to detect changes in the process, and keep the process centered within the specifications, even when the capability is 2.0 or larger!
4. Problems with Defects Per Million

In an attempt to explain the economics of operating with capabilities of 1.5 to 2.0 many have converted such capabilities into parts-per-million nonconforming, sometimes referred to as defects per million (DPM).

The first problem with this approach is that it is incomplete. Unlike the Effective Cost of Production, the parts-per-million nonconforming argument focuses only upon the scrap and rework rate and ignores the excess costs experienced by the customer. But the conversion of capability indexes into the typical six-sigma parts-per-million nonconforming values has other problems besides being incomplete.

The conversion of capabilities into fractions nonconforming is fairly straightforward: you choose some probability model to use, determine the relationship between the model and the specification limits using the capability indexes, and compute the area under the model outside the specifications. The result is your fraction nonconforming. While there is nothing inherently wrong with this conversion, there are situations where the results lack credibility. In particular, when the capability indexes get to be substantially greater than 1.0 the computed values will depend upon the infinitesimal areas under the extreme tails of the probability model. Since the correspondence between our model and our data will always break down in the extreme tails, the conversion of large capability indexes into parts-per-million nonconforming values has always been questionable. Using the infinitesimal areas under the extreme tails of a probability model that you have assumed will characterize your process outcomes is equivalent to raising an assumption to the third or fourth power—the result simply has no credibility. Yet it is exactly these parts-per-million values that are used to obtain the six-sigma DPM values. So the second problem with the six-sigma parts-per-million nonconforming values is that they take a straightforward conversion that is appropriate for parts-per-hundred computations and use it in an inappropriate manner.

Then we have the problem of unpredictable processes. The use of a probability model in the conversion outlined in the previous paragraph implicitly assumes that your underlying process is being operated predictably. So how can the parts-per-million values be adjusted to reflect the demonstrable reality that most processes are not operated predictably?

When a process is operated unpredictably there is not one universe, and one model, but many universes and many potential models. While we might select a generic normal probability model for a predictable process, the problem of selecting a collection of probability models to characterize an unpredictable process quickly becomes intractable. At this point the six-sigma sales pitch engages in a bit of pure rationalization—*it assumes that an unpredictable process will not shift more than 1.5 standard deviations in either direction*. As justification the older documents, those dating from the early 1990s, would usually make a vague allusion to a “research study” supporting this result, however no citation was ever given. More recently even this vague allusion is missing and the assumption is merely taken as an axiom. Given this marvelous, but unfounded, result, it was then possible to adjust the capability indexes to reflect a shift in location of 1.5 standard deviations in one direction and to recompute the incredibly small parts-per-million values. The common practice of listing these recomputed values along with the original, unshifted capability indexes has generated many questions about the origin of the “goofy” DPM numbers found in the six-sigma literature. Thus the third problem with the six-sigma parts-per-million values is their dependence upon the assumption that a 1.5 standard deviation shift in location is a *worst-case* scenario. Not only is this incorrect, it is actually the opposite of the truth.

In the previous section we saw that a 1.5 standard deviation shift was actually a *best case* number. A
process operated with the benefit of an efficient mechanism for monitoring the process location will occasionally drift off center. Small shifts will be hard to detect and slightly larger shifts will only be detected slowly, meaning that the process will operate off-center some of the time. However, in the absence of an efficient mechanism for monitoring the process location, there is no limit on the size of the shifts that can occur. The following charts provide examples of this in practice.

The X Chart in Figure 10 shows a process that is shifting around by ±3.0 sigma, which is twice as much shifting as is assumed to be the “worst case” by the parts per million arguments. While some points fall outside the limits, none fall very far outside those limits. Anyone who has created even a few process behavior charts will have encountered points further outside the limits than those seen in Figure 10.

![Figure 10: X Chart for Process Shifting ±3.0 Sigma](image)

Now consider the X Chart in Figure 11. There we see excursions with points that are up to 9 sigma above the central line and up to 8 sigma below the central line. Excursions like these are quite common in practice.

![Figure 11: X Chart for Process Having Points at +9 Sigma and –8 Sigma](image)

Or consider the X Chart shown in Figure 12, where the process location moves by an amount equal to 25 sigma during this two week period.

In the light of these examples of actual processes, the assumption that an unpredictable process will not shift location more than 1.5 sigma is completely indefensible. It is simply not true. It never was true, nor will it ever be true. Any argument built on the assumption that an unpredictable process is not going to shift by more than ±1.5 sigma is completely undermined by examples such as those above.
Finally, the fourth problem with the six-sigma parts-per-million nonconforming values is the way they are used in reverse to define a “sigma-level” for a process. Based on the parts-per-million numbers obtained with the 1.5 sigma shifts, the actual defect rate observed during a period of production is used in reverse to create what is, in effect, a pseudo capability index for a process. There are so many problems with this tortured computation that it is difficult to know where to start. Perhaps the most fundamental flaw is that this conversion completely ignores the demonstrated fact that some processes are operated predictably while others are not operated predictably. While this conversion claims to deal with this issue based on the 1.5 sigma shift, the mythological nature of the 1.5 sigma shift undermines this claim. Finally, the pseudo capability index obtained from this conversion (usually expressed as a sigma-level for the process) is grossly incorrect for a predictable process and hopelessly optimistic for an unpredictable one.

Thus, there are four problems with the defects per million numbers commonly used in the six-sigma program. They are incomplete, ignoring the excess costs experienced by the customer. They apply a standard conversion in a non-standard way to obtain values that have no credibility. They treat a best-case adjustment as a worst-case bound. And they then are used in reverse to convert an observed level of nonconforming product into a pseudo-capability index for a process without any consideration of process predictability or the lack thereof. As a result of these four problems any use of the DPM values can only be characterized as a triumph of computation over common sense.

A second, flawed parts-per-million number commonly found in the six-sigma literature is defects per million opportunities (DPMO). As soon as DPM was used in reverse to define a “sigma level” for a process it was inevitable that someone would want to do the same with data based on the counts of blemishes or defects. Of course the problem with counts of blemishes or defects is that they have an area of opportunity that is defined as a finite portion of some underlying continuum. This means that defect rates will inevitably have units attached (e.g. 2.5 blemishes per hundred yards in a bolt of cloth). To work the magic conversion in reverse using the DPM numbers so laboriously computed earlier, these units got in the way (parts-per-million values are dimensionless). So the blemish rate of 2.5 blemishes per hundred yards was simply converted into a Defects Per Million Opportunities value by dividing by the “number of opportunities per hundred yards.” If we had “one opportunity per foot” we would get:

\[
\text{DPMO} = \frac{2.5 \text{ blemishes per hundred yards}}{300 \text{ opportunities per hundred yards}} \times \text{one million} = 8333 \text{ DPMO}
\]

However, if we thought we had “one opportunity per inch” we would get:
DPMO = \frac{2.5 \text{ blemishes per hundred yards}}{3600 \text{ opportunities per hundred yards}} \times \text{one million} \approx 694 \text{ DPMO}

Thus, the DPMO is a totally subjective value that depends upon how you subdivide the continuum into potential opportunities. It is nothing more than data divided by an assumption.

Ultimately, these illogical attempts to define the sigma-level for a process are merely trying to do that which is already done by capability indexes or by direct computations of losses. Since we can now convert capability indexes directly into Effective Costs of Production, these faulty parts per million values should be scrapped.

5. Summary

- It can be economical to operate with a capability indexes of 1.5 to 2.0.
- To realize the full benefits of having a capability index of 1.5 or larger you will need to have an effective mechanism for detecting changes in the process average.
- With an effective mechanism for detecting process shifts you can expect to operate with an Effective Cost of Production of 1.10 or less only when your capability index is 1.5 or greater.
- Without a mechanism for detecting process changes there is no capability index value that is large enough to guarantee that you will operate in the economic zone.

With regard to the defects per million numbers commonly used in the six-sigma program:

- They are incomplete, being based only on the costs of scrap and rework and ignoring the costs of using conforming product.
- They apply a standard conversion in a non-standard way to obtain values that have no basis in reality and no mathematical credibility.
- They treat the amount of drift you will occasionally experience in the best-case scenario as the worst that can happen in the absence of a mechanism for detecting process changes.
- They are used in reverse to convert an observed level of nonconforming product into a pseudo-capability index for a process without any consideration of process predictability or the lack thereof.
- DPMO values are merely data divided by an assumption, and are therefore totally subjective.
- Thus, the best that can be said is that these numbers represent a triumph of computation over common sense.
Trauma center

From Wikipedia, the free encyclopedia

The tone or style of this article or section may not be appropriate for Wikipedia. Specific concerns may be found on the talk page. See Wikipedia's guide to writing better articles for suggestions.

For the Atlus video games, see Trauma Center: Under the Knife (Nintendo DS), Trauma Center: Second Opinion (Wii), or Trauma Center: New Blood (Wii).

A trauma center is a hospital equipped to perform as a casualty receiving station for the emergency medical services by providing the best possible medical care for traumatic injuries 24 hours a day, 365 days per year. Trauma centers were established as the medical establishment realized that such injuries often require immediate and complex surgery to save the patient.

In order to qualify as a trauma center, a hospital must have a number of facilities including, a high-quality intensive care ward, and an operating room staffed around the clock. A trauma service is led by a team of trauma surgeons, including specialists such as neurosurgeons and orthopedic surgeons. A trauma center may have a helipad for receiving patients by MEDEVAC.

The operation of a trauma center is extremely expensive. Some areas are under-served by trauma centers because of this expense (for example, Harborview Medical Center in Seattle serves the states of Washington, Idaho, Montana, and Alaska). In Florida, Orlando Regional Medical Center, built to serve five counties, serves more than twenty. Still, in many cases, persons injured in remote areas and brought to a trauma center by helicopter can receive faster and better care than a person injured in a city and taken to a normal hospital by ground ambulance.

In the United States, trauma centers are ranked, from limited care facilities up to comprehensive service in Level I centers. Some centers specialize in adult or pediatric care.

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History

The concept of a trauma center was developed at the University of Maryland, Baltimore in the 1960s and 1970s by heart surgeon and shock researcher R Adams Cowley, who founded what became the Shock Trauma Center in Baltimore, Maryland in 1961[1] (http://www.umm.edu/shocktrauma/history.html) [2] (http://www.umm.edu/shocktrauma/history.html). Cook County Hospital in Chicago, Illinois claims to be the first trauma center (opened in 1966) in the United States.[3]
units, and regular surgical floor beds. Intensive care at Shock Trauma is a multidisciplinary endeavor; the facility boasts dedicated beds for victims of multisystem and neurosurgical trauma.

Education

Shock Trauma trains physicians and medical personnel from locations overseas and throughout the United States. The facility hosts emergency medicine residents from the Johns Hopkins University and medical schools in Canada. Resident physicians from the department of emergency medicine at the University of Maryland are present on every trauma team. Shock Trauma receives over 7500 admissions per year and provides its residents with intensive training in the evaluation and management of both blunt and penetrating injury.

In May 2007, Dr. Thomas M. Scalea, physician-in-chief for the R Adams Cowley Shock Trauma Center presented a case at the University of Maryland Medical School's annual historical clinicopathological conference in Baltimore on the assassination of President Lincoln and if the world's first center for trauma victims could have improved the outcome had Lincoln's assassination occurred today. 'This could be a recoverable injury, with a reasonable expectation he would survive,' Scalea said, noting that assassin's weapon was relatively impotent compared to the firepower now on the streets today. [1]

Shock Trauma's educational mission extends beyond the training of future physicians. The facility hosts members of the United States Armed Forces in addition to providing education for local emergency medical service providers.

References


External links

- The R Adams Cowley Shock Trauma Center (http://www.shocktrauma.org/)
- University of Maryland Medical Center (http://www.umm.edu/)
- The University of Maryland Residency in Emergency Medicine (http://www.umem.org/)
- Maryland Institute for Emergency Medical Services Systems (http://www.miemss.org/)
- Maryland State Police Aviation Command (http://www.mspaviation.org/)
- University of Maryland Medical System (http://www.umms.org/)
- University of Maryland Medical School's Annual Historical Clinicopathological Conference (http://www.medicalalumni.org/CPC/pages/previous.htm)

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Categories: Hospitals in Maryland | University of Maryland, Baltimore

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John H. Stroger, Jr. Hospital of Cook County

From Wikipedia, the free encyclopedia

(Redirected from Cook County Hospital)

The John H. Stroger, Jr. Hospital of Cook County (formerly Cook County Hospital and also known as the New Cook County Hospital) is a public urban teaching hospital in Chicago that provides primary, specialty and tertiary healthcare services to the five million residents of Cook County. The hospital has a staff of 300 attending physicians along with more than 400 medical residents and fellows. The hospital campus, located at 1901 W. Harrison Street Chicago, Illinois, is a part of the 305 acre (1.2 km²) Illinois Medical District, which is one of the largest concentrations of medical facilities in the world.

Eliseo Loera Jr. was born here on November 16, 1981. The northeast wing is named in his honor.

The hospital’s 1.2 million square feet represent the equivalent of 25 football stadiums. The layout of the facility organizes services in a “main street-style” to accommodate the needs of patients, physicians and staff. The hospital offers dedicated units for obstetrics and pediatrics, intensive care, and burns. It boasts one of the most respected emergency rooms in Chicago and a Level 1 Trauma Center. The Adult ER treats over 110,000 patients annually, while the Pediatrics ER treats 45,000 children and adolescents each year. The Ambulatory Screening Clinic treats approximately 105,000 patients per year. In 2003, The new Stroger Hospital Eye Clinic opened as the (then) most up-to-date eye center in the city of Chicago. All patient rooms in the 464-bed hospital are private or semi-private, with their own bathrooms, televisions, and telephones.

The hospital also serves as the hub for the Cook County Bureau of Health Services for delivery of specialty and sub-specialty care. More than 40% of the hospital’s space is dedicated to an outpatient Specialty Care Center, operated by the Bureau’s Ambulatory & Community Health Network. The Specialty Care Center sees 220,000 or more patient visits every year. Recognized as a leading center, the Stroger Hospital residency training and education program has an academic affiliation with nearby Rush Medical College for both undergraduate and graduate medical education, and RFUMS/The Chicago Medical School for medical rotations.

The Stroger/New Cook County Hospital was completed in December 2002 and is housed in a state-of-the-art facility located adjacent to the old Cook County Hospital building. The old hospital traces its origins to the Board of Commissioners’ establishment of a “Poor House” in 1834 to provide free medical care to indigents. By 1847, the Poor House was unable to meet the demands of the population. At Kinzie and State Streets, the County rented Tippecanoe Hall, which became the original Cook County Hospital.

In 1983, Ron Sable, MD, and Renslow Sherer, MD, founded Chicago’s first HIV/AIDS clinic. Ten years later, the HIV/AIDS clinic was re-named the Sable/Sherer Clinic. This clinic treats one-third of Cook County’s HIV/AIDS patients. Today, services are delivered in a new state of the art facility, the Ruth Rothstein CORE Center.

County General Hospital, a fictional hospital that serves as the setting for the NBC serial medical drama ER, is loosely based on Stroger/New Cook County hospital.

The old Cook County Hospital building was used in the 1993 movie The Fugitive.

Recently, the Cook County Board of Commissioners passed a budget which would eliminate 1,032 jobs in the health bureau. The final budget eliminated 260 doctors and residents in addition to 230 nurses and certified nursing assistants. The County currently has a $502 million dollar budget gap to close.

External links

- Google Map
  (http://maps.google.com/maps?q=1901+W+Harrison+Street,+Chicago,+IL&ll=41.872373,-87.669911&spn=0.020795,0.028213&hl=en)
- John H. Stroger, Jr. Hospital of Cook County (http://www.cchil.org/)

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Categories: Hospital stubs | Chicago stubs | Hospitals in Illinois | Cook County, Illinois

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R Adams Cowley Shock Trauma Center

From Wikipedia, the free encyclopedia

(Redirected from Shock Trauma Center)

R Adams Cowley Shock Trauma Center (also known simply as Shock Trauma or Shocktrauma) is a trauma center in Baltimore, Maryland. It was the first facility in the world to treat shock. Shock Trauma was founded by R Adams Cowley, who is considered the father of trauma medicine.

Contents

- Early years
- Facilities
- Education
- References
- External links

Early years

While serving in the United States Army in France immediately following World War II, Cowley found that many severe injuries could be stabilized if the patient could be transported to a military hospital, where a surgeon was present, within one hour of the initial injury. Dr. Cowley coined the phrase Golden Hour to describe this crucial period of time. Dr. Cowley lobbied the legislature in Maryland to purchase helicopters for the transport of trauma patients. When the Maryland legislature denied his request due to the cost of helicopters, Dr. Cowley was able to convince the State of Maryland to purchase helicopters by agreeing to share them with the Maryland State Police. Today every major trauma center in the United States employs helicopters to transport trauma patients to the hospital.

During the early years of trauma center, R Adams Cowley fought with the medical community to change the policy of "nearest hospital first" which was prevalent at the time. In the early 1970s, first responders would take all patients to the nearest hospital emergency room. The flaw to this system was the nearest hospital was usually not capable of treating severe trauma. In 1975 a young prosecutor named Dutch Ruppersberger was involved in a near fatal automobile accident and his life was saved after being transported directly to Shock Trauma (not the nearest hospital). Mr. Ruppersberger ran for public office in part to advocate the trauma facility. The "nearest hospital first" was eventually abandoned and emergency medical systems across the United States now follow the model first advocated by Shock Trauma.

Facilities

Shock Trauma houses over 100 inpatient beds dedicated to emergency surgery, resuscitation, intensive care, and acute surgical care. The facility boasts a dedicated resuscitation area in excess of 12 beds. The Trauma Resuscitation Unit (TRU) is located on the building's second floor. Helicopters and ambulances bring injured patients directly to the TRU for emergent treatment and stabilization. Specialized trauma teams comprised of trauma surgeons, trauma fellows, surgical residents, emergency medicine residents, students, nurses, and technicians stand ready to receive victims 24 hours a day, 365 days per year. The helipad at Shock Trauma can accommodate several medevac helicopters at a time and has direct elevator access to the resuscitation area several stories below.

Adjacent to the TRU is a vast array of equipment and facilities that are immediately available to the patient in extremis. Shock Trauma has six dedicated operating suites in addition to two multislice CT scanners, an angiography suite, and digital plain film capability. The inpatient wards of the Shock Trauma center consist of specialized intensive care units, intermediate care...
Dr. David R Boyd interned at Cook County Hospital from 1963-1964 before being drafted into the United States Army. Upon his release from the Army, Dr. Boyd became the first shock-trauma fellow at the Shock Trauma Center from 1967-1968. Dr. Boyd returned to Cook County Hospital where he went on to serve as resident director of the Cook County Trauma Unit.[4]

Definitions

The four levels refer to the kinds of resources available in a trauma center and the number of patients admitted yearly. These are categories that define national standards for trauma care in hospitals. Developed and recommended by the American College of Surgeons.

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A Level I trauma center has a full range of specialists and equipment available 24-hours a day and admits a minimum required annual volume of severely injured patients. Additionally, a Level I center has a program of research, is a leader in trauma education and injury prevention, and is a referral resource for communities in nearby regions. A Level II trauma center works in collaboration with a Level I center. It provides comprehensive trauma care and supplements the clinical expertise of a Level I institution. It provides 24-hour availability of all essential specialties, personnel and equipment. Minimum volume requirements may depend on local conditions. These institutions are not required to have an ongoing program of research or a surgical residency program. A Level III trauma center does not have the full availability of specialists, but does have resources for the emergency resuscitation, surgery and intensive care of most trauma patients. A Level III center has transfer agreements with Level I and/or Level II trauma centers that provide back-up resources for the care of exceptionally severe injuries. A Level IV trauma center provides the stabilization and treatment of severely injured patients in remote areas where no alternative care is available.</td>
</tr>
<tr>
<td>II</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td></td>
</tr>
</tbody>
</table>

See also

- Emergency department
  - Emergency department in France

External links

- Verified Trauma Center Listing (http://www.facs.org/trauma/verified.html)
People
Certified first responder • Emergency medical technician (EMT) • Paramedic • Emergency physician • BASICS Doctor

Drugs
Atropine • Epinephrine • Amiodarone • Magnesium • Bicarbonate

Other
Golden hour • Emergency department • Emergency medical services • Emergency psychiatry • Triage

Retrieved from "http://en.wikipedia.org/wiki/Trauma_center"

Categories: Wikipedia articles needing style editing | All articles with unsourced statements | Articles with unsourced statements since May 2007 | Hospitals | Emergency medicine

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Wikipedia® is a registered trademark of the Wikimedia Foundation, Inc., a U.S. registered 501(c)(3) tax-deductible nonprofit charity.
Trauma Surgery Goes Virtual to Aid Rural Arizona

A new "teletrauma" system that links the emergency room at Southeast Arizona Medical Center in Douglas, Ariz., and the Level 1 Trauma Center at University Medical Center in Tucson is saving lives.

On Nov. 21, an 18-month-old baby was injured critically in a car accident with three fatalities. The baby was rushed by paramedics to the hospital in Douglas, a small, rural town along the U.S.-Mexico border. The baby was in shock, having lost almost two-thirds of her blood from multiple injuries. She was minutes from death and the nearest trauma center was in Tucson, more than 100 miles away.

In the Douglas emergency room, the doctor called the UMC Level 1 Trauma Center in Tucson for assistance. Activating the new teletrauma system using the Arizona Telemedicine Program network, the trauma surgeon at UMC, Dr. Rifat Latifi, was able to see the baby and examine her injuries. He and UMC's trauma team looked at the patient's vital signs, X-rays and lab test results and "virtually" led the doctor and nurses in Douglas through the emergency medical procedures. The baby was resuscitated and once stabilized, transported to UMC for further treatment. She is expected to recover.

UMC trauma surgeon Rifat Latifi, MD, said, "If we had not had this connection today, that child would have died."

Southern Arizona Teletrauma and Telepresence (SATT) Program
The UA Department of Surgery Section of Trauma and Critical Care, the Arizona Telemedicine Program and University Medical Center, Southern Arizona's only Level 1 Trauma Center, have created the Southern Arizona Teletrauma and Telepresence (SATT) Program to assist trauma patients in rural communities. The UA Department of Surgery Section of Trauma and Critical Care, the Arizona Telemedicine Program and University Medical Center, Southern Arizona's only Level 1 Trauma Center, have created the Southern Arizona Teletrauma and Telepresence (SATT) Program to assist trauma patients in rural communities.

Using advances in technology (ViTel Net(tm)), SATT provides a live consultation link -- including state-of-the-art videoconferencing, telemetry, digital X-rays and ultrasound -- between the trauma team at UMC and rural emergency departments in the southern section of the state.

A person injured in a car accident in a small town is nearly twice as likely to die from his/her injuries as a person in an urban area, explains Dr. Latifi, UA associate professor of clinical surgery and associate director of the UMC trauma program.

Trauma victims have the best chance of survival if the right resources and expertise intervene within the "golden hour," the first hour after injury. However, in rural areas resources and experts are scarce, forcing smaller emergency departments to waste critical time transporting patients to the nearest city with a trauma center.

"Through this program, remote emergency rooms can have access to an
entire team of surgeons and specialists at UMC that can help with diagnoses and critical care," says Dr. Latifi, director of SATT. "This program allows us to virtually transport the trauma surgeon to that hospital."

Dr. Latifi, who also is a director of telesurgery and international affairs for the Arizona Telemedicine Program, the largest telemedicine program in the country, says he can take another doctor through a procedure if necessary, providing state-of-the-art trauma and surgical care by "telepresence."

The program's first remote site is in the Southeast Arizona Medical Center's emergency room in Douglas. Other sites will be added in the emergency rooms along Arizona's southern border, including in Sierra Vista, Benson, Bisbee, Safford and Nogales, he says.

About 60 percent of transports to UMC possibly could be avoided if specialists were available for consultations, saving hundreds of thousands of dollars and many lives, Dr. Latifi says. Another major benefit of SATT is the opportunity to train rural doctors in the latest trauma care and emergency medicine techniques with neither having to leave their own hospitals, he says.

Dr. Latifi plans to expand the program even further south -- across the border into the Sonora, Mexico, municipalities of Nogales, Hermosillo, Caborca, Puerto Penasco and Aqua Prieta. In partnership with the Arizona Department of Health Services, the Arizona-Mexico Tele-trauma and Telepresence (AMTT) Program is an international telemedicine initiative that will ensure the telepresence of trauma surgeons and emergency care specialists in the emergency rooms of medical centers in these towns.

"This will create a unique opportunity to provide large-scale educational trauma and emergency programs, and make available equal standards of medical care for trauma and emergency patients on both sides of the border," Dr. Latifi says.

Dr. Latifi is the author of the book, Telemedicine and Telehealth in Developing Countries: From Inception to Implementation, published in July 2004, and is director of the Telemedicine Project in Kosova.
Census Data and Maps for Cloudcroft, New Mexico

Primary Data Source: [Census 2000](#)  [Census Glossary](#)  *Density* per square mile of land area.

Cloudcroft, New Mexico *(Otero County)*

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<td><a href="#">Census Data</a></td>
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<td>County:</td>
<td><a href="#">Census Data</a></td>
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<td>State:</td>
<td><a href="#">Census Data</a></td>
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<td>Total Area:</td>
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<td>Housing Density:</td>
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Zip Code 88317 (Cloudcroft, New Mexico) cost of living

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Cloudcroft, NM Cost of Living data

Our cost of living indices are based on a US average of 100. An amount below 100 means Cloudcroft (zip 88317), NM is cheaper than the US average. A cost of living index above 100 means Cloudcroft (zip 88317), NM is more expensive.

Overall, Cloudcroft (zip 88317), NM cost of living is 81.94.

Cloudcroft, NM Cost of Living data

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Aerial Photo

Food, Restaurants, and Bars

Yelp Restaurants

Yelp Food

Yahoo Restaurants

Wildlife

Wildlife refuges in New Mexico

Endangered species in New Mexico

New Mexico Audubon Sanctuaries

Audubon Local Chapter by Zip code
Cloudcroft, New Mexico (NM) cost of living resources - Sperling's Best Places

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- Crime
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- Transportation
- Cost of Living
- Data
- Religion
- Voting

Zip Code 88317 (Cloudcroft, New Mexico) cost of living

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- Endangered species in New Mexico
- New Mexico Audubon Sanctuaries
- Audubon Local Chapter by Zip code
## Zip Code 88317 (Cloudcroft, New Mexico) people data

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<thead>
<tr>
<th>Category</th>
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<td>Female Population</td>
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<td>Age 5 to 9</td>
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<td>Age 10 to 14</td>
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<td>Age 75 to 84</td>
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<td>Age 85 and over</td>
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<td>RACE</td>
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<td></td>
<td>Black</td>
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<tr>
<td></td>
<td>Asian</td>
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<tr>
<td></td>
<td>American Indian</td>
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<tr>
<td></td>
<td>Other</td>
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<td></td>
<td>Hispanic</td>
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<td></td>
<td>Non-Hispanic</td>
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<td>FAMILY</td>
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<td>Single, w/children</td>
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<td>Divorced</td>
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<td>Widowed</td>
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<td></td>
<td>Now Married</td>
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<td></td>
<td>Never Married</td>
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### Welcome!

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Zip Code 88317 (Cloudcroft, New Mexico) people

The 2007 Cloudcroft (zip 88317), NM, population is 3,417. There are 1 people per square mile (population density).

Family in Cloudcroft (zip 88317), NM

The median age is 49. The US median is 37.6. 67.76% of people in Cloudcroft (zip 88317), NM, are married. 10.31% are divorced.

The average household size is 2.3 people. 19.93% of people are married, with children. 4.92% have children, but are single.

Race in Cloudcroft (zip 88317), NM

91.72% of people are white, 0.25% are black, 0.41% are asian, 1.13% are native american, and 6.44% claim 'Other'.

17.89% of the people in Cloudcroft (zip 88317), NM, claim hispanic ethnicity (meaning 82.11% are non-hispanic).

Cloudcroft, NM People data

Cloudcroft SperlingViews

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- Yelp Food
- Yahoo Restaurants

Wildlife

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- Endangered species in New Mexico
- New Mexico Audubon Sanctuaries
- Audubon Local chapter by zip code
### Zip Code 88317 (Cloudcroft, New Mexico) economy data

<table>
<thead>
<tr>
<th>Category</th>
<th>Cloudcroft, NM</th>
<th>United States</th>
</tr>
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<tbody>
<tr>
<td>Unemployment Rate</td>
<td>3.70%</td>
<td>4.60%</td>
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<tr>
<td>Recent Job Growth</td>
<td>0.12%</td>
<td>1.40%</td>
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<tr>
<td>Future Job Growth</td>
<td>16.66%</td>
<td>11.90%</td>
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<tr>
<td>Sales Taxes</td>
<td>6.88%</td>
<td>6.00%</td>
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<tr>
<td>Income Taxes</td>
<td>7.10%</td>
<td>5.02%</td>
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<tr>
<td>Income per Cap.</td>
<td>$21,792</td>
<td>$24,020</td>
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<tr>
<td>Household Income</td>
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<td>$44,684</td>
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<td><strong>ESTIMATED HOUSEHOLDS BY HOUSEHOLD INCOME</strong></td>
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<tr>
<td>Income Less Than 15K</td>
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<td>13.64%</td>
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<tr>
<td>Income between 15K and 25K</td>
<td>14.18%</td>
<td>11.21%</td>
</tr>
<tr>
<td>Income between 25K and 35K</td>
<td>15.70%</td>
<td>11.46%</td>
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<td>18.92%</td>
<td>15.84%</td>
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<tr>
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<td>19.28%</td>
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<td>Income between 75K and 100K</td>
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<td>11.53%</td>
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<tr>
<td>Income between 100K and 150K</td>
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<tr>
<td>Income between 150K and 250K</td>
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<tr>
<td>Income between 250K and 500K</td>
<td>0.57%</td>
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<tr>
<td>Income greater than 500K</td>
<td>0.19%</td>
<td>0.61%</td>
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<table>
<thead>
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<tr>
<td>Management, Business, and Financial Operations</td>
<td>13.65%</td>
<td>13.61%</td>
</tr>
<tr>
<td>Professional and Related Occupations</td>
<td>23.48%</td>
<td>20.24%</td>
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<td>Service</td>
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<td>Sales and Office</td>
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<tr>
<td>Farming, Fishing, and Forestry</td>
<td>1.13%</td>
<td>0.74%</td>
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<tr>
<td>Construction, Extraction, and Maintenance</td>
<td>12.59%</td>
<td>9.48%</td>
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<tr>
<td>Production, Transportation, and Material Moving</td>
<td>8.77%</td>
<td>14.44%</td>
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</table>

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The unemployment rate in Cloudcroft (zip 88317), NM, is 3.70%, with job growth of 0.12%. Future job growth over the next ten years is predicted to be 16.66%.

Cloudcroft (zip 88317), NM Taxes
Cloudcroft (zip 88317), NM, sales tax rate is 6.88%. Income tax is 7.10%.

Cloudcroft (zip 88317), NM Income and Salaries
The income per capita is $21,792, which includes all adults and children. The median household income is $38,580.
### Zip Code 88317 (Cloudcroft, New Mexico) education data

<table>
<thead>
<tr>
<th>Category</th>
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<tbody>
<tr>
<td><strong>Education</strong></td>
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<tr>
<td>School Expend.</td>
<td>$5,278</td>
<td>$6,058</td>
</tr>
<tr>
<td>Pupil/Teacher Ratio</td>
<td>15</td>
<td>15.9</td>
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<tr>
<td>Students per Librarian</td>
<td>278</td>
<td>907</td>
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<tr>
<td>Students per Counselor</td>
<td>567</td>
<td>546</td>
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<td>2 yr College Grad.</td>
<td>6.83%</td>
<td>8.22%</td>
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<td>4 yr College Grad.</td>
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<td>Graduate Degree</td>
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<tr>
<td>High School Grad.</td>
<td>89.22%</td>
<td>79.62%</td>
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**View level:** [ ] [ ] [ ] [ ]

**Zip Code:** 88317 (Cloudcroft, New Mexico)
Zip Code 88317 (Cloudcroft, New Mexico) education

Cloudcroft (zip 88317), NM, schools spend $5,278 per student. There are 15 pupils per teacher, 278 students per librarian, and 567 children per counselor in Cloudcroft (zip 88317), NM schools.

Cloudcroft, NM Education data
All Cloudcroft, NM schools

Cloudcroft SperlingViews
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- Yahoo Restaurants

Wildlife
- Wildlife refuges in New Mexico
- Endangered species in New Mexico
- New Mexico Audubon sanctuaries
- Audubon Local Chapter by Zip code
## Zip Code 88317 (Cloudcroft, New Mexico) housing data

<table>
<thead>
<tr>
<th>Category</th>
<th>Cloudcroft, NM</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median Home Age</td>
<td>19</td>
<td>27</td>
</tr>
<tr>
<td>Median Home Cost</td>
<td>$179,500</td>
<td>$217,200</td>
</tr>
<tr>
<td>Home Appreciation</td>
<td>7.30%</td>
<td>9.80%</td>
</tr>
<tr>
<td>Homes Owned</td>
<td>33.34%</td>
<td>64.07%</td>
</tr>
<tr>
<td>Housing Vacant</td>
<td>60.39%</td>
<td>14.48%</td>
</tr>
<tr>
<td>Homes Rented</td>
<td>5.98%</td>
<td>21.45%</td>
</tr>
<tr>
<td>Property Tax Rate</td>
<td>$5.31</td>
<td>$13.28</td>
</tr>
</tbody>
</table>

### OWNER-OCCUPIED HOUSING UNITS BY VALUE

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Cloudcroft, NM</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less Than $20,000</td>
<td>2.83%</td>
<td>3.01%</td>
</tr>
<tr>
<td>$20,000 to $39,999</td>
<td>6.86%</td>
<td>4.37%</td>
</tr>
<tr>
<td>$40,000 to $59,999</td>
<td>7.01%</td>
<td>5.74%</td>
</tr>
<tr>
<td>$60,000 to $79,999</td>
<td>12.38%</td>
<td>7.07%</td>
</tr>
<tr>
<td>$80,000 to $99,999</td>
<td>14.39%</td>
<td>8.41%</td>
</tr>
<tr>
<td>$100,000 to $149,999</td>
<td>26.03%</td>
<td>19.74%</td>
</tr>
<tr>
<td>$150,000 to $199,999</td>
<td>12.38%</td>
<td>14.06%</td>
</tr>
<tr>
<td>$200,000 to $299,999</td>
<td>13.80%</td>
<td>16.59%</td>
</tr>
<tr>
<td>$300,000 to $399,999</td>
<td>3.13%</td>
<td>8.21%</td>
</tr>
<tr>
<td>$400,000 to $499,999</td>
<td>0.67%</td>
<td>4.53%</td>
</tr>
<tr>
<td>$500,000 to $749,999</td>
<td>0.89%</td>
<td>4.75%</td>
</tr>
<tr>
<td>$1,000,000 or more</td>
<td>0.30%</td>
<td>1.86%</td>
</tr>
</tbody>
</table>

### HOUSING UNITS BY YEAR STRUCTURE BUILT

<table>
<thead>
<tr>
<th>Year Range</th>
<th>Cloudcroft, NM</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999 to October 2005</td>
<td>14.61%</td>
<td>10.15%</td>
</tr>
<tr>
<td>1995 to 1998</td>
<td>12.49%</td>
<td>6.69%</td>
</tr>
<tr>
<td>1990 to 1994</td>
<td>12.00%</td>
<td>6.70%</td>
</tr>
<tr>
<td>1980 to 1989</td>
<td>22.34%</td>
<td>14.75%</td>
</tr>
<tr>
<td>1970 to 1979</td>
<td>17.40%</td>
<td>17.11%</td>
</tr>
<tr>
<td>1960 to 1969</td>
<td>8.13%</td>
<td>12.78%</td>
</tr>
<tr>
<td>1950 to 1959</td>
<td>4.77%</td>
<td>11.64%</td>
</tr>
<tr>
<td>1940 to 1949</td>
<td>2.61%</td>
<td>6.64%</td>
</tr>
<tr>
<td>1939 or Earlier</td>
<td>4.65%</td>
<td>13.55%</td>
</tr>
</tbody>
</table>
Cloudcroft, New Mexico (NM) real estate resources - Sperling’s BestPlaces

Zip Code 88317 (Cloudcroft, New Mexico) housing

The median home value in Cloudcroft (zip 88317), NM, is $179,500. Home appreciation is 7.30% over the last year. The median age of Cloudcroft (zip 88317), NM, real estate is 19 years.

Cloudcroft (zip 88317), NM Apartments and Rentals

Renters make up 5.98% of the Cloudcroft (zip 88317), NM, population. 60.39% of houses and apartments in Cloudcroft (zip 88317), NM, are unoccupied (vacancy rate).

Cloudcroft, NM Housing data

Cloudcroft SperlingViews

We're looking for comments about Cloudcroft. Express your opinion.

Cloudcroft Aerial Photos & Maps

- Aerial Photo
- Area Code Map for New Mexico

Food, Restaurants, and Bars

- Yelp Restaurants
- Yelp Food
- Yahoo Restaurants

Wildlife

- Wildlife refuges in New Mexico
- Endangered species in New Mexico
- New Mexico Audubon sanctuaries
- Audubon Local Chapter by Zip code
3 School(s) in Cloudcroft, NM

Get the facts on over 85,000 U.S. schools. From the Dept. of Education and other sources.

<table>
<thead>
<tr>
<th>School Name</th>
<th>Grades</th>
<th>Address</th>
<th>Zip</th>
<th>Phone</th>
<th>County</th>
<th>Type</th>
<th>District Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloudcroft Elementary School</td>
<td>PK-5</td>
<td>800 James Canyon Hwy</td>
<td>88317</td>
<td>(505) 682-2820</td>
<td>Otero</td>
<td>public</td>
<td>Cloudcroft Municipal Schools</td>
</tr>
<tr>
<td>Cloudcroft High School</td>
<td>9-12</td>
<td>10 Swallow Cloudcroft, NM</td>
<td>88317</td>
<td>(505) 682-2524</td>
<td>Otero</td>
<td>public</td>
<td>Cloudcroft Municipal Schools</td>
</tr>
<tr>
<td>Cloudcroft Middle School</td>
<td>6-8</td>
<td>800 James Canyon Hwy</td>
<td>88317</td>
<td>(505) 682-2524</td>
<td>Otero</td>
<td>public</td>
<td>Cloudcroft Municipal Schools</td>
</tr>
</tbody>
</table>
### Total for ZIP Code 88317

<table>
<thead>
<tr>
<th>Number of establishments: 74</th>
<th>First quarter payroll in $1,000: 1,995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of employees: 450</td>
<td>Annual payroll in $1,000: 8,881</td>
</tr>
</tbody>
</table>

### Number of Establishments by Employment-size class

<table>
<thead>
<tr>
<th>Industry Code</th>
<th>Industry Code Description</th>
<th>Total Estabs</th>
<th>1-4</th>
<th>5-9</th>
<th>10-19</th>
<th>20-49</th>
<th>50-99</th>
<th>100-249</th>
<th>250-499</th>
<th>500-999</th>
<th>1000 or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>11------------</td>
<td>Forestry, fishing, hunting, and agriculture</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>22------------</td>
<td>Utilities</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>23------------</td>
<td>Construction</td>
<td>14</td>
<td>10</td>
<td>4</td>
<td>0</td>
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</tr>
<tr>
<td>31------------</td>
<td>Manufacturing</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>44------------</td>
<td>Retail trade</td>
<td>19</td>
<td>13</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>48------------</td>
<td>Transportation &amp; warehousing</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>Detail</td>
<td>Category</td>
<td>na1</td>
<td>na2</td>
<td>na3</td>
<td>na4</td>
<td>na5</td>
<td>na6</td>
<td>na7</td>
<td>na8</td>
<td>na9</td>
<td>Submission Amount</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------------------------</td>
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<td>-----</td>
<td>-----</td>
<td>-----</td>
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<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-------------------</td>
</tr>
<tr>
<td>51-----</td>
<td>Information</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>52-----</td>
<td>Finance &amp; insurance</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>53-----</td>
<td>Real estate &amp; rental &amp; leasing</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>54-----</td>
<td>Professional, scientific &amp; technical servi</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>56-----</td>
<td>Admin, support, waste mgt, remediation serv</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>61-----</td>
<td>Educational services</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>62-----</td>
<td>Health care and social assistance</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>71-----</td>
<td>Arts, entertainment &amp; recreation</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>72-----</td>
<td>Accommodation &amp; food services</td>
<td>10</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>81-----</td>
<td>Other services (except public administration)</td>
<td>7</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Save as text file.

Save as csv file.

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301-457-1296 Fax

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