
The Hospital Built Environment: What Role Might Funders of Health Services Research Play?

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I. Introduction

Several noteworthy reports that have been released in the past few years raise troubling concerns about the quality and safety of health care in the United States. Among these are a RAND study on the quality of health care delivered to adults in the United States,(1) the National Healthcare Quality Report (2) and National Healthcare Disparities Report (3) from the Agency for Healthcare Research and Quality (AHRQ), the Pennsylvania Health Care Cost Containment Council report on hospital-acquired infections, (4) and the Johns Hopkins University study of the impact of quality improvement organizations in five States.(5) Many factors may contribute to the shortfalls in quality, including the way care is delivered and the adequacy of the facility within which that care takes place. This report focuses on the latter, particularly hospitals, their design and how that affects patient outcomes and satisfaction and staff working conditions.

A body of evidence is developing about how attributes of the various environments in which health care is provided mediate health care quality. But no one has yet identified what questions remain to be answered that might help health services researchers, architects, or others decide where more research is needed or how research dollars could be best spent to address the many outstanding issues. This environmental scan is intended to assess what is and is not known about the relationships between hospital design and construction – the built environment – and:

1. Patient outcomes.
2. Patient safety and satisfaction.
3. Hospital staff safety and satisfaction.

This environmental scan is organized to address the following research questions of interest:

1. What is currently known about the relationships between hospital design and construction and factors influencing patient and staff safety, patient outcomes and patient and staff satisfaction levels? This includes identifying important areas and gaps in available research, barriers and facilitators of evidence-based design, best practices in evidence-based design and emerging trends.
2. Who is funding, conducting and disseminating research and applying research findings in the design and construction of hospitals, and who is evaluating the impact of the hospital physical environment on patient outcomes, quality and other areas of interest?
3. What are appropriate potential future roles and areas for involvement by those interested in conducting research or disseminating research findings and best practices about the hospital built environment?

II. Methodology

This environmental scan was conducted between February and May 2005. It consisted of two primary tasks:

1. Conducting a focused literature review to determine what is known and who is conducting research on topics relevant to the hospital built environment.
2. Conducting hour-long, semi-structured interviews with key informants in the field, including hospital executives, architects and designers, academics and researchers involved in the built environment.

A. Literature Review

A focused literature review was conducted to better understand what is known about the built environment and to help identify where there are gaps in the research. The search to obtain relevant PubMed® citations involved using the following MeSH® terms: hospital design and construction; health facility environment; interior design & furnishings; stress, psychological/prevention & control; infection control; patients’ rooms; hand washing/standards; outcome assessment (health care); patient satisfaction; safety management; and job satisfaction.

Text words/phrases used for searching PubMed® included built environment, therapeutic environment, hospital design, patient outcomes, patient safety, staff safety and staff satisfaction. The search was limited to English language citations and citations with abstracts. When reviewing articles for relevance, we excluded those that did not involve hospitals. Our PubMed® search yielded 297 relevant articles.

In addition to PubMed®, we searched other relevant sources, such as The Center for Health Design (CHD), Institute of Medicine and a broad Internet search (using Google®). **Table 1** summarizes the yield of relevant articles (excluding duplicates) on main areas of interest by source.

Table1. Summary of articles by main topic and source

Source	Patient Outcomes	Patient/Staff Safety	Patient/Staff Satisfaction	N	%
PubMed®	145	116	36	297	90%
Center for Health Design	21	10	1	22	7%
Institute of Medicine	1	1	1	2	<1%
Google®	1	4	2	7	2%
Total	168	131	40	328	100%

B. Informant Interviews

Fifteen semi-structured interviews were conducted with a targeted sample of architects, researchers, academics, designers and health care executives (see **Appendix A**). These interviews lasted 45-60 minutes and were conducted by telephone.

The purpose of the interviews was to: (1) identify who is leading the field in funding, conducting, disseminating and applying research findings in the design of hospitals; (2) obtain insights on current areas of research focus, outcomes to date and gaps in available research;

(3) identify challenges to advancing the field; (4) discuss future research directions; and (5) obtain feedback regarding possible roles for funders supporting and disseminating research in this area. Interview feedback was reviewed and consolidated to identify trends and recurring themes.

Stakeholders were fairly responsive to requests to participate in these interviews. **Table 2** provides information on the effectiveness of data collection efforts within each of the six main stakeholder groups.

Table 2. Response results by key informant group

Key informant group	Contacted	Interviewed (%)
Researchers/academics	4	3 (75%)
Architects/designers	9	7 (78%)
Provider (neonatologist)	1	1(100%)
Health care executives	4	1 (25%)
Federal/local government	3	2 (67%)
Foundations/associations	2	1 (50%)
Total	23	15 (65%)

III. Background

Hospital design and construction is vital, yet costly, to our health care system. An estimated \$200 billion will be spent on new hospital construction across the United States in the next 10 years.(6) Among the factors driving the market for hospital design and construction are: 1) competition for patient market share; 2) technology innovation and diffusion; 3) efficiency and cost effectiveness; and 4) regulatory compliance.

Despite the enormous expenditures projected for new hospital construction, there remains considerable potential for quality improvement in our nation’s hospitals. The Institute of Medicine’s widely cited report, *To Err is Human*, concluded that tens of thousands of patients die each year from preventable medical errors while in the hospital.(6) Furthermore, up to two million U.S. hospital patients contract dangerous infections during their hospital stays that complicate treatment and frequently result in adverse patient outcomes.(6)

Hospital physical environments also can create stress for patients, their families and staff. This stress derives from factors such as excessive noise due to hospital alarms, paging systems and equipment; feelings of helplessness and anxiety triggered by poor signage, confusing building and corridor lay-outs and other flawed aspects of hospital design; and lack of privacy as a result of double-occupancy rooms. These may disturb a patient’s rest, more readily enable transmission of infection and prompt the need for more frequent, time-consuming and potentially error-inducing patient transfers.(6)

Due to growing knowledge and awareness of these issues, the hospital built environment increasingly is being influenced by research linking the physical environment to patient outcomes and patient and staff safety and satisfaction. Consistent with the growing movement

to apply clinical evidence-based approaches to improve patient outcomes, hospital administrators and researchers also are placing greater emphasis on “evidence-based design” to support and facilitate clinical advances in the field.(7) This is a process for creating hospital environments that is informed by the best available evidence concerning how the physical environment can affect patient-centered care and staff safety and satisfaction.(8) However, the field is relatively new, evidence supporting this approach is not yet robust in many areas and existing research on evidence-based hospital design is not widely known among policymakers, regulators and other decision-makers and opinion leaders.

These issues are discussed in the remainder of this environmental scan, which includes the following sections:

- What is currently driving the market for hospital design and construction?
- To what extent are hospitals requesting evidence-based designs?
- What is the research base for the hospital built environment?
- What are major challenges in building the field of evidence-based hospital design?
- What are the major gaps in current research and relevant areas of future focus?
- What are appropriate roles for funders of health services research interested in furthering improvements within the built environment?

IV. What is Currently Driving the Market for Hospital Design and Construction?

There appear to be four major factors currently shaping the market for hospital design and construction. First, the hospital market is highly competitive, and health care executives must invest in newer designs to remain desirable to patients, affiliated physicians who influence patient referrals, and payers.(9, 10) Competition among hospitals reportedly is influenced more by the availability and sophistication of services and facilities than by price.(10)

The growth of consumer-driven health care has created a demand for hospitals to focus on patient-centered care with services such as concierge services, bedside Internet access, spaces to involve families in the healing process and private rooms.(11) Hospitals also are increasingly incorporating design elements such as big windows, soft lighting and art and gardens into their designs to enhance patient and staff satisfaction. Changes in hospital design to improve staff satisfaction and safety are among the strategies for slowing high staff turnover rates, especially among nurses.

A second factor driving the market for hospital design is the need to incorporate new technology.(12) Research by the National Institute of Building Sciences shows that hospitals increasingly are housing more sophisticated diagnostic and treatment technology.(13) Hospitals continue to adapt to the flow of new technology into inpatient and outpatient departments, including the cost implications of replacing old technology with new technology and the necessary supporting infrastructure.(11)

Third, hospitals are being redesigned in an effort to be more efficient and cost-effective.(13) Efficient hospitals can diminish inpatient lengths of stay and improve patient flow in outpatient settings, thereby freeing beds for new patients, improving productivity and increasing hospital revenue. Efficiency affects hospital staff in other ways. For instance, an efficient hospital layout promotes clinical staff productivity by maximizing the accessibility of patients and other critical patient care support departments, such as radiology, laboratory and pharmacy.

The fourth factor driving the market for hospital design is that hospitals must be renovated and updated regularly, in order to maintain patient and staff safety consistent with newer hospital guidelines and regulations.(11) New guidelines for the design and construction of hospital and health care facilities are introduced by the Health Guidelines Revision Committee (HGRC) every 5 years, often necessitating changes on the part of hospitals. For instance, the 2001 version of the Guidelines for the Design and Construction of Hospital and Health Care Facilities produced by HGRC had more than 1,500 changes from the previous edition.(14)

V. Are Hospitals Requesting Evidence-based Designs?

Evidence-based design incorporates results of outcomes of real projects and research into design goals. A growing body of evidence indicates that aspects of hospital environment design are yielding measurable benefits to patient safety, outcomes and satisfaction. As a result, a growing number of hospital administrators are requesting evidence-based designs. Researchers and architects anticipate that hospital administrators increasingly will request evidence-based designs to achieve cost savings through risk avoidance and improved patient outcomes and satisfaction.

Hospitals are collaborating through organizations that seek to advance the field through applied research. CHD and Planetree are two such organizations. CHD launched its Pebble Project, to measure the effects of the built environment. The project also aimed to create a ripple effect of sharing documented examples of health care facilities in which design has improved quality of care and financial performance of the institution.

Currently, 27 providers are participating in the Pebble Project and there are two alumni. Pebble Project Partners have access to information and expertise regarding current research in the built environment. Data are collected early in the planning process and after the completion of design efforts, to measure the effects of the built environment. Examples of three Pebble Project Partners and their design efforts are highlighted below.

Pebble Project Partners and their design initiatives*

Bronson Methodist Hospital, Kalamazoo, MI

Bronson Methodist Hospital completed a \$181 million renovation to design a new medical pavilion, outpatient pavilion and an inpatient pavilion. The new facility features an indoor garden, artwork, private rooms and a facility design that is easier to navigate than most traditional hospital designs. The health care and outcome improvements attributed to this renovation to date include: nursing vacancy rates are half the State average; patient transfers are down due to private rooms; patient sleep quality is up; and the hospital's market share has increased 1 percent, leading to 1,000 more admissions in 2001 than in 2000.

Methodist Hospital/Clarian Health Partners, Indianapolis, IN

Methodist Hospital built a 56-bed comprehensive cardiac critical care unit that focused on creating an environment to promote healing and involving families or significant others in the care process. The new facility features curving walls, carpet, indirect lighting and private rooms that were equipped to adapt to varying technology. As a result of the redesign efforts, patient falls are reportedly down 75 percent, attributed to the unit's decentralized design that allows for better observation. In addition, patient room layout, equipment integration and other design features have helped push patient transfers down 90 percent. Unit design also helped reduce the caregiver workload and improve nursing efficiency.

The Barbara Ann Karmanos Cancer Institute, Detroit, MI

The Institute initiated redesign of two inpatient units. Some of the features of the new facility include a partially enclosed unit clerk area, flat screen computers outside every patient room, a sleeper chair in every patient room and artwork in the hallways. CHD reports that, since the unit opened in 1999 and 2000, patient satisfaction rose 18 percent, nurse attrition fell from 23 percent to 8.3 percent, there was a 30 percent reduction in medical errors and there was a 6 percent reduction in patient falls as a result of improvements in lighting and room/hallway layout.

**Information provided by Center for Health Design*

In addition to the work of the Pebble Project Partners, other organizations are demonstrating the benefits of using evidence-based knowledge in designing facilities that improve patient outcomes, safety and satisfaction. Planetree, a membership organization working with hospitals and health care centers to develop and implement patient-centered care in healing environments, has more than 62 hospital affiliates nationwide that have adopted core components of the organization. These components include incorporating architectural and interior design that is conducive to health and healing; empowering patients through information and education; embracing the families, friends and social supports of the patients; using complementary and alternative medicine in the healing process; and creating an atmosphere of serenity. All hospitals are to focus on "putting the patient first" and strive to treat the entire human spirit, not just the disease condition.

VI. What is the Research Base for the Hospital Built Environment?

Hospitals are among the most expensive facilities to build, due to complex infrastructure, expensive diagnostic and treatment technology and prevailing government regulations and safety codes.⁽¹¹⁾ Deciding to invest in hospital design, and deciding what elements to incorporate into a newer facility, requires a clear understanding of the intended outcomes.

Of the 328 articles recovered from PubMed® and other sources (see **Table 3**), 168 pertained primarily to improving patient outcomes, 182 examined patient or staff safety issues and 44 focused on areas of patient or staff satisfaction and efficiency, as described in the following sections. The majority of the studies were observational studies (n=212), including 88 case studies, 66 cohort studies and 58 case series studies. Twenty-five RCTs were identified, most of which studied the relationship between hospital design and patient outcomes. In addition, there were 20 other controlled trials, 2 systematic reviews, 1 practice guideline and 68 non-systematic review articles.

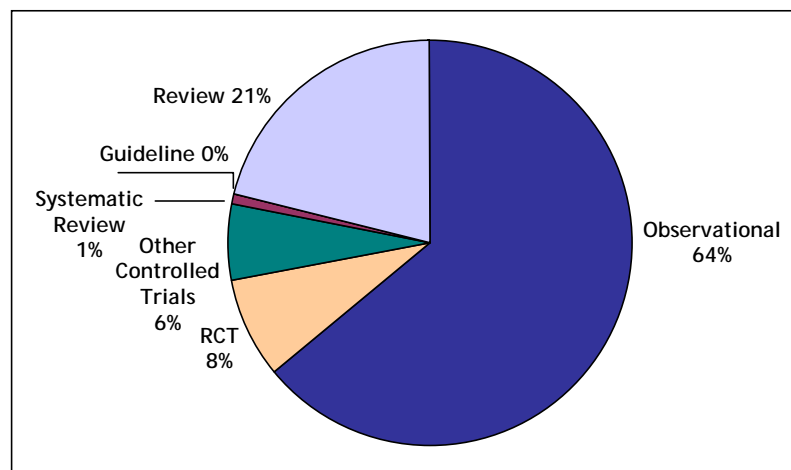
Table 3. Articles by study design and key topic

	Patients and Families				Staff			Totals*
	Safety	Outcomes	Satisfaction	Efficiency	Safety	Satisfaction	Efficiency	
Primary Studies								
<i>Experimental Studies</i>								
RCT	0	19	5	2	0	1	0	25
Other Controlled Trials	5	15	0	0	3	0	0	20
<i>Observational Studies</i>								
Cohort Studies	23	31	9	0	5	1	4	66
Case Series	20	35	1	0	14	1	0	58
Case Studies	51	28	3	0	23	2	0	88
Secondary Studies								
Systematic Reviews	1	1	0	0	1	0	0	2
Guidelines	1	0	0	0	1	0	0	1
Other Reviews	25	39	10	0	9	2	3	68
Total	126	168	28	2	56	7	7	328

*Citations pertaining to more than one key topic are counted for each such topic, but only once for the Totals column.

Figure 1 illustrates what percentage each study design represented out of the total number of articles recovered. Among these, 64 percent of articles were observational studies, 21 percent were review articles, 8 percent were RCTs, 6 percent were other controlled trials, 1 percent were systematic reviews and less than 1 percent were practice guidelines. While observational studies may be more feasible and less costly in many settings, they are less effective than RCTs and other controlled experiments in demonstrating a causal relationship between hospital design and patient outcomes, and patient and staff safety, satisfaction and efficiency.

Figure 1. Study design (n=328)



Among the more comprehensive resources was a review of existing literature published in 2004 by Craig Zimring of Georgia Tech and Roger Ulrich of Texas A&M University. This review was sponsored by CHD and funded by The Robert Wood Johnson Foundation.(8) The review concluded that evidence-based design can improve hospital environments in three main ways:

1. Enhance patient safety by reducing infection risk, injuries from falls and medical errors.
2. Eliminate environmental stressors, such as noise, that negatively affect patient outcomes and staff performance.
3. Reduce stress and promote healing by making hospitals more pleasant, comfortable and supportive for patients and staff alike.(8)

The body of literature assembled here is organized into the main categories of patient outcomes, patient satisfaction, patient efficiency, patient and staff safety, staff efficiency and staff satisfaction. These categories represent current areas of emphasis in research on the built environment, although there is considerable interaction across these main categories. For instance, environmental stressors, such as noise pollution, affect patient outcomes; noise pollution also is disturbing to hospital employees and, therefore, may affect staff efficiency. Environmental factors, such as access to bright light, may improve patient outcomes and reduce length of stay. These effects may be achieved through the higher levels of patient and staff satisfaction that have been shown to improve with access to sunlight.(15) Also, as communication contributes to staff efficiency, it also positively influences patient safety.(16)

A. Patient Outcomes

There were 168 relevant articles pertaining to patient outcomes. Articles pertaining to patient outcomes focused on noise pollution, improving sleep, reducing depression and a smaller group of studies of various factors affecting patient length of stay. We identified 19 RCTs addressing patient outcomes. Most of these were concerned with the influence of noise on patient outcomes.

1. Noise Pollution

Seventy-five articles focused on the impact of noise pollution in the hospital setting. Many studies indicated that hospital noise levels frequently rise above the recommended guidelines set forth by the World Health Organization. Five studies demonstrated that hospital noise levels are often in the range of 45 dB to 68 dB, while the guidelines recommend that noise levels not exceed 35 dB.(17-21) Factors contributing to noise in hospital settings include paging systems, alarms, telephones, staff voices and surfaces, such as walls and ceilings, that are not sufficiently sound absorbing.

Of the 75 articles recovered, 35 examined the impact of noise in the intensive care unit, with particular focus on neonatal and pediatric intensive care units. Several studies found that patients in the pediatric ICU sleep significantly less than is normal for children of the same ages, and their patterns of sleep are seriously disturbed.(22, 23) According to a study conducted at the National Maternity Center in Dublin, Ireland, physiological and psychological changes associated with sleep disturbance decrease the ability of critically ill children to adapt to hospitalization and, thus, hamper recovery. Research indicated that higher noise levels increase heart and respiratory rates in infants and children.(24)

Open bay areas in pediatric wards reportedly are common, despite their being known to generate high traffic volumes and coincident noise.(25) According to research conducted at the Christiana Hospital's Special Care Nursery at the University of Delaware, installing sound-absorbing walls and ceilings and modifying or abolishing open bay areas may help to reduce noise pollution in these settings.(26)

2. Factors Affecting Length of Stay

A small body of research has been conducted on whether environmental factors influence the length of patients' hospital stays. According to an RCT conducted at the Department of Neuropsychiatric Sciences at the University of Milan, bipolar patients assigned to rooms with more sunlight had a mean 3.67-day shorter hospital stay than patients with the same diagnosis in rooms with little or no sunlight.(27) As noted above, studies also have demonstrated negative effects of windowless hospital rooms on patient outcomes and satisfaction.(28) Much of the research suggests that access to sunlight has positive effects on patient outcomes and patient and staff satisfaction. A separate study found that psychiatric and orthopedic patients treated in new or upgraded units rated their experience and treatment significantly higher than those on old wards.(29) In addition, length of stay on new psychiatric units was lower than in old units, although it is not clear whether there were particular aspects of the new unit that were preferred to the old unit or whether patients simply perceived "new" as better than "old."

Several research articles found under the positive distractions section of this report demonstrated significant improvements in patient outcomes resulting from factors such as music, access to sunlight and views of nature. Better outcomes may decrease length of stay.

B. Patient Satisfaction

There were 28 articles focused on patient satisfaction. Articles pertaining to patient satisfaction focused on design aspects mediating family interactions and positive distractions.

1. Family Interactions

Family visits to hospitalized patients provide a form of social support that can help to alleviate the effects of stress that can arise with an illness or associated hospitalization. Several studies addressed whether family involvement or interactions affected patient outcomes during hospital stays. One study concluded that family presence during invasive procedures in the pediatric intensive care unit decreased procedure-related anxiety.(30) Several studies also found that there are barriers to involving families and social support networks during a patient's hospital stay, such as restricted visiting hours or a lack of beds or rooms where parents can stay with hospitalized children.(31, 32) According to the literature, single rooms allow for increased privacy and confidentiality, as well as decreased stress of family, staff and patients.

2. Positive Distractions

Twenty-three articles focused on the effects of positive distractions on patient outcomes. Positive distractions have been defined as "environmental-social conditions marked by a capacity to improve mood and effectively promote restoration from stress."(33) Positive distractions may include views of nature, bright light (natural or artificial) and the arts or entertainment. Several studies evaluated patient and staff satisfaction in hospitals that have incorporated design elements such as access to nature, artwork, music and single-patient rooms. For instance, among the Pebble Project Partners, the Barbara Ann Karmanos Cancer Institute in Detroit, MI, renovated two inpatient nursing units. Following renovation, patient satisfaction rose 18 percent. In a separate study, patients who stayed in hospitals with well-decorated and well-appointed, hotel-like rooms provided more positive evaluations of physicians and nurses and more favorable evaluations of support and ancillary services than patients who stayed in typical hospital rooms.(15)

A considerable research base highlights the benefits of bright light for improving health outcomes, particularly for mental disorders. Several studies found that bright light, especially morning light, is effective in reducing depression among hospitalized patients with bipolar disorder or seasonal affective disorders.(27, 34-37) An RCT conducted by Columbia University found that bright light acts as an antidepressant in patients with seasonal affective disorder.(38) Other studies have demonstrated the negative effects of windowless hospital rooms on patient outcomes and satisfaction.(28) Such studies have linked the lack of windows with high rates of anxiety, depression and delirium.

A growing body of research focuses on nature,(33) music and artwork in the hospital environment. An RCT conducted by the University of Washington compared patient outcomes and satisfaction on the Planetree Model Hospital Unit (which incorporated holistic healing, nature, and artwork) with those experienced at other medical-surgical units in the hospital that lacked these elements.(39) Planetree patients were significantly more satisfied with their hospital stay than patients in the medical-surgical units, and they reported more involvement in their care while hospitalized and higher satisfaction with the education they received. Other studies have focused on the benefits of playing music in the hospital setting. Playing music during stressful times has been demonstrated to have a positive effect on patient comfort and to lower heart rate and anxiety.(16, 40-42) Another RCT investigated the effect of music during bronchoscopy on patient perception of the procedure.(40) Patients who received music during

the procedure reported significantly greater comfort and less coughing than the patients that did not receive music. Post-operative patients with views of nature also have less anxiety and require fewer strong pain medication doses.(43) Several studies also found that patients in single-bed rooms reported higher levels of satisfaction than patients in multi-bed rooms due to many factors, including avoidance of transfers and improved continuity of care.(29, 44-46)

C. Patient Efficiency

There were two relevant articles for patient efficiency, both of which focused on wayfinding in hospital settings. Difficulty navigating hospitals is costly to patients, families and staff. According to a study conducted at Emory University, it was estimated that the annual cost of supplementing its formal wayfinding system exceeded \$200,000. This cost was attributable largely to time spent giving directions by hospital staff whose job assignments did not include that responsibility. Time spent giving directions by these individuals exceeded 4,500 staff hours over the course of a year.

Two articles highlighted the difficulty that elderly and post-operative patients experience in navigating hospital corridors and hallways.(47, 48) Today, hospitals more often are designing systems that include clear and consistent verbal directions, easy-to-understand signs and numbers and an intuitive architectural design. For example, an improved unit design and layout at a new comprehensive cardiac care unit at the Methodist Hospital/Clarian Health Partners reportedly resulted in increased caregiver time with patients and increased nursing efficiency.

D. Patient and Staff Safety

There were 131 articles that focused on patient or staff safety. Articles pertaining to patient and staff safety included reports of research on hospital-acquired infections and hand washing practices, single-bed rooms, air filtration, reducing medication errors and reducing patient falls.

1. Hospital-acquired Infections

More than 100 articles were recovered that addressed the relationship between the hospital environment and hospital-acquired infections. Hospital design strongly affects hospital-acquired infection rates. Several studies focused on hospital employees' risk of contracting infectious diseases from patients due to airborne and surface contamination.(8, 49-53) Factors affecting infection rates include hand washing compliance (which can be influenced by the built environment), multi-bed rooms, air filtration and construction.

Rates of hand washing by health care staff are lower than accepted standards, and hand washing rates are observed to be even lower in units that are understaffed and have a high bed-occupancy rate.(54, 55) Several studies examined whether hand washing is improved by increasing the number of sinks or hand-cleanser dispensers in the wards; however, there was limited evidence for the benefit of increasing the number of sinks in the wards.(56-58) There is also little evidence regarding the advantages of introducing educational programs to improve hand washing practices.(59)

Additional studies demonstrate the benefit of providing single-patient rooms with a conveniently located sink in the room.(60-63) A pre-/post-study of an anesthesiology department in Israel found a nearly 50 percent reduction (3.6 percent to 1.9 percent of patients) in nosocomial infections coinciding with a shift from multi-bed units to single-bed units in 1995.(64) Reasons given for lower nosocomial infection rates include the relative ease of decontaminating single-bed rooms and decreased opportunities for person-to-person spread of infection. Studies also were recovered that demonstrated the advantages of using HEPA air filtration in reducing hospital-acquired infection rates.(65-68) Another study conducted in an Israeli hospital found that keeping acute leukemia patients in a special ward equipped with air filtration through a HEPA system eliminated the rate of pulmonary aspergillosis, as demonstrated by a decrease in the rate of pulmonary aspergillosis from 50 percent in 1993 to 0 percent in 2001.(68)

2. Medication Errors

There is limited evidence regarding the influence of environmental factors on errors in prescribing or dispensing medications. Factors associated with medication errors include frequent interruptions or distractions, inadequate space for performing work and insufficient lighting.(69, 70) One study found that medication errors are closely associated with daylight and darkness hours.(69) There is also a small body of evidence that links patient transfers to medication errors. Investigators call for further studies in these areas.(71)

3. Patient Falls

Patient falls are costly to patients, their families and to hospitals. It is estimated that, by 2020, falls will cost hospitals more than \$30 billion annually.(72) Patient falls also result in longer hospital stays and may prolong recovery times. Most falls that occur in the hospital are due to slippery floors, poor placement of handrails and inappropriate door openings or furniture heights.(73) A growing body of research suggests that most falls occur when patients try to get in and out of bed without the assistance of hospital staff. According to an Australian study, transfers to and from bed were the cause of 42 percent of inpatient falls.(73) After the hospital implemented fall-prevention strategies, such as a hospital design that enabled staff to view all patients simultaneously and more attention to ergonomic design elements, the number of falls decreased to less than 25 percent. According to Zimring and Ulrich's research, Methodist Hospital/Clarian Health Partners decreased the number of patient falls per day from six falls per thousand patients in 1997 to two falls per thousand in 2001 as a result of switching to single-bed rooms and incorporating decentralized nurse stations into the hospital's design.(71)

E. Staff Efficiency

A total of seven articles focused on patient efficiency. Articles on staff efficiency focused on ways in which the hospital environment affects staff communication and productivity.

1. Staff Communication

A small number of articles address how the hospital environment, including single vs. double rooms and hospital layout, affects staff communication. Some of these articles also address how improved staff communication in turn affects patient experience. According to Zimring and Ulrich's research, in double rooms, staff may be reluctant to discuss patient issues or give information in the presence of a roommate, out of respect for the patient's privacy. Compared to those staying in double rooms, patients in single rooms report that staff communicate better with them, based on their willingness to discuss patient information more freely.(8) More open communication between patients and staff appears to improve patient outcomes by alleviating anxiety and increasing the likelihood that patients and families will continue to deliver adequate care once they leave the hospital.(16) Other research suggests that sound-reflecting surfaces and noise sources, such as paging systems and telephones, adversely affect the caregiver's ability to communicate with other staff and with patients.(18)

2. Productivity

Several studies indicate that the type of unit layout influences the amount of time nurses spend walking. For example, one study found that a radial nursing unit reduced the amount of nurse walking time. This translated into more time for patient-care activities and reduced exhaustion.(74) A separate study found that redesigning placement of an outpatient pharmacy to be better aligned with staff work patterns led to improved work flow, reduced waiting times and increased patient satisfaction.(75)

F. Staff Satisfaction

A small number of articles addressed how aspects of the hospital environment affect staff satisfaction, ranging from safety hazards to positive distractions.

1. Staff Turnover

Low nurse retention rates and the growing nursing shortage have direct implications for the quality of care and overall patient satisfaction with the care provided in hospital settings. In the United States, the average annual nurse turnover rate is 20 percent and the average age of nurses is 43 years.(76) Working conditions, including matters of workplace safety and stress, are among the key factors contributing to staff turnover. According to a 2002 Peter D. Hart Research Associates study reported by the Joint Commission on Accreditation of Healthcare Organizations, the top reason, after retirement, why nurses leave patient care is to seek a job that is less stressful and less physically demanding (56 percent).(76) Several studies examined factors that create more stressful or dangerous work environments, including studies that evaluated health care employees' risks of contracting infectious diseases from patients. A separate body of literature deals with staff risk of injury from medical equipment.(49, 50) There is also evidence that staff perceive higher sound levels as stressful and sufficiently high to interfere with their work.(53) All of these factors may influence staff job satisfaction and turnover rates.

There also is strong evidence that design changes that make the environment more comfortable and aesthetically pleasing increase staff satisfaction. Design that encourages positive interactions with staff, such as gardens and lounges, could promote greater job satisfaction.(16)

G. Summary of the Research Base for the Built Environment

While the evidence linking hospital design to patient outcomes, patient and staff safety and patient and staff satisfaction is growing, much of the literature comprises observational studies and review articles that are qualitative and anecdotal. As noted in **Table 3**, of the 328 studies identified, 45 are reports of controlled clinical trials, including 25 RCTs, 19 of which addressed patient outcomes. About 65 percent of the studies identified here are observational studies, most of which addressed patient outcomes and safety and staff safety. There appears to be little empirical evidence on how the built environment affects staff efficiency and satisfaction. Although we identified 68 other review articles, there were only 3 reports of systematic reviews or guidelines. This suggests that much of the diffuse literature in this field has not been well consolidated. Certainly, as noted above, there are many interactive effects among the impacts of the hospital built environment on patients and families and staff. Improved patient satisfaction likely contributes to patient outcomes, improved staff efficiency and safety likely contribute to staff satisfaction which, in turn, likely contributes to lower staff turnover. Better communication and improved satisfaction among staff and patients likely contribute to patient outcomes.

VII. What are the Major Challenges in Building the Field of Evidence-based Hospital Design?

Hospital designers, administrators and researchers face challenges in building the field of evidence-based hospital design and incorporating what is learned toward improving patient safety, other outcomes and satisfaction. Based on our review of the literature and feedback from expert interviews, five major challenges are:

1. Insufficient resources for conducting evaluations of the built environment.
2. Difficulty gaining provider input and feedback on design.
3. Reluctance to learn from design strategies that were ineffective.
4. Obsolete or ineffective laws and regulations regarding hospital design.
5. Capital costs of evidence-based design and renovation projects.

A. Insufficient Resources in Conducting Evaluations of the Built Environment

Currently, there are no major funders for research focused on the built environment. Many of our interviewees highlighted the need for more funding to support empirical studies that can be published in peer reviewed journals. Some studies have been funded by companies that provide services and products for office interiors, such as Herman Miller and Steelcase. However, our interviewees noted the need for research that is funded by unbiased and objective sources.

B. Provider Input

A second obstacle in building the field of hospital design and construction is the challenge in obtaining provider input and feedback. Hospital staff spend much of their working lives, including interacting with patients, in the context of the hospital physical environment. They are likely aware of changes that could be made to create safer, more effective and more efficient hospitals. Certainly, clinicians are among the professionals, including architects, engineers and other professionals, who provide input to standards. However, the level of provider interaction with designers and architects during the hospital design and construction typically is limited and focused on capital planning issues rather than evidence-based design.

C. Information Sharing

There is an apparent reluctance to learn from design innovations that have been ineffective or harmful to patients and staff and insufficient incentives to share best practices in hospital design. According to several experts, architects and designers are hesitant to share “lessons learned” with colleagues, and there is little financial incentive for architects to measure and evaluate the success of their work after the completion of a project. As a result, there are limited opportunities for designers and architects to learn from hospital design innovations, whether successful or not.

D. Laws and Regulations Regarding Hospital Design

Our interviewees indicated that obsolete or ineffective laws and regulations also interfere with building the field of evidence-based hospital design. One expert estimated that 85 percent of the codes are promulgated for safety purposes, which are important for eliminating risks and hazards in the hospital. However, only 15 percent of the regulations pertain to other design factors, such as incorporating sound-absorbing walls and ceilings and adequate HEPA air filtration systems.

Many prevailing codes are ineffective or irrelevant today because of new hospital standards. For instance, most hospitals are required to have a shower that can be rolled into a patient’s room for every 100 beds in the facility. However, all patient rooms are equipped with built-in bathrooms and showers, making this regulation irrelevant. Our interviewees suggested that eliminating antiquated regulations would unencumber certain hospital resources for investment in design innovations for use in hospital design toward improving patient care and the working environment for staff.

Some interviewees noted that most building codes are prescriptive rather than proactive. These tend to restrict the freedom and flexibility of designers and architects to incorporate new elements into the built environment. Hospital architects are subject to accepting the status quo dictated, at least in part, by the regulatory environment and are less inclined to advance the evidence base or implement current knowledge regarding how to design hospitals in ways that contribute to improve patient and staff outcomes. Most architects whom we interviewed observed that building codes, including ones that are no longer relevant and can be wasteful, are in place largely to protect patient and staff safety. However, without sacrificing safety in the current environment, building codes and other regulations can be modified to enable or facilitate more therapeutic hospital environments.

E. Capital Costs of Evidence-based Design

Renovating or building new hospitals is costly, particularly for hospitals that operate in competitive environments and generate low profit margins. Many hospitals have limited access to capital for construction projects and are under pressure to recoup their investment as rapidly as possible.

As noted by some of our interviewees, there is a perception among many providers that there is insufficient evidence to demonstrate that investing in this type of design produces an adequate return on investment, and that implementing what is known about evidence-based design is significantly more expensive than traditional design. To help address the issue of whether there is a financial incentive for investing in evidence-based design, researchers at the Center for Health Design conducted quantitative modeling of a “fable hospital,” based on design elements incorporated into various Pebble Project Partner hospitals. They calculated that an array of therapeutic design innovations, such as single-patient rooms and decentralized nursing stations, added almost \$12 million in cost (about 6 percent) to the hospital reconstruction. However, the researchers also determined that the hospital would recoup these costs in as little as one year through operational savings and increased revenue.⁽⁸⁾ This modeling exercise was shared with other hospital administrators who wanted to learn whether incorporating therapeutic design elements can achieve return on investment in a relatively short period with the potential for longer-term efficiencies.⁽⁷⁷⁾

Despite their efforts, controversy remains regarding whether the high cost of hospital design and construction outweighs the operational savings and increased revenues that may be generated from design innovations. Among our interviewees and in the literature, there is a lack of consensus regarding whether there is sufficient evidence to support the business case for better built environments or whether the evidence is sufficient, but has not been presented or transferred effectively to health care executives, designers and other decision-makers. This apparent lack of consensus suggests that what is known must be shared and applied more effectively, and that more work is needed to validate the business case (or lack of it) in ways that will be persuasive to decision-makers.

VIII. Where are the Gaps in Current Research and Areas for Future Focus?

The literature and the majority of our key informants highlighted considerable gaps and areas for future focus in the field of hospital design and construction, reflecting in part the early stages of development of this field. These gaps are summarized below.

A. Patient Privacy and Confidentiality

Physicians and nurses frequently breach patient confidentiality and privacy by talking in public spaces where they are overheard by other patients and staff.⁽⁷⁸⁾ A separate study conducted at a university-based hospital emergency room showed that 100 percent of physicians and hospital staff breached confidentiality while treating patients.⁽⁷⁹⁾ However, little research has been conducted to date on privacy and confidentiality breaches associated with the physical environment, such as single versus double rooms, waiting rooms and nurses’ stations.

There is also a need for more research that investigates how the quality of communication and information from patients to physicians and nurses is affected by the physical environment.(8) Additional research is needed to determine how wayfinding can be changed to reduce stress on patients and their families.

B. Patient Safety and Environmental Factors

Given the widespread emphasis on patient safety and medication errors in particular, there is insufficient research that examines the relationship between environmental factors (such as lighting, distractions and interruptions) and errors in prescribing or dispensing medications. Consistent with the findings of the review by Zimring and Ulrich, we found few studies examining whether environmental factors affect errors in prescribing or dispensing medications. The findings of limited available research suggest there is a relationship between environmental factors and medication errors.(69, 70)

Additional research is needed on evidence-based fall prevention strategies, as patient falls remain a serious safety problem in hospitals. This includes better quantitative assessments of the effectiveness of alternative strategies, such as establishing decentralized nurses' stations, to increase observation and improve assistance to patients attempting to get out of bed.

Much research demonstrates the importance of frequent hand washing to reduce transmission of infection among health care staff, patients and visitors. However, less research has focused on defining accessible locations for hand cleaning stations on the basis of staff movement patterns and paths, interactions with patients and work processes.

C. Staff Health, Safety and Performance

Another gap in research is the extent to which the built environment affects workplace efficiency and staff health, safety and performance. Currently, there is limited research on environmental interventions for reducing staff stress and fatigue. While there is considerable research on the impact on patients of efforts to reduce noise, few studies examine this issue for hospital staff. There is also a lack of research on how design elements, such as access to nature and sunlight during the day, affect staff stress, turnover and efficiency.

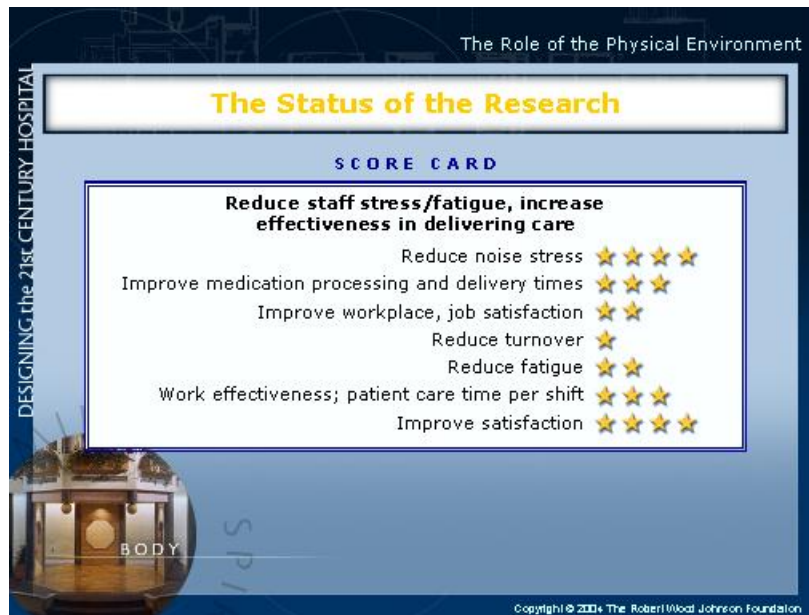
1. Summary of Areas for Future Focus

As discussed above, there are considerable gaps in the evidence base to support beneficial hospital design and construction. When asked to recommend strategies to help close these gaps, several interviewees suggested focusing initially on a limited number of specialized hospital units, such as intensive care units, bronchoscopy units and MRI suites. These settings are well suited for pre- and post-implementation evaluation of outcomes and as learning laboratories and platforms for wider replication to other hospital units.

A useful road map depicting areas for future focus in the hospital built environment is the scorecard system developed by Zimring and presented at a 2004 national conference entitled "Designing the 21st Century Hospital: Serving Patients and Staff," sponsored by The Robert Wood Johnson Foundation.

The scorecard system summarizes the strength of the research in areas of the built environment that affect staff and patients, as derived from the literature review by Zimring and Ulrich.(8) The strength of research in each area is ranked from one star (“little research has been conducted”) to five stars (“a great deal of research has been conducted”). The figure below summarizes the current strength of evidence-based research related to factors that influence the effectiveness, performance and satisfaction levels of hospital staff. These findings suggest that priority areas for future investigation include the influence of the built environment on the overlapping areas of reducing staff turnover and fatigue and improving job satisfaction.

Figure 2. The status of the research scorecard related to reduce staff stress/fatigue



As summarized below and consistent with our findings, Zimring and Ulrich conclude that the strength of research in different areas of improving patient safety and quality of care is mixed. For example, much research has been conducted to better understand linkages between the built environment and nosocomial infection rates. In contrast, little research has focused on the role of evidence-based design in increasing hand washing compliance by staff, an important factor in reducing infection rates, and improving the quality of communication among hospital staff, patients and their families.

Figure 3. The status of the research scorecard related to patient safety and quality of care improvement



IX. What are Appropriate Future Roles for Funders in Advancing Evidence-based Hospital Design and Architecture?

The United States is embarking on one of the largest hospital building booms in history. Anticipated to be a decade-long undertaking, this is being done to replace aging hospitals, incorporate new technologies and medical practices and respond to external market factors, including America's growing and aging population. This new wave of hospitals likely is to remain operational for several decades.

In light of the hospital building boom, many informants suggested that immediate emphasis should be on organizing and disseminating existing research. Interviewees observed that the present may represent a unique opportunity to "unfreeze" existing barriers and create opportunities to raise the visibility of the evidence-based hospital built environment in ways that capture the attention of architects, designers, hospital executives, policymakers, thought leaders and the American public.

Based on what was learned from key informant interviews, there are two main potential roles for funders in developing and transferring knowledge about the hospital built environment. These include:

- Funding empirical research.
- Disseminating evidence-based research output to decision-makers.

A. Funding Empirical Research

A commonly held view among our interviewees is that funders could help frame the value of evidence-based hospital design in ways that capture attention and promote change in the industry by supporting carefully designed research and willing researchers. This includes identifying and seeding research topics, either individually or in clusters, in priority areas. Several informants suggested there is a distinct opportunity for funders to engage in building the business case for evidence-based design and construction by supporting applied research that describes and quantifies return on investment in this area.

Several respondents observed that, in some instances, a critical mass of evidence-based findings may help change the way hospital administrators, regulators and other decision-makers think about these issues and help shape the direction and speed in which this field evolves. Supporting additional research and consolidating and transferring its findings may accelerate the adoption of best practices in evidence-based design and construction by the greater hospital community.

There also was support to fund research to determine when and under what circumstances evidence-based design can make a difference in safety, outcomes and satisfaction sufficient to justify investment. This includes research to discern the extent to which evidence-based designs that affect the physical structure of hospitals in their entirety directly influence outcomes compared to the extent to which they facilitate and channel productive processes. Informants believe that funding research on these topics is a natural evolution of research being funded that focuses on health care interventions and services.

B. Transferring Evidence-based Research Output to Decision-makers

In addition to funding research, virtually all interviewees agreed upon the need to create a meaningful role for researchers to build the field of evidence-based hospital design and construction by increasing stakeholders' understanding and awareness of key issues through the improved sharing of research findings and successful practices and outcomes. Possible dissemination and knowledge transfer roles that were most supported by respondents include:

- **Providing or supporting a repository or national clearinghouse for information regarding evidence-based research on the hospital design and construction.** Most respondents noted that current research studies and best practices are not well organized and lack effective dissemination strategies, largely because there is no central repository of research and practice regarding the hospital built environment. There is also a perceived need for a national clearinghouse on environmental research that does not have a commercial interest or bias.
- **Convening and facilitating events to foster collaboration across stakeholder groups.** Interviewees cited a need to connect health care executives, architects and researchers who have insufficient opportunity to interact to share research and project results. Noting a critical need for effective exchange of what is known about the hospital built environment, respondents supported roles in fostering transdisciplinary networking and helping to extend transfer of this body of knowledge to broader audiences.

Almost all respondents commented on the importance of lifting the profile of the field by maximizing availability of research through convening and facilitating conferences, workshops and other knowledge sharing and networking vehicles. A typical comment was that funders could help "spread the word." Specific dissemination approaches to be considered might include:

- Publishing and disseminating case studies of best practices in new-generation hospitals linked to outcomes, to promote wider uptake of evidence-based results and help build the business case for hospital return on investment
- Sponsoring or co-sponsoring hospital physical environment related conferences and/or workshops that include representatives from major stakeholder groups and include panel discussions and informal networking on specific topics of interest to researchers, hospital administrators, designers and others.

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Appendix A: Key Informants Interviewed

- Leonard Berry, Distinguished Professor, Mays Business School, Texas A&M University
- Rosalyn Cama, President, Cama Inc.; and Chair, Center for Health Design
- Ken Dickerman, Architect, Leo A. Daly; and American Institute of Architects
- Marie Egan, Project Manager, “OR of the Future Project,” Massachusetts General Hospital, and the Center for Innovation at Massachusetts Institute of Technology (CIMIT)*
- John Gosbee, Director, Patient Safety Information Systems, National Center for Patient Safety, Department of Veterans Affairs
- Skip Gregory, Bureau Chief, Office of Plans and Construction, Agency for Health Care Administration
- Kirk Hamilton, Architect, Watkins Hamilton Ross Architects, Inc. (and) Texas A&M
- Susan Hassmiller, Robert Wood Johnson Foundation
- H. Scot Latimer, Vice President and National Director, Facility Planning Services, Kurt Salmon Associates
- Derek Parker, Architect, Anshen Allen*
- Jane Rhode, Designer, International Interior Design Association
- John Reiling, President and CEO, St. Joseph’s Community Hospital
- Dennis Rosenbaum, Neonatologist, St. Luke’s Hospital
- Ron Smith, Architect, HOK
- Craig Zimring, Professor, College of Architecture, Georgia Institute of Technology

* Denotes e-mail correspondence

Appendix B: Organizations with Staff Expertise in the Built Environment

- Academy of Architecture for Health (AIA)
- Academy of Neuroscience for Architecture
- Center for Health Design (CHD)
- Center for Innovation at MIT (CIMIT)
- Coalition for Health Environments Research (CHER)
- Environmental Design Research Association (EDRA)
- Planetree
- Robert Wood Johnson Foundation (RWJF)
- Salk Institute for Biological Studies

Academic Institutions

- Clemson University
- Georgia Institute of Technology
- Texas A&M
- University of California San Diego
- University of Miami
- University of Madison - Wisconsin

Appendix C: The Built Environment—Determining AHRQ’s Niche Interview Protocol

The Agency for Healthcare Research and Quality (AHRQ) has engaged The Lewin Group to conduct an environmental scan to help identify AHRQ’s role in addressing what is and is not known about the relationships between hospital design and patient outcomes, patient safety and satisfaction, and staff safety and satisfaction. The objective of this interview is for us to gain a better understanding of: 1) your personal experiences and perceptions regarding the built environment ; 2) who is leading the field in funding, conducting, disseminating and applying research findings in the design of health facilities; 3) your insights on current areas of research focus, outcomes to date and gaps in available research; 4) future research directions and 5) your feedback regarding possible roles for AHRQ in supporting and disseminating research in this area .

I. Background/Individual Role and Experiences in the Built Environment

1. How did you become involved with research related to the impact of the built environment on the following outcomes of interest?

Probes:

- Patient care outcomes
- Patient safety and satisfaction
- Staff safety and satisfaction

2. How long have you been working in this field?

Probes:

- Findings to date

3. What has been the focus of your work to date?

4. How much research has been conducted on your specific-research topic/area of interest?

II. Building the Field of Facility Design and Outcomes, Safety and Working Conditions

5. In your view, who are the leading researchers and experts in the field?

Probes:

- Architects
- Interior designers
- Health care practitioners
- Health system executives

- Academicians
- Researchers

6. What is driving the market for hospital design and construction?

Probes:

- Hospital errors
- Demonstrated success of other hospitals
- Financial incentives

7. Are hospital administrators requesting evidence-based designs? If no, why not?

8. Is it possible to “design-out” risks and hazards in hospital design, or is there always some level of risk/hazard involved?

III. Dissemination of Research Findings

9. Who are the major funders for research (that inform architects, interior designers, and health systems administrators) in the field?

10. In your view, what research and/or practical applications are particularly important and to what extent are they funded?

11. What types of studies are currently being funded? (e.g., descriptive, case studies, controlled trials, natural experiments). Are the published findings peer reviewed?

12. If the research is not currently available in peer reviewed journals, where do *you* typically find information and research on the built environment?

13. What organizations are involved in disseminating research findings and innovative successful practices?

IV. Implementation of Promising Practices

14. In your view, has the built environment influenced patient safety and patient and staff satisfaction? If so, in what ways? If not, why not?

15. Do existing laws and/or regulations regarding hospital design and construction impact patient safety & outcomes and staff satisfaction? If so, how?

Probes:

- JCAHO
- State Health Departments

16. Can you give examples where investing in facility design and construction led to “best practices” and/or noticeable improvements in patient safety & outcomes, staff safety, or patient & staff satisfaction levels?

Probes:

- Pebble Partners (St. Alphonsus in Boise, ID; Bronson Methodist in Kalamazoo, MI; Barbara Ann Karmanos Cancer Institute in Detroit, MI)

17. What elements are most desirable to include in designing hospitals that create therapeutic environments?

Probes

- Lighting
- Color
- Single beds
- Way finding systems
- Ventilation
- Corridor design (single versus radial)
- Other

18. What is the business case for incorporating these elements into hospital design and construction?

19. What obstacles do hospital designers, administrators and researchers encounter in building the field of hospital design as a vehicle for improving outcomes?

20. Have you seen any unexpected outcomes emerge from research or investment in the built environment?

V. Areas of Future Focus in the Built Environment

21. Are there apparent gaps in the research on the built environment that are important to address? (e.g., lighting and patient safety)

22. What areas of the built environment do you see gaining momentum in the future? (i.e., emerging trends).

VI. AHRQ: Potential Future Role and Areas of Impact

AHRQ, part of the U.S. Department of Health and Human Services, is the lead agency charged with supporting research designed to improve the quality of health care, reduce its cost, and broaden access to essential services. The Agency consists of nine major departments including the Center for Quality Improvement and Patient Safety (CQuIPS), the Center for Outcomes and Evidence, and the Office of Communications and Knowledge Transfer.

23. AHRQ is interested in assessing its potential role in the built environment. If they were to get involved in the built environment, what do you think their priority should be? Funding new research? Disseminating what is already known about the built environment? Are there other options that you would recommend AHRQ pursue?
24. Would greater involvement by AHRQ help lift the profile of the built environment among researchers, designers, hospital administrators and other stakeholders?