Wall Finish Selection in Hospital Design: A Survey of Facility Managers

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Abstract

Objective: This paper seeks to analyze healthcare facility managers’ perceptions regarding the materials used for interior wall finishes and the criteria used to select them. It also examines differences in wall finish materials and the selection process in three major hospital spaces: emergency, surgery, and in-patient units. These findings are compared with healthcare designers’ perceptions on similar issues, as currently documented in the literature.

Background: Hospital design and the materials used for hospital construction have a considerable effect on the environment and health of patients. A 2002 survey revealed which characteristics healthcare facility designers consider when selecting materials for healthcare facilities; however, no similar study has examined the views of facility managers on building finish selection.

Methods: A 22-question survey questionnaire was distributed to 210 facility managers of metropolitan, for-profit hospitals in Texas; IRB approval was obtained. Respondents were asked to rank 10 interior wall finish materials and 11 selection criteria for wall finishes. Data from 48 complete questionnaires were analyzed using descriptive statistics and nonparametric statistical analysis methods.

Results: The study found no statistically significant differences in terms of wall finish materials or the characteristics for material selection in the three major spaces studied. It identified facility managers’ four most-preferred wall finish materials and the five-most preferred characteristics, with a statistical confidence level of greater than 95%.

Conclusions: The paper underscores the importance of incorporating all perspectives: facility designers and facility managers should work together toward achieving common organizational goals.

Key Words: Healthcare facilities, facility management, building design, wall finishes, survey

Introduction

Architectural design has a major impact on human health because it furnishes the required determinants of health, particularly social support and psychological well-being (Mitrione, 2007; Ulrich, 2001). Mitrione (2007) observes the field of design must be explored to understand its impact on human health and to fully incorporate design as a healing strategy. Furthermore, conventional medicine and healthcare alone may not always provide complete physical and mental well-being; therefore, the role of design is seen
Healthcare design is an emerging field, reflecting a number of trends. Ulrich (2001) identifies the need for a new perspective on healthcare that incorporates the social and psychological needs of humans, along with conventional economic and biomedical concerns. As part of this process, interior finish selection is vital in the whole life cycle of a hospital building (Barker, Vipond, & Bloomfield, 2004; Hota, 2004; Ulrich et al., 2008; Wilson & Ridgway, 2006). Onaran (2009) underscores the importance of interior finishes such as wall and floor coverings on the interior environment of a healthcare facility. Onaran (2009) further states that these finishes possess the potential to affect the health and satisfaction of patients as well as provide visual character to inside spaces.

Healthcare buildings are perhaps the most complex building type in terms of operations and maintenance management. Hospital facility management divisions focus on effective operation and maintenance to achieve organizational and business goals. The construction, operation, and maintenance of healthcare buildings require specialized consultation (Milner & Narayan, 2005), because hospital design and construction materials have a considerable effect on both the environment and patients’ health (Vittori, 2002). Because the building envelope covers and safeguards the valuable building materials contained within, its design is an important phase of the design process. It keeps the interior space and finishes intact by preventing problems such as water infiltration, moisture penetration, and the growth of mold and mildew.

Interior finishes play a vital role in a healthcare facility, because proper wall treatments can contribute to the creation and maintenance of a positive therapeutic environment for patients (Mayer, 2005). A major portion (32%) of the initial construction cost of a healthcare facility is consumed in interior finishing and interior construction (Shohet, Lavy-Leibovich, & Bar-on, 2003). Factors such as durability, easy maintenance, robustness, etc., influence the selection of wall finishes in healthcare spaces (Bower, 2006; Carter & Barr, 1997; Moulavi, Bushy, Peterson, & Stullenbarger, 1999; Onaran, 2009; Parsons, Hussey, Abbott, & Jager, 2008). In addition, regulations and standards may affect decisions made about different wall finish materials (Schultz, 1979).

Facility managers face a wide range of challenges, from the maintenance, repair, and cleaning of buildings to budget management (Straub, 2003). Issues such as real estate transactions, floor planning, office equipment, transportation, and catering may also be included under the responsibilities of facility managers (Changing Role of
Facility Manager, 2003). Architects and interior designers select the materials for wall coverings, and after construction is complete, facility managers take charge of these components. Facility managers deal with building finishes more than anyone else throughout the service life of a building; hence, they possess material preferences based on their own experience and knowledge. Although facility managers are the main professionals in charge of operating and maintaining a building for its users, their collaboration with external parties, such as designers, consultants, technicians, suppliers, and other professionals, is desirable for an integrated approach to informed decision making and building sustainability (Federal Facilities Council, 2001).

**Research Problem**

Ulrich (2001) discusses the fact that healthcare design has traditionally concentrated on the functional efficiency of hospitals, resulting in a stressful healthcare environment that may be harmful for patient healing. However, Ulrich et al. (2008) also suggest that interior finishes contribute greatly to maintaining a clean and infection-free atmosphere in a hospital. Thus, wall finish selection must consider issues relating to maintenance and infection control (Ulrich et al., 2008). Pati, Park, and Augenbroe (2010) argue that maintenance and facility management issues are overlooked when initial design decisions are made. These issues should be considered throughout all phases of design execution.

There are differing perspectives about wall finish selection. Ulrich (2001) and Onaran (2009) suggest an approach that emphasizes psychological and healing issues. Pati and colleagues (2010) point out the need to underscore maintenance aspects during design decision making. Furthermore, Ulrich and others (2008) point out that research efforts that evaluate and compare various wall finishes based on performance criteria like infection control are limited. For such a study, it would be vital to solicit the opinions of facility managers regarding wall finish materials and their selection. These opinions could be based on technical performance as well as other criteria, such as aesthetics and initial cost. This paper, based on Barman (2008), seeks to analyze the perceptions of healthcare facility managers and compare the findings with healthcare designers’ perceptions, as described in the relevant literature. The findings of this paper provide needed insights (in terms of operations and maintenance issues) for designers and decision makers to use during the design phases of healthcare buildings.

**Literature Review**

According to Pati and colleagues (2010), two phases of a building’s life cycle are vital to contribute to the business performance of the organization: facility design and facility maintenance. Pati et al. (2010) also argue that facility maintenance issues rarely enter the decision-making process at the design stage. Furthermore, organizational performance is affected by not considering facility maintenance issues during initial facility design. The following sections describe differences relating to wall finish materials and their selection in the perspectives of the healthcare design and facility management fields.
Importance of Wall Finishes in Healthcare Design

Hospital and healthcare environments significantly affect patients’ healing process. Moreover, a conducive and positive environment can improve feelings of satisfaction and hope among hospital patients and generate patient confidence in hospital staff’s abilities (Onaran, 2009; Mróczek, Mikitarian, Vieira, & Rotarius, 2005; Ulrich et al., 2008). Onaran (2009) explores how interior surfaces, such as wall finishes, floor coverings, and ceiling finishes, govern the quality of inside atmosphere to a great extent. The color, hue, and saturation that provide character to a hospital interior are essential for the quality of indoor atmosphere; thus, they have a significant impact on the mood and behavior of patients, on the one hand, and on the psychological well-being of healthcare staff, on the other (Onaran, 2009; Schweitzer, Gilpin, & Frampton, 2004). The selection of wall finishes is an important design activity that also influences the construction, operation, and maintenance phases of a healthcare facility (Wilson & Ridgway, 2006).

Ulrich and colleagues (2008) reveal that hospitals are traditionally designed with surfaces that reflect sound, eventually leading to increased noise levels that are often found to be uncomfortable and harmful to patients’ recovery. Therefore, noise reduction should be considered during the design phase of a hospital building (Ulrich, 2000; Ulrich, 2001; Ulrich et al., 2008; Schweitzer et al., 2004). High-performing and sound-absorbing interior surfaces benefit patients as well as hospital staff, as Ulrich et al. (2008) suggest. In addition to noise levels, a significant issue affecting wall finish decision making during initial design relates to the toxicity of certain interior finishes (Rossi & Lent, 2006; Schweitzer et al., 2004).

Additionally, according to a survey conducted by Blakey & Rohde (2002), healthcare facility designers consider the following characteristics in the selection of materials for a healthcare facility, in declining order: aesthetics, durability, ease of maintenance, client preference, initial cost, cost of maintenance, infection control, ease of installation, and life-cycle cost. Finishes in an acute care facility should be robust, solid, and durable, because they are prone to routine and accidental impacts (Bower, 2006; Moulavi et al., 1999; Onaran, 2009; Parsons et al., 2008). Among the numerous considerations that enter into the decision process and selection of interior wall finishes in a healthcare facility, the type and scope of activity conducted in a particular space is one of the main factors governing the selection of wall finish materials (Onaran, 2009).

Infection control is another primary criterion to consider when selecting internal finishes; Carter and Barr (1997) even suggest that an infection control professional be involved in the process to help clinicians and architects choose appropriate wall coverings. Wall finish materials like plastic-laminated, fire-retardant plywood are more durable, and fiberglass composite substrate and vinyl, respectively, are aesthetically appealing and easy to maintain (Moulavi et al., 1999). Additionally, vinyl wall coverings offer a variety of colors, textures, and patterns for wall surfaces, and they are...
available in a large range of cost and quality levels (Bower, 2006).

Rossi and Lent (2006) discuss building materials that release harmful volatile organic compounds (VOCs), and they mention that they are used widely in hospital interior finishes. Furthermore, plastics and polyvinyl chlorides (PVCs), considered excellent in terms of functional performance, are actually unhealthy and have an adverse environmental impact (Rossi & Lent, 2006; Ulrich et al., 2008). However, Wilson and Ridgway (2006) have found that vinyl materials are preferred in hospitals because of their durability and ability to control infection.

Standards and regulations often affect interior wall finish selection during the design of a healthcare facility. Marshall-Baker (2006) discusses the new standards put forth for neonatal intensive care unit design, which regulate the use of harmful materials that might release dangerous gases and thus degrade the quality of the indoor atmosphere.

**Importance of Wall Finishes in Healthcare Facility Management**

Interior finishes have a direct relationship to the successful operation and maintenance of a healthcare facility (Barker et al., 2004; Hota, 2004; Ulrich et al., 2008; Wilson & Ridgway, 2006). Any architectural decision—such as wall finish selection—made during the design phase should also support facility management during the occupancy phase of the building. Wilson and Ridgway (2006) emphasize the importance of

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**Properly selecting wall finishes that are functional, cost-effective, and easy to maintain is crucial for healthcare facilities because of the septic conditions present in hospitals.**

“smooth, impervious and coved” wall coverings that do not harbor infection and help to create a healthy and infection-free atmosphere (p.267).

Sterile areas like operating rooms, isolation wards, and sterile processing spaces must be designed with a wall finish that is smooth, continuous, and without joints and fissures to avoid the accumulation of harmful substances (Facility Guidelines Institute, 2006). Wall finishes in a healthcare facility should be easily washable and free from joints and crevices, which can retain dust or other harmful substances. The wall surfaces near water fixtures or in spaces with water use must be smooth and water resistant. A fluid-resistant and easily cleanable wall covering is preferred in the design of hospitals and other similar healthcare facilities; however, Noskin and Peterson (2001) report that walls and ceilings are not among the major sources of infection in these buildings. They also indicate a preference for sound-absorbing wall coverings for hospital facilities.

Cost and maintenance play important roles in the process of wall finish selection during design and also during the occupancy phase and refurbish-
ment (Ulrich, 2001; Wilson & Ridgway, 2006). Properly selecting wall finishes that are functional, cost-effective, and easy to maintain is crucial for healthcare facilities because of the septic conditions present in hospitals. Wall finish materials vary from natural products, e.g., porcelain, natural stone, terrazzo, linoleum, rubber, and wood, to synthetic materials, e.g., vinyl (Milner & Narayan, 2005). Selecting suitable materials for healthcare wall coverings from this extensive list is complicated and requires thorough study. To prevent the spread of microbes in a hospital, it is essential to maintain a hygienic environment by cleaning medical instruments, clothing, and dressings. All finishes and coverings should tolerate treatment for bacterial and fungal agents, because a hospital is vulnerable to the spread of infections caused by the presence of sick patients (Hart, 1998).

Also entering the decision process are regulations and voluntary standards that state the type of wall finishes suitable for surgical units in a hospital. All federally funded healthcare facilities must comply with the Hill-Burton Act, as set forth in *Minimum Requirements of Construction and Equipment for Hospital and Medical Facilities* (Schultz, 1979). Because staff members from different departments, representing numerous opinions, are involved in specifying finishes in a hospital, a survey on the preferences of facility managers would be valuable.

**Wall Finish Materials**

A large variety of wall finishes can be used for any new construction or renovations, including paint, wall coverings, mosaics, and tiles. Healthcare buildings, however, require special attention and scrutiny in the selection of wall finishes during design and renovation phases for a number of reasons. The most important of these is the health and safety of patients and employees. Wall coverings can affect several measures of quality, including (a) the relative humidity (RH) of a room (Mortensen, Rode, & Peuhkuri, 2005); (b) indoor air quality (IAQ) (Hodgson, Rudd, Beal, & Chandra, 2000); and (c) the transmission of harmful bacteria (Lankford et al., 2006).

**Wall Coverings and Relative Humidity**

Is there any correlation between wall covering and the RH of a room? In fact, surface materials do play an important role in absorbing moisture when the RH increases, and desorbing moisture when RH levels decrease. Proper moisture control is essential to reduce health risks and Sick Building Syndrome in an enclosed space (Mortensen et al., 2005).

Given the health effects of humidity, the choice of wall finishes also has health implications. The growth of mildew and mold in walls is caused by moisture in the air. Hygroscopic (absorbing or attracting moisture from the air) materials keep indoor RH stable in rooms that are not ventilated frequently. Nonporous materials (i.e., that do not absorb water) are generally polycrystalline and characterized by continuous grain boundaries (Padfield, 1999). Thus, moisture control through wall coverings is vital to (1) reduce health risk and Sick Building Syndrome...
(Mortensen et al., 2005); and (2) prevent the growth of mildew and mold (Clausen, 2000). When surface humidity exceeds 80%, drywall and ceramic tiles can harbor mold and mildew, and it is difficult to prevent their growth. Hence, wall surfaces should remain dry and clean to prevent the growth of fungus (Hodgson et al., 2000). As noted, there is a relationship between wall covering and RH, which could affect the health and comfort levels of hospital occupants.

**Wall Coverings and Indoor Air Quality**

Attention to air quality is necessary, because patients are susceptible to common environmental microbes present in the air. In addition, chemicals and infectious agents already present in a hospital can affect IAQ (Streifel, 1998). Overall, IAQ may be affected by the following factors: (1) VOCs emitted by finishes and products used in the room (Burton, 1997); and (2) an increase in the RH of a room, which may lead to fungal growth (Hodgson et al., 2000).

Materials like carpets, paints, wallpaper, and PVCs can emit VOCs, which could have a negative effect on IAQ, possibly cause irritation and odor annoyance, and even have behavioral, neurotoxic, hepatotoxic, and genotoxic effects (Hodgson et al., 2000; Hoskins, 2003; Meininghaus, Gunnarsen, & Knudsen, 2000). According to Hoskins (2003), VOCs can be carcinogenic, depending upon the compound. To reduce the effect of VOCs in hospital rooms, low-VOC-content paints, low-emitting carpet systems, and low-VOC-content wall finishes should be used.

**Risk of Bacteria Transmission From Walls**

The transmission of bacteria from walls and floors is minimal unless these surfaces have residual moisture. To keep wall finishes from transmitting harmful bacteria, they should be easy to clean and able to withstand repetitive wear and frequent germicidal decontamination, and have the ability to repel moisture (Lankford et al., 2006). In hospital design, the risk of infection for hospital patients can be minimized via the participation of infection control professionals who specialize in facility design. Issues of infection control can thereby be identified early in the design process, and design and planning can be conducted accordingly (Noskin & Peterson, 2001). As such, the task of specifying wall finishes for a hospital is not a simple one that can be handled only by the owner or a designer. It requires the input of professionals who are familiar with hospital requirements as well as with the characteristics and properties of different materials.

**Wall Covering Material Selection in Healthcare Facilities**

The literature indicates that material selection for wall finishes in a healthcare facility is the result of architectural, environmental, and facility management factors. The primary material for wall finishes in public healthcare spaces is vinyl type II because of its aesthetics (Burns, 2002). Vinyl wall coverings may seem costlier than paint when, in fact, they are not: they clean far more easily and retain their appearance far longer, which may make them more efficient in the long run (Jacob, 2006). Characteristics of vinyl include (1) it maintains IAQ (Borrelli, 2007); (2) it is an easy-
Another finish is paint, but conventional water-based latex paints use solvents and additives, which contain VOCs (Bentley & Turner, 1997). Low-VOC latex paint emits considerably fewer VOCs and performs equally well as or better than conventional latex paint. Additionally, latex paint is much more environmentally friendly, nontoxic, and nonflammable than oil paints (Chang, Fortmann, Roache, & Lao, 1999). The following three healthcare units are analyzed in this paper: surgery, emergency, and inpatient units. The following sections describe the literature review on wall finish material preferences in these three spaces.

**Wall Finishes in Surgery, Emergency, and Inpatient Units**

The wall finishes of a surgery unit should be (a) hard; (b) nonporous; (c) free from joints and crevices; (d) easy to wash; and (e) able to withstand repeated contact with strong cleaning agents (Abreu & Potter, 2001; Fogg, 1999). Walls with ceramic tiles are not recommended in surgery units because the joints are difficult to clean, nonresistant to wear, and not durable. Lime wash (lime putty) is unsuitable for any wall surfaces in operating rooms because it is water soluble and therefore dissolves when washed. Cement paint also is inappropriate for surgery units because its rough finish easily harbors dirt and therefore makes cleaning difficult (Abreu & Potter, 2001). Latex paint (Bentley & Turner, 1997) and vinyl (Jacob, 2006) are suitable for use in surgery units.

For inpatient units, paint is considered the most versatile material because of its wide range of colors and textures. Textured and easy-to-clean paints are preferred because they diminish glare and facilitate acoustical control (Piotrowski & Rogers, 2007).

**Summary**

In summary, the literature emphasizes that to avoid the transmission of bacteria, wall finishes should be regularly cleaned and maintained. Therefore, cleanliness is of utmost concern for surgery, emergency, and inpatient units. Wall finishes used in any of these units should resist the effects of cleaning agents such as acids and be durable (not peel off the wall). Also, wall coverings have a direct impact on the RH of a room, indoor IAQ, and the transmission of bacteria. To control RH, suitable wall finishes that can absorb or desorb moisture should be used. IAQ depends to a great extent on the emission of harmful gases from the wall coverings. Hence, hospital finishes
require low levels of gas emission. In addition, consideration of the long-term maintenance costs in the selection of wall finishes can benefit healthcare facilities.

**Research Methods**

The primary objective of this study was to identify facility managers’ preferences regarding wall finishes in acute care hospitals. To do this, the opinions of facility managers were obtained by administering a survey questionnaire consisting of 22 questions. The emphasis of the study was on identifying the preferences of facility managers for wall finishes in emergency, surgery, and inpatient units of acute care hospitals in the state of Texas. For each of these units, the survey questions addressed the following aspects: (1) wall finishes preferred by facility managers; and (2) characteristics upon which facility managers base their preferences and selections. Approval for conducting the survey was obtained from the university’s institutional review board, because human subjects were the source of information for this research. Another objective of the study was to compare the results of the empirical study with designers’ attitudes, as described in the literature. By offering the results of this study to those in healthcare design, it is hoped that decisions concerning wall finishes will be better informed.

The sample population for this study was composed of facility managers in metropolitan, for-profit hospitals in the state of Texas. Nonmetropolitan and not-for-profit hospitals were excluded from the study, as per Wang, Wan, Falk, and Goodwin (2001). Moreover, it is assumed that material selection for an institution depends on local availability, traditional selection, and type of design. It is assumed that materials available for hospital design are similar throughout the entire state of Texas. According to the Hospital Survey Unit, Center for Health Statistics, the local Department of State Health Services, there are 210 for-profit, metropolitan acute care hospitals in the state of Texas. To collect data for this study, the facility managers of these hospitals were sent a Web-based survey. Follow-up phone calls were made, if no responses were received within a reasonable period of time.

A pilot survey was administered to three of the total 210 for-profit acute care hospitals, which resulted in two responses. No further modifications to the survey questionnaire were made as a result of this pilot. The survey was distributed to the remaining 207 hospital representatives. Of these, 54 responses were collected, with 48 of the 54 responses complete; incomplete responses were not included in the study. This resulted in a response rate of 23.2%. The designations of the respondents were Plant Managers, Directors of Facilities Management, Plant Operations Direc-
tors, and Facility Managers.

Analysis of the data utilized descriptive statistical methods, such as graphical displays of the data and tabular descriptions. Because an ordinal scale was used, responses represented the scale of the respondents’ opinions. Because these scales were not quantitative, they cannot be analyzed using standard parametric statistical analysis. A non-parametric Wilcoxon rank sum test was used to further analyze the relationship of materials, selection criteria, and the types of spaces studied.

**Findings**

**Wall Finish Materials**

Results of the survey are summarized in Tables 1 and 2. Table 1 indicates the responses for the top wall finish materials, as obtained from the respondents’ rankings. The respondents were asked to rank these materials on an ordinal scale from 1 through 10, with “1” and “10” indicating the most-preferred and least-preferred selections, respectively. Table 1 shows the number of responses received for the top five rankings (out of 10) for each of the wall finish materials considered, per unit of the hospital. As mentioned earlier, 48 responses were collected in this survey; however, because the number of responses obtained for rankings 6 through 10 is not included in Table 1, the total number of responses presented in this table may be less than 48 for each building material in each unit.

The results suggest that vinyl type II was the most-preferred wall finish material in all three healthcare units. It is rated as most preferred by 25, 32, and 33 respondents in emergency, surgery, and inpatient units, respectively. The second most-preferred wall finish material was paint—water-based or latex—with 18, 27, and 27 respondents in emergency, surgery, and inpatient units, respectively, ranking it as second choice. Rigid fiberglass panels were selected as the third most-preferred wall finish in all three units, with 18, 17, and 15 respondents in emergency, surgery, and inpatient units, respectively, ranking it as their third choice.

Because these data represent the rank of the

<table>
<thead>
<tr>
<th>Material</th>
<th>Emergency Unit (Nos.)</th>
<th>Surgery Unit (Nos.)</th>
<th>Inpatient Unit (Nos.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Vinyl type II</td>
<td>25 15 5 1 1</td>
<td>32 10 1 2 1</td>
<td>33 11 1 0 3</td>
</tr>
<tr>
<td>Paint—water/latex</td>
<td>18 18 5 2 1</td>
<td>10 27 4 2 0</td>
<td>12 27 4 1 2</td>
</tr>
<tr>
<td>Rigid fiberglass panels</td>
<td>2 4 18 5 2</td>
<td>3 3 17 5 5</td>
<td>0 6 15 7 2</td>
</tr>
<tr>
<td>Paint—solvent/oil</td>
<td>1 4 6 6 6</td>
<td>2 1 12 6 3</td>
<td>1 2 10 5 3</td>
</tr>
<tr>
<td>Acoustical tile</td>
<td>0 0 3 9 8</td>
<td>1 0 2 12 7</td>
<td>0 0 3 9 8</td>
</tr>
<tr>
<td>Wallpaper</td>
<td>0 1 3 9 11</td>
<td>1 0 1 9 10</td>
<td>0 0 6 8 11</td>
</tr>
<tr>
<td>Vinyl type III</td>
<td>2 3 3 5 6</td>
<td>1 0 5 3 9</td>
<td>2 1 0 9 9</td>
</tr>
<tr>
<td>Ceramic tile</td>
<td>1 0 2 3 5</td>
<td>3 1 0 2 7</td>
<td>0 1 6 3 3</td>
</tr>
<tr>
<td>Wood paneling</td>
<td>0 0 2 5 5</td>
<td>1 1 2 2 1</td>
<td>1 0 2 2 1</td>
</tr>
<tr>
<td>Vinyl type I</td>
<td>0 2 3 2 4</td>
<td>2 3 2 3 3</td>
<td>1 1 2 4 6</td>
</tr>
</tbody>
</table>

Table 1. Occurrences of Each Wall Finish Material in the Top Five Rankings, by Unit
materials in the opinion of survey respondents, mean values could not be assumed as an appropriate central tendency. Mean values can be calculated only when actual values, such as scores or weights (not ranks) are being analyzed, which is not the case in this study. Following vinyl type II, latex paint, and fiberglass panels, the list of top-six materials preferred by facility managers were paint—solvent/oil, acoustical tile, and wallpaper. Interestingly, the pattern of preference for wall finishes is similar, but not identical, in the three spaces studied. The other four wall finish materials, namely vinyl types I and III, ceramic tile, and wood paneling, are ranked lower in facility managers’ order of preference.

Wall Finish Materials: Selection Criteria Ratings
Respondents were then also asked to rank the eleven criteria for wall finish selection on an ordinal scale of 1 through 11, with “1” and “11” being the highest and lowest rankings, respectively. Table 2 summarizes the five top rankings, as suggested by the survey respondents. Rankings for the three hospital units demonstrate a similar pattern in which the top-two-rated criteria were infection control and gas emission, followed by IAQ, and ease of maintenance; sound resistance was not far behind. The other six criteria, namely durability, cost of maintenance, flame resistance, aesthetics, initial cost, and ease of installation, were ranked lower in facility managers’ order of preference for wall finish material selection criteria.

As seen in Tables 1 and 2, survey participants were given two lists to work with: one was a list of 10 wall finish materials, and the second included 11 selection criteria, where respondents were asked to rank all of the items within each of the two groups. Therefore, responses were collected based on the rankings of wall finish materials compared to each other, and the same was done for the selection criteria of these materials. Alternatively, a performance score could have been obtained for each item within each list. The problem with the alternative method (performance scores obtained) was the possibility of being unable to
differentiate between two or more items in cases where respondents felt that two or more of the materials or criteria presented should receive a similar score.

### Ranking of Wall Finish Materials and Their Selection Criteria

The first null hypothesis tested in this study was that the ranking of each material in the three spaces studied is similar. The Wilcoxon rank sum test was used and \( p \)-values were calculated for the null hypothesis. The Wilcoxon rank sum test is a nonparametric statistical test that makes no assumptions about the distribution of data; therefore, it can be used with any data whose distribution is unknown or unspecified (Hayter, 2007). Each material was tested as part of a pair of the three healthcare spaces under study, with three possible pairs of spaces being analyzed: emergency surgery, emergency inpatient, and surgery inpatient units.

Table 3 shows the \( p \)-values for each material in the three hospital pair spaces studied. Based on Table 3, the null hypothesis cannot be rejected in any of the pair spaces with a statistical significance of .05 (95% confidence level); therefore, it was found that each material has an identical ranking in all three spaces considered for this study. The null hypothesis is accepted at a 95% confidence level, because all \( p \)-values shown in Table 3 are considerably higher than .05. Thus, it can be concluded that the ranking of wall finish materials is similar in all three healthcare spaces: emergency, surgery, and inpatient units.

Because Table 3 demonstrates that the pattern of ranking is similar in all three spaces, the responses for each material in the three spaces were also averaged for a paired comparison. Table 4 presents the averaged response scores (with arithmetic mean rank and the standard deviation of the mean rank) for each material in the three healthcare spaces combined. Although each material was analyzed for its mean ranking score and standard deviation, it was also compared with any of the other materials studied by applying a similar Wilcoxon rank sum test on the responses received from the 48 facility managers.

![Table 3](image-url)
ranked vinyl type II the top preferred material with a statistical significance lower than .05 (more than 95% confidence level) compared to any of the other nine materials. The second-ranked material was paint—water-/latex-based, with a statistical significance lower than .05 (more than 95% confidence level) compared to any of the other eight materials. The null hypothesis for comparing the ranking of materials was that the ranking of each pair of materials is identical. The pair of the top two preferred materials (vinyl type II and paint—water-/latex-based) possesses a \( p \)-value of .0004 (see Table 4), significantly higher than the 95% confidence level, indicating that the rankings of these two materials are dissimilar, with vinyl type II being preferred over paint—water-/latex-based.

Following in the ranking of materials are rigid fiberglass panels and paint—solvent-/oil-based, ranked as the third and fourth most-preferred materials. Although there is a statistically significant difference of less than .05 between the ranking of these two materials and the rest of the materials, there is no 95% confidence level regarding which one of them is preferred over the other (a \( p \)-value of .3122 was found). Thus, in this case the null hypothesis for the paired materials of rigid fiberglass panels and paint—oil-/solvent-based is accepted, and it can be concluded that their ranking is identical in the three spaces studied.

There is no statistically significant difference lower than .05 in the rankings of the other six materials; therefore, they are all ranked as the least-preferred materials (numbers 5 to 10 in the order of ranking); thus, there is no way to differentiate among them, other than by using their mean ranking score. By analyzing the mean ranking scores of these materials, it can be seen that wallpaper has a slightly higher preference over vinyl type III, acoustical tile, ceramic tile, and wood paneling, and these, in turn, have a slightly higher preference than vinyl type I, which was ranked as the least-preferred wall finish material by hospital facility managers. Yet the confidence

Table 4. P-values for Testing the Null Hypothesis: The Ranking of Each Pair of Materials Is Similar

<table>
<thead>
<tr>
<th>Material</th>
<th>Vinyl II</th>
<th>Paint—water-/latex-based</th>
<th>Rigid fiberglass panels</th>
<th>Paint—solvent-/oil-based</th>
<th>Wallpaper</th>
<th>Vinyl III</th>
<th>Acoustical tile</th>
<th>Ceramic tile</th>
<th>Wood paneling</th>
<th>Vinyl I</th>
<th>Mean rank</th>
<th>SD/rank</th>
<th>Total ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinyl II</td>
<td>-</td>
<td>.0004</td>
<td>.0004</td>
<td>.0007</td>
<td>.0004</td>
<td>.0004</td>
<td>.0007</td>
<td>.0004</td>
<td>.0004</td>
<td>.0004</td>
<td>5.06</td>
<td>2.48</td>
<td>1</td>
</tr>
<tr>
<td>Paint—water-/latex-based</td>
<td>-</td>
<td>2.88E-8</td>
<td>5.20E-9</td>
<td>1.69E-9</td>
<td>3.70E-9</td>
<td>1.69E-9</td>
<td>3.82E-9</td>
<td>1.80E-9</td>
<td>1.68E-9</td>
<td>1.80E-9</td>
<td>5.06</td>
<td>2.48</td>
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</tr>
<tr>
<td>Rigid fiberglass panels</td>
<td>-</td>
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<td>9.88E-7</td>
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<td>2.39</td>
<td>1.25</td>
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<tr>
<td>Paint—solvent-/oil-based</td>
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<td>.0040</td>
<td>.0004</td>
<td>7.15E-5</td>
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<td>.0004</td>
<td>5.06</td>
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<td>-</td>
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<td>-</td>
<td>.0036</td>
<td>.0002</td>
<td>.0034</td>
<td>.0005</td>
<td>8.98E-6</td>
<td>2.02E-6</td>
<td>5.32</td>
<td>1.59</td>
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<td>Vinyl III</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>2.342</td>
<td>.0301</td>
<td>.0664</td>
<td>.0029</td>
<td>.0032</td>
<td>6.17</td>
<td>1.55</td>
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<td>-</td>
<td>-</td>
<td>.9789</td>
<td>.8656</td>
<td>.7806</td>
<td>.0040</td>
<td>.0004</td>
<td>6.65</td>
<td>1.87</td>
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<td>6</td>
</tr>
<tr>
<td>Ceramic tile</td>
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<td>-</td>
<td>-</td>
<td>.8407</td>
<td>.5588</td>
<td>.1585</td>
<td>.1585</td>
<td>6.65</td>
<td>1.79</td>
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<td>Wood paneling</td>
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<td>7.858</td>
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<td>.0004</td>
<td>6.66</td>
<td>1.49</td>
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<tr>
<td>Vinyl I</td>
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</tbody>
</table>

There are no statistically significant differences lower than .05 in the rankings of the other six materials; therefore, they are all ranked as the least-preferred materials (numbers 5 to 10 in the order of ranking); thus, there is no way to differentiate among them, other than by using their mean ranking score. By analyzing the mean ranking scores of these materials, it can be seen that wallpaper has a slightly higher preference over vinyl type III, acoustical tile, ceramic tile, and wood paneling, and these, in turn, have a slightly higher preference than vinyl type I, which was ranked as the least-preferred wall finish material by hospital facility managers.
level for the ranking preferences of these six wall finish materials is a less than 95%.

Similar to wall finish materials, the criteria for wall finish selection were analyzed for their pattern of ranking in the three spaces studied. Table 5 presents the p-values for each pairing of the three spaces studied, and similar to the findings presented in Table 3, it can be seen that these p-values represent a confidence level considerably higher than 95%. Based on Table 5, the null hypothesis cannot be rejected in any of the paired spaces with a statistical significance of .05 (95% confidence level); therefore, it can be assumed that each criterion has an identical ranking in all three spaces. Based on this finding, each respondent’s score for each criterion in the different spaces was averaged and then compared with the others.

The averaged ranking scores, along with the standard deviations of the facility managers’ preferences of criteria used for selecting wall finishes, are shown in Table 6. This table indicates that the top criterion was found to be infection control, differing by a more than 95% confidence level compared to any of the other 10 criteria. This was followed by gas emission/VOC and ease of maintenance as the second and third most-preferred criteria; however, there was no statistical significance lower than .05 in the ranking of these two criteria (p-value of .4444 was calculated); therefore, the null hypothesis was not rejected, and they are both assumed to have identical ranking. Yet, there is a statistical confidence level of more than 95% that these two criteria are ranked above any of the other eight criteria studied. Following these top three criteria are IAQ and sound resistance, ranked as the fourth and fifth most-preferred criteria. Although the rankings of these two criteria and any of the six other criteria differ by a statistically significant .05, there is no statistically significant difference of .05 in their own rankings as the fourth and fifth most-preferred criteria (with a p-value of .1090.) There is

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Emergency Surgery</th>
<th>Emergency Inpatient</th>
<th>Surgery Inpatient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial cost</td>
<td>.7141</td>
<td>.7342</td>
<td>.8893</td>
</tr>
<tr>
<td>Ease of installation</td>
<td>.7763</td>
<td>.2797</td>
<td>.6753</td>
</tr>
<tr>
<td>Ease of maintenance</td>
<td>.6563</td>
<td>.7870</td>
<td>.5816</td>
</tr>
<tr>
<td>Cost of maintenance</td>
<td>.9159</td>
<td>.6133</td>
<td>.3898</td>
</tr>
<tr>
<td>Durability</td>
<td>.9033</td>
<td>.1725</td>
<td>.1454</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>.9459</td>
<td>.7224</td>
<td>.4200</td>
</tr>
<tr>
<td>Flame resistance</td>
<td>.8906</td>
<td>.6392</td>
<td>.3782</td>
</tr>
<tr>
<td>Gas emission/VOC</td>
<td>.6318</td>
<td>.8442</td>
<td>.8370</td>
</tr>
<tr>
<td>Infection control</td>
<td>.2769</td>
<td>.3258</td>
<td>.7609</td>
</tr>
<tr>
<td>Sound resistance</td>
<td>.1090</td>
<td>.2162</td>
<td>.7355</td>
</tr>
<tr>
<td>Indoor air quality</td>
<td>.4561</td>
<td>.9722</td>
<td>.5735</td>
</tr>
</tbody>
</table>
no statistically significant difference lower than .05 in the rankings of the other six criteria; therefore, they are all ranked as the least preferred criteria (sixth to eleventh in the order of ranking), with no way to differentiate among them other than their mean ranking scores. By analyzing the mean ranking scores of these criteria, it can be seen that durability, aesthetics, and flame resistance have a slightly higher preference over cost of maintenance, ease of installation, and initial cost.

**Discussion**

Consistent with the literature (Borrelli, 2007; Burns, 2002; Jacob, 2006; Nussbaumer, 2006), findings of this study suggest vinyl type II as a primary choice for wall finishes in healthcare facilities. Although a range of vinyl materials may be available, each product in that range may not be suitable for one or more healthcare units. Hence, findings of this study are specific to a material type, but not to a particular product. This study does not endorse vinyl type II as the most-preferred material in healthcare facilities; rather, it presents a survey opinion.

There are studies (such as Rossi & Lent, 2006) that support the idea of avoiding vinyl materials because of their adverse impact (such as VOC emission) on indoor atmosphere. Similarly, latex paint, which emerged as a second choice for wall finishes in this study, is also recommended by the literature (Bentley & Turner, 1997) for use in hospital general and surgery units. Although there are concerns regarding VOC emissions from latex-/water-based paints, a range of low-VOC materials exists that could perform equally well, or even better than, conventional latex paints (Bentley & Turner, 1997).

In this study, facility managers’ most-preferred

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**Table 6. P-values for Testing the Null Hypothesis: The Ranking of Each Pair of Criteria Is Similar**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Infection Control</th>
<th>Gas Emission/VOC</th>
<th>Ease of Maintenance</th>
<th>Indoor Air Quality</th>
<th>Sound Resistance</th>
<th>Durability</th>
<th>Aesthetics</th>
<th>Flame Resistance</th>
<th>Cost of Maintenance</th>
<th>Ease of Installation</th>
<th>Initial Cost</th>
<th>Mean Rank</th>
<th>SD Rank</th>
<th>Total Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection Control</td>
<td>-</td>
<td>2.46E-9</td>
<td>2.46E-8</td>
<td>1.69E-9</td>
<td>1.98E-9</td>
<td>2.63E-9</td>
<td>1.86E-9</td>
<td>1.69E-9</td>
<td>1.69E-9</td>
<td>2.74E-9</td>
<td>1.47</td>
<td>0.94</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Gas Emission/VOC</td>
<td>-</td>
<td>-</td>
<td>.4444</td>
<td>.0010</td>
<td>1.18E-5</td>
<td>4.87E-7</td>
<td>5.90E-7</td>
<td>2.88E-8</td>
<td>1.24E-7</td>
<td>1.80E-8</td>
<td>7.64E-8</td>
<td>3.75</td>
<td>1.70</td>
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<tr>
<td>Ease of Maintenance</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>.0001</td>
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<td>8.11E-8</td>
<td>2.47E-8</td>
<td>2.55E-9</td>
<td>5.08E-9</td>
<td>6.07E-9</td>
<td>3.91</td>
<td>1.50</td>
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<td>Indoor Air Quality</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>.1090</td>
<td>5.72E-5</td>
<td>2.19E-5</td>
<td>1.91E-6</td>
<td>1.87E-5</td>
<td>7.32E-5</td>
<td>4.71E-5</td>
<td>5.17</td>
<td>2.32</td>
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<tr>
<td>Sound Resistance</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>.0025</td>
<td>.0012</td>
<td>.0003</td>
<td>.0003</td>
<td>.0003</td>
<td>.0003</td>
<td>5.75</td>
<td>2.19</td>
<td>5</td>
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<tr>
<td>Durability</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>.6503</td>
<td>.5606</td>
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<td>.0125</td>
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<td>1.41</td>
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<tr>
<td>Aesthetics</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>.5606</td>
<td>.0277</td>
<td>.0305</td>
<td>.0125</td>
<td>.0331</td>
<td>7.17</td>
<td>1.60</td>
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<tr>
<td>Flame Resistance</td>
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<td>.0125</td>
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<tr>
<td>Cost of Maintenance</td>
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<td>-</td>
<td>-</td>
<td>-</td>
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<td>7.37</td>
<td>1.42</td>
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<tr>
<td>Ease of Installation</td>
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<td>-</td>
<td>-</td>
<td>-</td>
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<td>7.66</td>
<td>1.42</td>
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<tr>
<td>Initial Cost</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>.0331</td>
<td>7.92</td>
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criterion for making wall finish choices is infection control. This differs, however, from facility designers, who recommended aesthetics, durability, and ease of maintenance as top criteria for wall finish selection, as demonstrated in a study by Blakey & Rohde (2002). This difference of opinion may be explained by different motivations, because facility designers are more concerned about the design of the facility, whereas facility managers tend to emphasize facility operations and maintenance.

Another difference may have been caused by the time that has passed since the healthcare designers’ study was conducted, approximately 7 years before the current study of healthcare facility managers. In any case, this study makes it clear that healthcare designers should note that material selections based primarily on aesthetics may have a short life if they are not appropriately cared for by those responsible for facility operations. Essentially, the designers’ aesthetic goals may have no staying power. Because this study emphasizes the perspective of facility managers, the criteria for wall finish material selection clearly reflect their relationship with facility management practices (ease of maintenance), indoor environment quality (emission/VOC), and special requirements (e.g., infection control) of the hospital environment.

Furthermore, healthcare designers are more concerned about how healthcare facility design helps users heal, whereas facility managers are more pragmatic, concentrating on how well they can maintain and operate the facility. Interestingly, the quality of the indoor environment, as it relates to facility designers, means an environment that provides patients with comfort and healing; facility managers relate indoor environmental quality mostly to nontoxicity. Durability seems to be an issue of common interest, although healthcare designers likely give it more attention than healthcare facility managers. Some healthcare design studies have emphasized infection control in the selection of wall finish materials, and that is also reflected in the findings of this study.

Although it is not surprising that facility managers ranked initial cost as the least-preferred criterion, because they are responsible for the building components for the rest of their service life following installation, it was somewhat surprising to find that facility managers also gave the cost of maintenance a low ranking. One explanation for this may be that facility managers are more concerned with ease of maintenance (ranked second or third) than with its cost, which is typically covered by the owner. Thus, this analysis can be concluded by saying that facility managers tend to prefer materials that are easier to maintain rather than materials that are cheaper to maintain.

In addition, it is interesting that neither healthcare designers nor healthcare facility managers consider financial aspects among their major criteria for wall finish material selection. Although the literature suggests that healthcare designers ranked initial cost, cost of maintenance, ease of installation, and life cycle cost as their least-preferred criteria, healthcare facility managers also ranked the cost of maintenance, ease of installa-
tion, and initial cost as their least-preferred criteria for the selection of wall finish materials. In this case, it seems that both groups tend to leave the financial decisions to facility owners. It is also possible that the findings might have been different had other types of healthcare facilities been studied.

There may be a relationship between the most-preferred wall finish material and the top criteria for its selection; for example, Wilson and Ridgway (2006) suggested that characteristics such as durability and infection control make vinyl materials a preferred choice in hospitals. In this study, respondents were not asked directly to link their opinion of wall finish materials to the criteria for selecting these materials. Hence, the relationship between the most-preferred wall finish materials and the top-ranked criteria in any given space needs additional analysis and further validation.

Conclusions

Wall finishes and their materials play an important role not only in creating a healing and comfortable environment, but also in maintaining a clean, nontoxic, and infection-free healthcare facility. Facility designers’ viewpoints differ from those of facility managers, and it becomes important for them to understand and communicate their motivations. This study discusses related literature to healthcare facility designers’ opinions of wall finish materials and their selection criteria. It also included a survey of healthcare facility managers in the state of Texas to identify their opinions about this.

This paper studies and analyzes healthcare facility managers’ perspectives on wall finish preferences and selection criteria. It does not undermine issues related to facility design or management, but it presents facility managers’ viewpoints, as demonstrated via the survey. Facility design and facility management professionals should work together to achieve organizational goals, although their expertise lies at opposite ends of a building’s service life. While facility design is in the preliminary process of establishing criteria for the selection of building systems and components, facility management comes later, during the long-term process of dealing with the results of choices made earlier, while also operating and maintaining these systems and components and helping decision makers improve their decision process for the design of new buildings.

Concerning the limitations of this study, the fact that it was conducted solely in Texas may have introduced a bias toward the selection of one material over another, or toward preferring one specific approach in wall finish criterion selection over another. The authors recommend conducting a larger study that involves facility managers from different states and different parts of the country to validate the preliminary findings presented in this paper. Another recommendation for further research is to select a larger study population. To increase the representation of different stakeholders in built healthcare facilities, a larger study could include owners, designers, contractors, facility managers, and users. Such a study could examine additional building components (e.g., floor finish materials, plumbing and rough-in materials, and electrical components).
to further analyze and compare the perspectives of the diverse stakeholders in healthcare facilities.

Healthcare facility designers can use this paper to raise awareness of facility managers’ perspectives, in terms of decisions regarding wall finish material selection, while considering the complex functions and requirements of a healthcare facility. Other research studies have indicated the need for a collaborative approach between those who design facilities and those who operate them, and this paper provides a useful resource to inform an approach to healthcare design and management from a long-term perspective.

References


Meininghaus, R., Gunnarsen, L., & Knudsen, H. N. (2000). Diffusion and sorption of volatile organic compounds in building ma-


