EXPLORING THE EFFECTIVENESS OF LEED CERTIFICATION IN LEED CERTIFIED HEALTHCARE SETTINGS IN CLIMATE ZONE 2 AND 3

A Dissertation

by

XIAODONG XUAN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2012

Major Subject: Architecture

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Approved by:

Chair of Committee,	Mardelle Shepley
Committee Members,	Daniel Hamilton
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	Zofia Rybkowski
Head of Department,	Ward Wells

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ABSTRACT

Exploring the Effectiveness of LEED Certification in LEED Certified Healthcare Settings in Climate Zone 2 and 3. (August 2012)

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Chair of Advisory Committee: Dr. Mardelle Shepley

Most LEED (Leadership in Energy and Environmental Design) certified buildings are commercial office buildings and multi-use buildings. As of October 2009, 35,000 projects were registered in the LEED system, “comprising over 4.5 billion square feet of construction space in all 50 states and 91 countries”. However, as of April 30, 2009, only 43 healthcare projects had achieved LEED certification. Currently, most studies focus on the economic benefits and energy consumption of LEED certified buildings, rather than human factors. A small gain in productivity can result in a heftier financial gain. Even modest improvements in productivity and absenteeism can substantially outweigh the energy cost.

This study surveyed 164 staff in the two healthcare settings for case study, and 146 staff in the six LEED certified healthcare settings for the main study in climate zone 2 and 3. Telephone interviews with the six facility managers were used to verify the survey results and further examine the healthcare facilities’ performance and the effectiveness of the LEED strategies from facility managers’ perspectives.

Independent t-test was used to examine the difference between the LEED and Non-LEED hospitals in one healthcare system and results showed that building performance were rated higher by staff in LEED certified hospital than Non-LEED hospital. MANOVA was conducted to compare the staff's ratings between Silver and Gold certification levels, male and female, and also explore the possibility of interaction effect. Multilevel regression modeling was used to test how the building performance variables affect the overall comfort and productivity. Study results showed that staff in the Gold certified hospital had significant higher ratings in most the performance variables. Gold certified healthcare settings were significant better in rated building overall, overall comfort and controllability than Silver certified healthcare settings. And males felt more comfortable in temperature than females in healthcare facilities. Regarding the overall comfort and productivity, building design, efficiency of the space use, temperature comfort and controllability over building system were significant predictors for staff overall comfort; and lighting comfort, temperature comfort and controllability over building system had significant positive relationship with perceived productivity.

LEED certified healthcare settings appear to have a good environment and building performance for occupants. Controllability, lighting, temperature, use of space, building design were important factors in staff comfort and productivity.

DEDICATION

To my Parents,

Xingli Xuan and Sujuan Chen,

for their endless encouragement.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Shepley, and my committee members, Prof. Hamilton, Dr. Culp, and Dr. Rybkowski, for their guidance and support throughout the course of this research.

Thanks also to my friends and colleagues and the department faculty and staff for making my time at Texas A&M University a great experience. I also want to extend my gratitude to all the facility managers and staff who were willing to participate in my study. Architectural design firms and healthcare setting managers and directors were gratefully appreciated for setting connection with facility managers and their facility.

Finally, thanks to my beloved parents who made all of this possible, for their encouragement and patience.

NOMENCLATURE

CLEANLINESS	Cleanliness of building
CNTCO	Control over cooling
CNTHT	Control over heating
COMFOVER	Comfort overall
DESIGN	Building design
IEQ	Indoor environmental quality
IMAGE	Image presented to visitors
LEED	Leadership in Energy and Environmental Design
LTOVER	Lighting comfort
NEEDS	Ability to meet occupants' needs
NSEOVER	Noise comfort
PROD	Productivity
SAFETY	Personal safety in and around building
SPACEBUILT	Space use efficiency
TSOVER	Temperature comfort in summer
TWOVER	Temperature comfort in winter

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1. INTRODUCTION

1.1 Background

In the United States, buildings consume approximately one-third of the total annual energy and raw materials, one-fourth of the total water, and generate more than one-third of the total atmospheric emissions and one-fourth of total solid waste (Levin, 1997). The US healthcare setting is the second largest contributor to carbon dioxide pollution, a greenhouse gas that causes global warming; only food service is higher than health care. As a result, more healthcare settings are turning to energy efficient building (Beidler, 2008).

The Leadership in Energy and Environmental Design (LEED) system was created in 2000 by U.S. Green Building Council (USGBC) for sustainable design practice (USGBC, 2011e). The LEED system is a rating system comprised of design and construction criteria that provide guidance for identifying and implementing practical and measurable green building design, construction, operations and maintenance strategies. A certification for utilizing such strategies is awarded deeming buildings that have achieved these criteria as being sustainable.

Currently, approximate 35,000 projects (4.5 billion square feet) are participating in the LEED system, these projects are in all 50 states and 91 countries (USGBC, 2011f). However, as of April 30, 2009, only 43 healthcare projects had achieved LEED certification. Of these, 13 are acute-care or specialty healthcare settings, five are

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This dissertation follows the style of *Health Environments Research & Design Journal.*

ambulatory care (mixed-occupancy) buildings, and 25 are medical office buildings/clinics (Houghton, Vittori, & Guenther, 2009).

In order to design and operate sustainable healthcare facilities, an increasing number of facilities are seeking LEED certification as a mark of green healthcare status. As of November 2010, there were 292 LEED-certified health care facilities in the U.S., and about 1,400 health care facilities were registered for LEED certification. In the same month as this data was gathered, LEED for Healthcare was approved after six years of planning and negotiations (Ferenc, 2011).

1.2 Significance of the Study

Thermal comfort, ventilation, controllability, lighting, acoustics and access to daylight and views are important to indoor environmental quality. We can hypothesize that LEED strategies have an impact on indoor environment and staff performance and comfort.

Buildings' performances sometimes do not meet design assumptions. Therefore, occupants experience feelings, such as comfort and productivity are important means of measuring building performance. However, currently, most studies focus on the economic benefits and energy consumption of LEED certified buildings, rather than human factors. The majority of studies in building performance focus on some physical factors, such as energy or water consumption. Information about the impact of building performance on occupants' experience lags far behind (Pyke, Mcmahon, & Dietsche, 2010).

1.2.1 Sustainable development

Miller (1995) claims that up to 43% of all commercial energy is wasted by poorly insulated and designed buildings. And the U.S. is one of the biggest consumers of resources in the world; it consumes not only energy, but also wastes the resources needed to make it. Therefore it is badly in need of sustainable practices.

The purpose of LEED is to "provide building owners and operators with a framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions." (USGBC, 2011e) And the LEED rating system can be used for all types of buildings, commercial and residential, it can be used in all the phases of the building process from design and construction to building operation and maintenance (USGBC, 2011e).

Using occupant perceived experience as variable, such as comfort and performance, and other variables related to building performance, this study explores the effectiveness of LEED certified healthcare settings, and identifies effective sustainable design strategies that positively impact on the environment, while improving the health and comfort of building occupants. Obtaining LEED certification does not mean the building is sustainable, but it opens a door to sustainability. The study and deployment of the LEED system will increase awareness of green building practice, and promote whole-building and integrated design practices, and environmental building industry leadership.

1.2.2 Financial saving

In addition to improving the health and safety of the living environment (USGBC, 2009a), studies show that LEED can offer reductions in operating costs (Northbridge Environmental Management Consultants, 2003), contribute to productivity, quality of the healing environment (Richards, Palibroda, & Guy, 2007). LEED provides a complete framework for assessing building performance and meeting sustainability goals. With my study, managers of healthcare settings, designers, engineers and contractors will find that sustainable strategies can not only save energy but can also improve staff productivity and comfort. My study will encourage clients and managers tend to incorporate sustainable strategies in their buildings, and these strategies can contribute to the environment and financial savings.

Up to half of the LEED credits can be evaluated by occupant experience, in addition, 82% of indoor environmental quality credits can potentially be tested in LEED NC. Pyke et al. (2010) believes that human experience can determine whether the implemented LEED strategies meet the intended effect.

Kubba (2010) demonstrated that LEED certified buildings have improved staff productivity and satisfaction, resulting in fewer sick days, and reduced employee turnover. Improved ergonomic interventions, together with improved air quality, reduced noise, and adequate lighting can have a positive influence on staff health (Ulrich, Zimring, Quan, Joseph, & Choudhary, 2004). Pyke et al. (2010) demonstrated that small improvements in worker productivity greatly outweigh savings in energy.

A study demonstrated that staff in highly rated LEED buildings have fewer sick days with better light, ventilation, and less contaminated, cleaner air (Miller, Pogue, Gough, & Davis, 2009). In healthcare facilities, staff may also have higher productivity with fewer sick days, which may represent potential financial savings.

This dissertation study attempts to identify building performance variables that are conducive to productivity and comfort by assessing the extent to which LEED certified healthcare settings provide an appropriate functional environment. Architects, facility representatives, constructors, and LEED accredited professionals will benefit from understanding the impact of LEED strategies related to indoor environment quality on comfort and performance. Designers will be able to design better indoor environments, which contribute to more sustainable healthcare design practices.

1.3 Purpose of the Study

The goal of the study is to assess staff overall comfort and performance in LEED certified healthcare settings. The reason to choose staff rather than patients is that patients usually stay in the environment for a short period, not long enough for them to adapt to the new setting. Staff, on the other hand, work in these environments for extended periods of time. The objectives of the study are to:

- Evaluate the relationship between staff comfort and IEQ variables (temperature, heating, cooling, ventilation, lighting, noise and controllability, etc.) in LEED certified healthcare settings.
- Evaluate the relationship between staff productivity and IEQ variables (temperature, heating, cooling, ventilation, lighting, noise and controllability,

etc.) in LEED certified healthcare settings.

- Evaluate the effectiveness of LEED strategies (temperature, heating, cooling, ventilation, lighting and controllability, etc.) for staff perceived comfort and performance.
- Identify key LEED attributes for comfort and productivity as evidence-based design in healthcare settings.
- Generate guidelines for effective LEED strategies in healthcare settings design relative to staff comfort and performance;

1.4 Research Hypotheses

In this study, a mixed-method approach was used, including surveys, and qualitative interviews. Hypotheses are as follows:

1. In a hospital case study, a LEED certified building will report higher staff ratings of building performance factors (such as building overall variables; heating; cooling; lighting; noise; personal control over heating, cooling, ventilation, lighting, and noise; comfort overall; and perceived productivity) than a non-LEED certified building.
2. The building performance of LEED certified healthcare settings will have relatively high rank of staff ratings in building performance factors (such as building overall variables; heating; cooling; lighting; noise; personal control over heating, cooling, ventilation, lighting, and noise; comfort overall; and perceived productivity) compared to the buildings in a benchmark database.
3. Building performance variables (such as building overall variables; heating,

cooling, lighting, noise, and personal control over heating, cooling, ventilation, lighting, noise; comfort overall; and perceived productivity) will be rated differently for LEED Gold and Silver certification.

4. Building performance variables (such as building overall variables; heating; cooling; lighting; noise; and personal control over heating, cooling, ventilation, lighting, noise; comfort overall; and perceived productivity) will be rated differently between males and females.
5. Building performance variables will have a positive relationship with overall comfort.
6. Building performance variables will have a positive relationship with perceived productivity.

2. LITERATURE REVIEW

The literature reviewed in this chapter includes two parts. The research theory part consists of history of LEED, LEED for healthcare, LEED system and IEQ, building performance and productivity, and comfort. The methodology part includes methods in evaluation of building performance. The history of LEED section addresses the development of LEED and the difference between versions. The LEED for healthcare section discusses the difference between LEED for healthcare and LEED for new construction. Building performance and comfort reviews the relationship between temperature lighting, noise, controllability, and comfort and productivity. The last section discusses the post occupancy evaluation, questionnaire survey and qualitative interview. Literature is related to the proposed study; the theory part supports the affect of building performance on occupants' comfort and productivity, the methodology part helps to confirm the methods employed in the proposed study.

2.1 History of LEED

The LEED rating system defines and measures green buildings; it was developed by the members of the U.S. Green Building Council (USGBC, 2006), which was formalized in 1993. The Council stipulates that "the composition of the [LEED rating] committee is diverse; it includes architects, real estate agents, a building owner, a lawyer, an environmentalist, and industry representatives. This cross section of people and professions add[s] a richness and depth both to the process and to the ultimate product" (USGBC, 2009a, p. xi).

2.1.1 Development of LEED

In 1998, the first LEED version 1.0 was introduced through a pilot program; LEED version 2.0 followed in March 2000, and about 8 million square feet of buildings obtained LEED certification at that time. In 2002, LEED version 2.1 was released, and by early 2003, over 100 million square feet of buildings were registered as LEED certified. LEED version 2.2 was released in November 2005 (Barsanti, 2011; Kats, Alevantis, Berman, Mills, & Perlman, 2003), and in mid-2009, LEED USGBC released LEED 2009. From LEED's inception in 2000 through October 7th 2011, the U.S. Green Building Council has LEED certified more than 24,561 projects in the United States and other countries covering over 1.589 billion square feet of area (USGBC, 2011a).

According to the USGBC LEED New Construction Version 2.2 Reference Guide, LEED version 2.2 can be used for new construction (LEED NC), commercial interiors (LEED CI), existing buildings (LEED EB), core & shell (LEED CS), as well as homes and neighborhoods. The LEED Version 2.2 addresses six categories: Sustainable Sites (SS); Water Efficiency (WE); Energy & Atmosphere (EA); Materials & Resources (MR); Indoor Environmental Quality (IEQ); and Innovation in Design (ID). Certification is awarded according to the following scale: Certified 26-32 points; Silver 33-38 points; Gold 39-51 points; Platinum 52-69 points.

2.1.2 Difference between versions

The LEED 2009 Vision and Executive Summary (n.d.) indicates rapid growth; therefore the existing LEED Rating Systems need to be reorganized as well as upgraded in three key areas: "LEED Prerequisite/Credit Alignment and Harmonization", “Predictable Development Cycle” and “Transparent Environmental/Human Impact Credit Weighting.” LEED 2009 adds a regional priority category that previous versions did not have; it also awards extra points according to regionally specific environmental issues (USGBC, 2009b).

USGBC merges the previous rating systems into five reference guides (as shown in Figure 2.1):

1. Green neighborhood development, which includes LEED 2009 for neighborhood development,
2. LEED for homes,
3. Green Building Design & Construction (BD & C), which includes LEED for new construction, LEED for core & shell, LEED for schools, LEED for healthcare and LEED for retail,
4. Green Interior Design & Construction (ID & C), which includes LEED for commercial interiors and LEED for retail interiors, and
5. Green Building Operation & Maintenance (O & M), which includes LEED for existing building (Steelcase, n.d.; USGBC, 2011b).

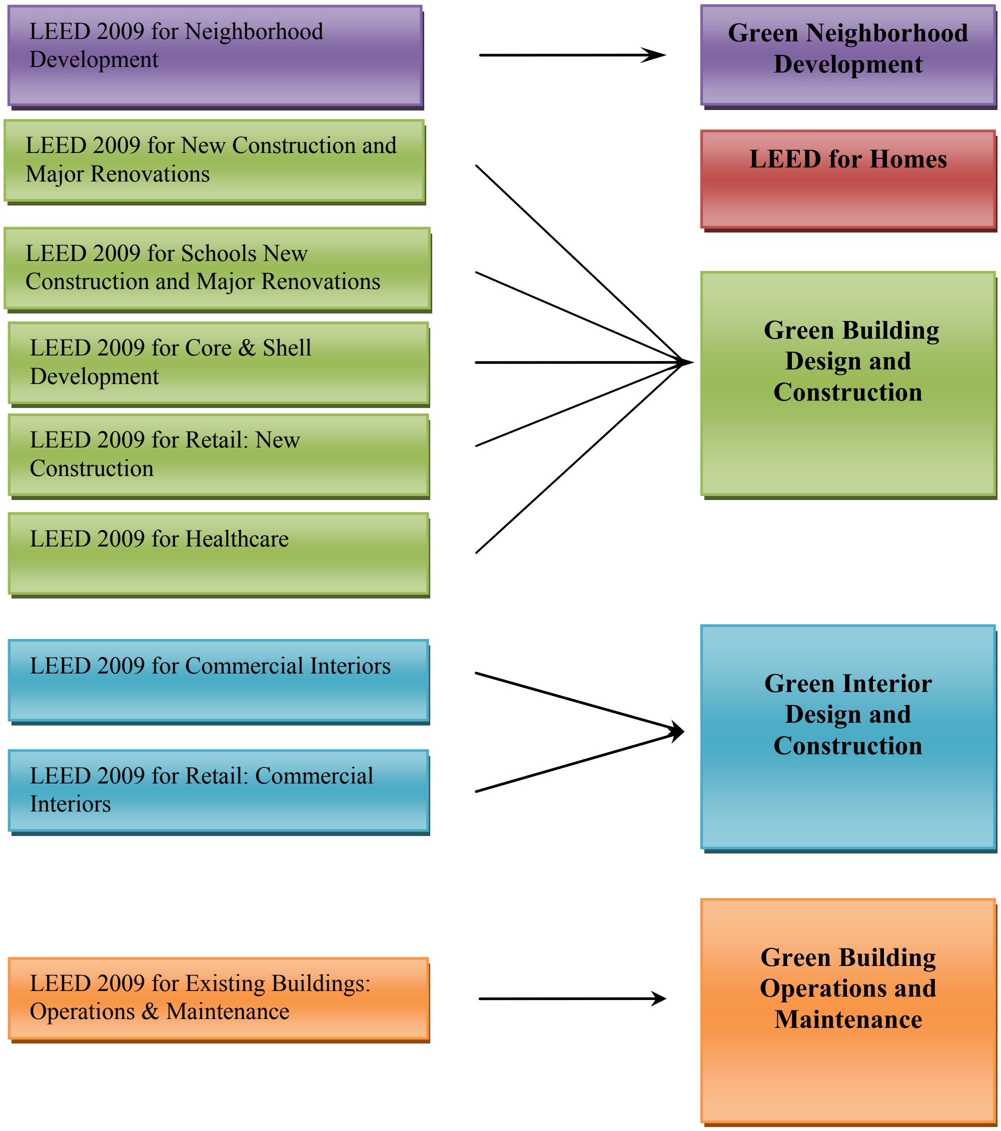

LEED 2009 for Neighborhood Development
Green Neighborhood Development
LEED 2009 for New Construction and Major Renovations
LEED for Homes
LEED 2009 for Schools New Construction and Major Renovations
LEED 2009 for Core & Shell Development
Green Building Design and Construction
LEED 2009 for Retail: New Construction
LEED 2009 for Healthcare
LEED 2009 for Commercial Interiors
Green Interior Design and Construction
LEED 2009 for Retail: Commercial Interiors
LEED 2009 for Existing Buildings: Operations & Maintenance
Green Building Operations and Maintenance

Figure 2.1 Merged LEED rating system (Steelcase, n.d.; USGBC, 2011b)

The credit system for LEED 2009 changed from a 69-point scale to a 100-point scale; for BD&C, ID&C, O&M, certification levels are: Certified 40-49 points; Silver 50-59 points; Gold 60-79 points; Platinum 80-100 points; and plus 10 extra credit points which include 6 pints in "Innovation in Design" and 4 in "Regional Priority" (Steelcase, n.d.).

Compared with the previous LEED version, LEED 2009 includes three major technical advancements:

1) Consolidation of credits and prerequisites; Credits and prerequisites in LEED 2009 are "consolidated and aligned"; this means they are consistent throughout the rating system (USGBC, 2011c).
2) Credit weightings: LEED 2009 revised credit weightings by awarding more points for strategies that have a greater impact on energy saving and result in a reduction of carbon dioxide emissions. Energy & Atmosphere points increase from 17 to 35 (USGBC, 2011c).
3) Regional priority credits: USGBC awards extra points for regionally specific environmental issues identified by USGBC's regional councils, chapters and affiliates. A project may be awarded up to four of the six credits for earning the priority credits (USGBC, 2011c).

2.2 LEED for Healthcare

Healthcare is a special building type that presents many complications. Issues such as 24/7/365 operations, high demands for energy and water, chemical use, infection control, medical waste, and formidable regulatory requirements can pose significant obstacles to implementing currently accepted sustainability protocols such as LEED NC rating system (Green Guide for Healthcare, 2007). There is an urgent need to develop an exclusively sustainable system that can make healthcare facilities green and sustainable and at the same time improve patient outcomes, well-being, staff productivity, and energy efficiency. After six years of planning and negotiations, LEED for Healthcare (LEED HC) was approved on November 16, 2010 by 87% of voting USGBC members (Ferenc, 2011). Beginning in January 1st, 2012, if buildings that include 60% healthcare space and are licensed or provide federal inpatient, outpatient or long term care want to obtain LEED certification, are required to use LEED HC as the rating system to obtain LEED certification (Table 2.1).

Table 2.1 LEED for Healthcare Applications (USGBC, 2011d)

	Percent of building square footage dedicated to healthcare use		
	more than 60%	40- 60 %	Less than 40 %
Licensed or federal inpatient care, outpatient care, long-term care	Must use LEED for Healthcare	Should use LEED for Healthcare	May use LEED for Healthcare
Other medically related buildings	May use LEED for healthcare	May use LEED for Healthcare	May use LEED for Healthcare

2.2.1 Difference between LEED HC and LEED NC

Compared to LEED NC, five prerequisites and twenty-nine credits are modified to address the special issues in healthcare settings; five prerequisites and fourteen credits were newly added in LEED HC. USGBC, (2011) shows the changes of LEED HC from LEED NC, the highlighted prerequisite and credits are newly added.

2.3 IEQ and LEED System

Indoor environmental quality (IEQ) relates to the thermal condition, air quality, lighting level, and acoustics. All these aspects of the indoor environment as a whole may have an effect on the occupant's overall comfort and on a building's energy consumption as well (Catalina & Lordache, 2012). In many countries, the assessment of green buildings' environment becomes a valued tool for evaluating the social, economic and environmental aspects in buildings. Buildings should be comfortable and safe for people's daily lives. Therefore, health, safety, comfort and well-being are important factors in the development of sustainable buildings (Yu & Kim, 2010).

The emergence of interest in indoor environmental quality is a windfall for green building design. Much research focuses on improved IEQ, that is air quality, lighting, ventilation, and acoustics, since it has the potential to improve worker productivity and well-being. IEQ design guidelines have become integral to rating systems such as LEED, which combines close adherence to IEQ guidelines with energy efficiency. Enhanced IEQ and controllability over heating, cooling, lighting, ventilation and glare will not increase the energy bill, but will improve interior comfort and boost output at the same time (Mella, 2006).

The Indoor Environmental Quality category in the LEED rating system was created to provide occupants a comfortable and productive environment (Portman, Clevenger, & France, 2006); as such, it is serving as an essential component of the LEED rating system. The LEED IEQ category addresses the indoor environment from the design phase through construction, but it mainly focuses on indoor air quality (IAQ), thermal quality, lighting quality and maintenance of both mechanical ventilation and HVAC systems before and after construction. IAQ compliance results in a large number of LEED credits because of increased ventilation, IAQ management plan, low emitting materials, and indoor pollutant source control. Thermal quality credits are awarded for thermal system controllability, thermal comfort, design and assessment, while lighting quality credits are given for the ability to control both daylighting and artificial lighting (USGBC, 2009b; Yu & Kim, 2010).

The LEED rating system sometimes refers to the standards of other professional organizations in order to establish their credits, following the organization's detailed guidelines on how to meet their requirements. For instance, LEED refers to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRE), for requirements related to ventilation, thermal, filtration and acoustics. For low-emitting materials and recycled content, they refer to several organizations: Forest Stewardship Council, Green Seal, Greenguard, Carpet and Rug Institute, South Coast Air Quality Management District (SCAQMD) Rule, etc. For daylighting and view, LEED refers to the American Society for Testing and Materials (ASTM) and Standard Test Method for

Haze and Luminous Transmittance of Transparent Plastics (Hucal, 2004; USGBC, 2009b).

The majority of research performed on LEED focuses on cost, energy, and water use. Research on indoor environmental conditions that directly affect the quality of an occupant's health and well-being is often forgotten (Lee & Kim, 2008, Yu & Crump, 2007). Luckily, designers and built environment researchers are now emphasizing the importance of occupant evaluation in LEED-certified buildings (Mendler, Odell, & Lazarus, 2005). However, there is no evidence that the indoor environment designed according to LEED standards is comfortable and productive to occupants (Lee & Guerin, 2010). Moreover, environmental factors are usually judged individually as to their effects on occupants, rather than viewed and judged as a whole, even though the occupants experience the environment as a whole (Kim, Kim, Yang, & K. Kim, 2008).

Further, the LEED rating system contributes to the development of sustainable building. In the LEED rating system, IEQ strategies are dominated by mechanical engineering, but IEQ encompasses more than mechanical engineering (Lee & Kim, 2008). Lee and Kim (2008) compared occupant satisfaction and performance between IEQ in LEED certified buildings and non-LEED certified buildings. They found that occupants in LEED certified buildings had higher satisfaction regarding furnishings quality, IAQ, and cleanliness and maintenance quality, but were less satisfied in office layout quality, lighting quality, and acoustic quality than Non-LEED certified buildings. Occupants in LEED certified buildings had more efficient performance in office furnishings quality, thermal comfort quality, IAQ, cleanliness and maintenance quality, but less efficient performance in office layout quality, lighting quality, and acoustic quality than non-LEED certified buildings.

Leaman, Thomas and Vandenberg (2007) used the Building Use Study (BUS) questionnaire survey to compare 22 green and 23 conventional buildings in Australia. They found that the best green buildings (according to the building performance variables in the survey) outperformed the best conventional buildings from the occupants' points of view, and well designed and operated green buildings achieved positive environmental outcomes and feedback for comfort and productivity.

2.4 Building Performance Factors and Productivity and Comfort

Studies demonstrate convincing evidence as to how environmental factors impact work performance. Good design that integrates proper IEQ factors and considers occupants' psychological feelings will have a positive impact on comfort, productivity and well-being (Kubba, 2010). Moreover, Leaman (1995) and Newsham et al. (2009) state that good indoor environment quality has a positive impact on occupants' satisfaction and productivity in office buildings. Several researchers have estimated that improving physical performance conditions increased productivity by approximately 15% (Oseland, 1999). Factors that affect the indoor environmental quality in buildings include indoor air quality, temperature, humidity, ventilation, noise pollution, the amount and quality of light and color, personal control over building systems, the sense of privacy, natural views, connection to nature, building envelope, and finish materials (Kubba, 2010; Singh, Syal, Korkmaz, & Grady, 2011).

Indoor environmental quality and productivity have a close relationship. Frontczak and Wargocki (2011) did a literature survey on the relationship between occupants' overall satisfaction and different indoor environmental factors, which included thermal comfort, acoustic, air quality and general lighting. They found that thermal comfort was slightly more important to satisfaction than the other factors (Figure 2.2).

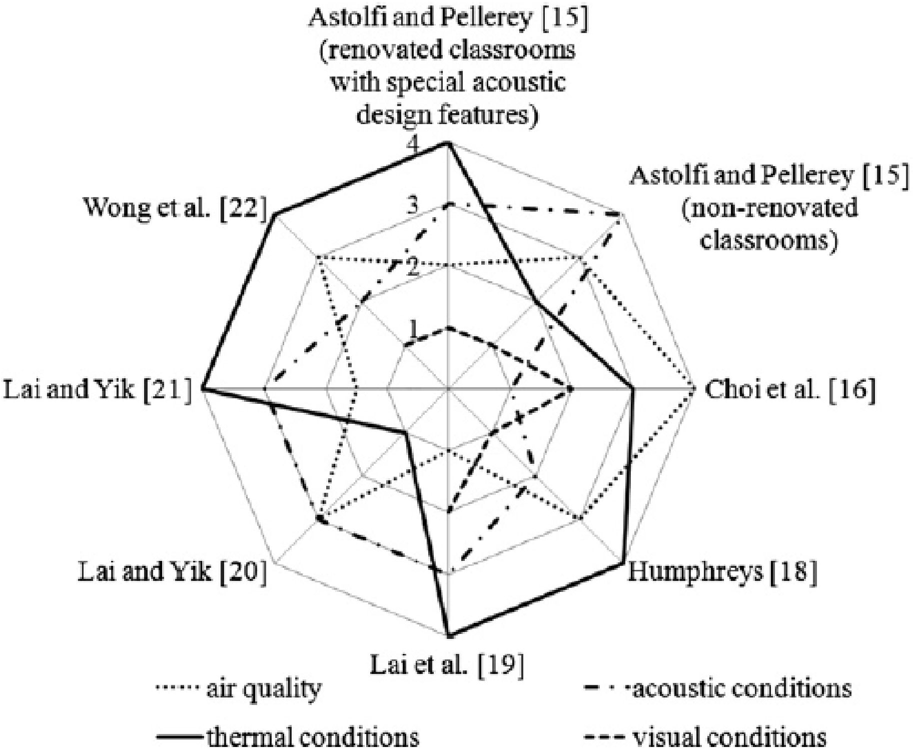


Figure 2.2 Importance of building performance factors for overall satisfaction (higher number means more important) (Frontczak & Wargocki, 2011)

2.4.1 Temperature

Thermal conditions dominate comfort. In buildings, satisfied occupants are those who would rate the temperature as just about right, slightly cool, or slightly warm (Fanger, 1972). One study found that 94% of occupants complained that the temperature was too cold, and 91% complained that the temperature was too hot (Office Temperature Study examines Comfort-Cost Relationship, 2009).

Why does temperature have an impact on productivity? Because in hot or cold spaces, occupants may be distracted by their surroundings and therefore be less able to focus on work. Research shows that people cannot perform normally and efficiently in very hot and very cold workplaces (Parsons, 1993). Moreover, Vischer (1989) demonstrated that thermal comfort was related to air quality; warm air can make occupants feel that the air is stuffy, while cool air is perceived as fresh.

Temperature has a significant impact on productivity; a worker’s performance suffers when temperatures fall out of the comfort zone (Andersson, Boerstra, Clements-Croome, Fitzner, & Hanssen, 2006; Mohamed & Srinavin, 2002), or the indoor temperature is increased (Federspiel et al., 2002; Link & Pepler, 1970; Niemela, Hannula, Rautio, Reijula, & Railio, 2002). Lan, Lian and Pan (2010) investigated the productivity of 21 people in a laboratory experiment in which the temperature was 17 degrees C, 21 degrees C, and 28 degrees C separately. The results showed that thermal discomfort caused by high or low temperature had a negative impact on productivity. Studies found a relationship between decrement in productivity and temperature raised from 25 degrees C to 33 degrees C. Additionally, they found that when the temperature went up to 21-22 degrees C, performance increased; participants had the highest productivity when the temperature was around 22 degrees C (Seppänen, Fisk, & Faulkner, 2004; Seppänen, Fisk, & Lei, 2006).

When employees feel cold, they make more mistakes and might be inefficient; the optimal temperature for employees is 22 degrees C to 25 degrees C (Budak, 2011). In factories, occupants in a slightly cooler or warmer environment might have higher productivity than in a neutral, comfortable environment (Ye, Chen, & Lian, 2010).

During the day, stable temperature is not conducive to productivity. Ngarmpornprasert and Koetsinchai (2010) found that a satisfactory temperature for office workers is 26 degrees C to 28 degrees C in the morning and 24.5 degrees C to 26 degrees C in the afternoon and evening. These temperature settings can improve the employees' productivity by 18% in the morning, 1% to 15% in the afternoon, and 7% in the evening.

2.4.2 Lighting

Lighting, which includes daylighting, artificial lighting and control of glare, plays an important role in peoples' daily lives. People's daily circadian rhythm, the pattern of sleep and waking, is strongly influenced by the timing of exposure to light and darkness (Gooley, 2008).

Analyzing the visual demands for workplace occupants is critical to lighting design. Designers should utilize daylighting to the maximum, and artificial lighting should be added only when necessary to complement the daylighting in a space (Vischer, 1989). Successful use of daylighting depends on determining where the glass is and of what quality it is, what amount of light it admits, and how well glare is controlled (Mella, 2006). Good daylighting design can increase worker productivity and visual comfort (Abdou, 1997; Hwang & Kim, 2011). Most of us prefer natural light to overhead fluorescents. One study showed that sunlight and a natural view could reduce job stress (Budak, 2011). Heschong Mahone Group (HMG) concluded that students in the classroom with more natural light had a 25% higher score than those whose classrooms had less daylighting (Kubba, 2010).

Numerous studies focus on how lighting influences indoor environmental quality. Lighting has been linked to occupant well-being and creating conditions conducive to productivity. Romm and Browning (1994) reported that improved lighting can increase productivity and reduce absenteeism, which can result in a significant economic benefit. Better lighting conditions can result in better work performance (in terms of higher speed and lower failure rate), lower accident rate, less absenteeism, and better health and well-being. Further, it might increase productivity by about eight percent in the metal industry (van Bommel, van den Beld, & van Ooyen, 2002). Another study found that because of poor lighting, one out of four workers experienced a loss in work time, and they estimated that improvements of the office lighting system could increase productivity by three to five percent (Bloom, 2008).

Hospitals are a special building type that encompass a broad range of functional departments and operate 24/7/365. The lighting design of a hospital should meet the separate and even conflicting requirements of different kinds of occupants such as staff, patients and visitors (Forster, 2005). Proper lighting design in a hospital is especially important. Lighting levels can affect staff effectiveness while they are performing critical tasks such as dispensing medical prescriptions (Ulrich et al., 2004). Kakooei et al. (2010) assessed the impact of bright light during breaks on the subjective alertness of nurses in a hospital, and they found that bright light could significantly improve alertness.

2.4.3 Noise

The acoustical environment plays an important role in people's daily lives. The goals of acoustic design are to amplify wanted sounds and eliminate undesired sound; people prefer to work in a quiet environment, but not one totally free of sound (Vischer, 1989). Occupants need a good acoustical environment, but realistically, noise is everywhere in buildings, the noise sources include HVAC systems, colleagues, vacuums, and pumps. For healthcare settings, medical equipments are another noise source.

Good design can mitigate noise pollution levels to some extent, but sustainable design strategies sometimes have negative impact on acoustic design. For example, some LEED strategies can make acoustic design difficult; operable windows and slots for natural ventilation allow external noise, and the lack of recycled material choices with the required acoustic properties makes acoustic design difficult (Field, 2008).

Many studies show that noise plays a significant role in an occupant's stress and productivity. Evans & Johnson (2000) measured forty female clerical workers' performance in a low intensity noise environment, and they found that after three hours exposure to the noise, workers attempted unsolvable puzzles less often. One study measured 2,458 workers' productivity, absenteeism and accidents in high and low noise levels in the textile industry. The study demonstrated that workers in a high noise level environment had less productivity and more absenteeism than workers had in a low noise environment, and concluded that decreasing noise could be conducive to employee productivity and well-being (Noweir, 1984).

Since well-planned acoustics can mask unwanted noise, acoustic design is gaining attention, especially in healthcare design. Besides the normal noise from building systems and the people in those buildings, hospitals also have a cacophony of equipment noise, such as ventilators, beepers, buzzers and assorted alarms. Researchers have found that the US Environmental Protection Agency (1974) standard of 45 decibels for rest and sleep in the hospital is often exceeded (Topf, 2000). Data gathered at various hospitals over the last 45 years indicate a trend of increasing noise levels during both daytime and night hours (Busch-Vishniac et al., 2005). Therefore, USGBC has added acoustic strategies in LEED for healthcare (USGBC, 2010a).

According to Ulrich et al. (2004), more than 130 research papers published before 2004 focused on noise in hospitals. In the newborn ICU, Evans and Philbin (2000) found that noise had a negative impact on infant health, communications between staff and parents, working efficiencies, and overall comfort of all occupants. As a result, they suggested that hospital design use appropriate acoustical design methods to reduce noise levels. Research shows that noise impacts the length of patient stay. Fife and Rappaport (1976) compared the length of patient stay between a noisy construction period and a period without construction noise; they demonstrated that the hospital stay was much longer in the construction period.

The impact of noise on patients has been copiously studied in recent years; however, relatively little research is focused on staff (Ulrich et al., 2004). Evidence shows that noise in hospitals can have a negative impact on staff as well. Noise can harm performance and may even cause medical errors by affecting staff's ability to hear one another (West, 2008). Bayo, García and Garcia (1995) measured the noise level in a university hospital in Spain; the staff felt that their work was interrupted by noise. Blomkvist, Eriksen, Theorell, Ulrich and Rasmanis (2005) examined the impact of sound reflecting tiles and absorbing tiles on the coronary intensive-care nurses, and found that when the ceiling tiles were changed to sound absorbing ones, the speech intelligibility was improved and nurses had less pressure and strain. Topf and Dillon (1988) showed that noise can cause occupational stress, and that staff can have negative reactions to noise, such as burnout.

2.4.4 Controllability

The relationship between control and comfort is very simple. When people feel uncomfortable, they can use the personal control system to adjust environmental conditions to reach satisfactory levels (Heerwagen, 2000).

According to Kubba (2010), occupant control over temperature, ventilation, and lighting are among the most significant factors that affect productivity and thermal comfort. Suttell (2006) claimed that increased control over ventilation, temperature, lighting and daylighting had a significantly increased productivity.

Vischer (1989) suggested that the thermostat zone should be small and the thermostat used to control a given zone should be placed unmistakably. Some studies suggested that providing personal control over temperature enhances productivity and comfort. Personal environmental control assures thermal comfort and acceptability (Brager & deDear, 1998). Kroner, Start-Martin, & Willemain (1992) claimed that individual control over temperature could increase the number of files processed per week per employee in an insurance firm. Menzies, Pasztor, Nunes, Leduc and Chan (1997) demonstrated that when workers were provided individual ventilation control, their productivity was enhanced by 11% compared to the control group of workers who did not have individual control. According to Raw, Roys and Leaman (1990), there was a positive relation between perceived productivity and controllability over temperature, ventilation and lighting.

Wyon (1996) estimated that providing ±3°C of individual temperature control would increase work performance by 2.7 to 7%. Menzies et al. (1997) confirmed Wyon's estimate when he examined the impact of ventilation control on worker productivity in a control group that had no ventilation control compared to an experiment group with ventilation control. After 16 months they found that worker productivity in the experiment group had improved by 11%, and worker productivity in the control group had decreased by 4%.

In regards to lighting, Vischer (1989) demonstrated that lighting requirements should be made for a particular individual and that they should depend upon that person's specific task; the lighting environment should be controlled by its occupants as long as there is no negative impact on an adjacent worker's space. The Heschong Mahone Group found that students who were in classrooms in which the amount of daylighting could be controlled improved faster than those in classrooms without daylighting controllability (Kubba, 2010). Abbaszaden, Zagreus, Lehrer and Huizenga (2006) compared survey results of the indoor environment quality in green and non green office buildings; they demonstrated that a higher percentage of occupants in green buildings were dissatisfied with lighting and acoustic environment than non-green buildings, and that this dissatisfaction could be improved by increasing the controllability of lighting. Hua, Oswald and Yang (2011) suggested that occupants should have control over building systems (on-off switch, a dimmer switch and operable shades) in their work environment to improve comfort, satisfaction and productivity. One study examined the impact of controllable task lighting on productivity between a control group without controllability and a research group with controllability, and the results showed that the research group had a 4.5% higher productivity rate compared to the control group (Juslen, Wouters, & Tenner, 2007).

2.4.5 Perceived productivity and actual productivity

2.4.5.1 Definition of productivity

Leaman and Bordass (1999, p. 6) demonstrate that productivity is the "ability of people to enhance their work output through increases in the quantity and/or quality of the product or service they deliver."

Productivity and occupant satisfaction are closely connected with daylighting, natural views, control over building systems, natural ventilation and improved indoor air (Mendler et al., 2005), but how best to evaluate the productivity of office workers remains a challenge for researchers (Lan et al., 2010). After literature review, Fisk (2000) found that potential financial gains resulted from the improved productivity was huge in the U.S. According to Bluyssen (2010) productivity can be measured:

- Objectively: by measuring the efficiency of performance through experiment tests,
- Subjectively: by using self-reported productivity to assess the individual opinions of people concerning their work and environment, and
- Combined measures: by using both physiological tests and the results of a perceived productivity questionnaire.

In Leaman and Bordass' (1999) study, the staff's perceived productivity was used to measure workers' performance. Much research related to productivity uses this technique.

The researchers explain:

> Work output is impossible to measure meaningfully for all building occupants. How do you compare, for instance, the productivity of telephonists in a call centre with their managers? Our answer is to use scales of perceived productivity, rather than measure productivity directly. (Leaman and Bordass, 1999, p. 6)

McCartney and Humphreys (2002) showed that the advantage of using perceived productivity was that it was not task dependent and was relevant to daily staff practice; researchers could compare the results as long as participants in the study used the same scale. Leaman and Bordass (1999) demonstrated that the advantages of perceived productivity outweighed the disadvantages. The advantages include:

- a single question covers the topic
- the question is common to all respondents giving a basis for consistent comparison
- it can be used for different building types and organizations
- it is cheap and provides a benchmark dataset
- and data analysis is easier with large samples.

Another study showed that self reported sick days were close to the number of recorded sick days (Ferrie et al., 2005). This correlates to the research of Severens, Mulder, Laheij and Verbeek (2000) that measured absence from work as a basis for calculating productivity costs. They found that the recall period for retrospective measurement of sick leave matched the registered absence precisely in a two-month period and about fifty-one percent matched the registered absence in a twelve-month period.

In Haynes' 2007 study, he evaluated the means of calibrating office productivity, and demonstrated that staff productivity was very complex to measure, and that further, there were no universally accepted approaches. Thus, researchers are inclined to utilize perceived productivity as the mean. Given the difficulty of measuring actual productivity, Oseland (1999) reviewed the perceived approach to productivity and claimed that perceived productivity could be as important as actual productivity, and further, perceived productivity can provide useful results; thus, perceived productivity could replace actual productivity. Measuring actual productivity is the most desirable, companies do not have a unified model to measure all types of work. Therefore, measurement of perceived productivity is a justifiable method in the absence of a quantifiable productivity measurement (Haynes, 2008).

2.5 Methods in Buildings Performance Evaluation

Todd and Fowler (2010) said that building performance is difficult to measure due to the many different ways that performance can be viewed. The least studied aspects of building performance are social, health and community factors. Post-occupancy evaluation is one method that can examine building performance from the occupants' perspectives.

2.5.1 Post occupancy evaluation

POE was developed over 40 years ago in the 1960s; the first POE of university dormitories was carried out by Sim van der Rijn of the University of California, Berkeley (Preiser & Nasar, 2008). The goal of a post-occupancy evaluation is to examine the performance of the building in order to improve the quality and to dig out the factors contributing to energy-efficiency and sustainability (Ansaldi, Corgnati, & Filippi, 2009). POE focuses on the requirements of building occupants including health, safety, security, functionality and efficiency, psychological comfort, aesthetic quality, and satisfaction; POE also evaluates the building performance from the occupants' point of view (Federal Facilities Council, 2001). That means the impressions of the occupants are recorded as a measure of the performance of the building (Ansaldi et al., 2009). Questionnaires, interviews, site visits, and field observations are widely used in the POE in order to gather information from occupants about their experience in buildings (Zimring, Rashid, & Kampschroer, 2010).

POE is an essential evaluation tool for building and can help ensure a productive outcome, especially for healthcare facilities. It focuses on building improvement so that historical problems are less likely to be repeated. Healthcare projects are very complicated and usually need several years for construction. Moreover, since medical technology develops rapidly, and medical equipment needs greatly impact healthcare design and construction, it is not surprising that requests for facility modification often occur within the first few months of operation (Manasc & Adams, 1987). Shepley (2002) used POE techniques to examine the time of staff in neonatal intensive care units (NICUs) spent walking before and after the remodeling of the NICU. Many other studies can also be found on healthcare facility evaluations (Shepley, 1995; Shepley, Bryant, & Frohman, 1995; Shepley & Wilson, 1999). *Health Facility Evaluation for Design*

Practitioners is also a very important guide for conducting evaluations for healthcare facilities (Shepley, 2011).

According to the POE model developed by Preiser, Rabinowitz and White (1988), three types of POE were defined: Indicative, Investigative (more extensive than indicative type), and Diagnostic (the most sophisticated type). All three methods had the same basic procedures: 1) reviewing the materials concerning building performance and utilization; 2) using a questionnaire survey to gather performance data from the occupants' perspectives; 3) site walking of building; 4) interviewing a few key people; 5) writing the final report (Cooper, Ahrentzen, & Hasselkus, 1991).

2.5.2 Questionnaire survey

Now that awareness is growing as to how indoor environmental quality impacts occupants' productivity and efficiency, feedback from building occupants often forms an integral part of an IEQ evaluation study. The use of questionnaires provides one of the most economical and efficient ways to gather such information (Kamaruzzaman, Egbu, Ahmad Zawawi, Ali, & Che-Ani, 2011). Thomas and Baird (2006) used the Building Use Studies Survey (BUS) Workplace Questionnaire, which was developed by the United Kingdom's Building Use Studies, to investigate a research building's performance and occupants. Jentsch, James and Bahaj (2006) also used the BUS refurbishment questionnaire from the UK's Building Use Studies to measure the visual and thermal comfort between existing building and new expansion. Andersen, Toftum, Andersen and Olesen (2009) carried out a questionnaire survey of occupants in Danish dwellings to get feedback about window use, solar shading use, air conditioning use and lighting use. Hua et al. (2011) developed a multiple tool methodology, which included a questionnaire survey, an interview and an onsite measurement to examine the effectiveness of the daylighting design.

Currently, web based surveys are becoming popular since they have low distribution and return cost, and can receive data easily (Zimring et al., 2010). Zborowsky, Bunker-Hellmich, Morelli and O'Neill (2010) found three U.S. hospitals that had both centralized and decentralized nursing stations; they used online questionnaires to assess nurses' experienced workplace demand, control and support in both kinds of nursing stations. Lee and Guerin (2010) used the IEQ survey (a web based questionnaire survey) database from the Center for the Built Environment at U.C. Berkeley to evaluate the IEQ of workplaces in the LEED certified buildings in the United States. Nome (2008) carried out a web based questionnaire survey to examine worker attitudes and perceptions about different workspace types and alternatives.

2.5.3 Qualitative interview

Interviews are widely used to obtain a large amount of rich and useful information and data (Silverman, 1993; Creswell, 2007). Bryman (2001) summarized three forms of interviews: unstructured, semi-structured and structured.

The unstructured interview is similar to an informal conversation and does not involve a detailed interview guide (Burgess, 1984; Gall, Borg, &Gall 2003). Usually interviewers use a memorandum summarizing the items as a brief reminder to deal with the research topics. The interviewee is allowed to respond freely in the unstructured interview (Bryman, 2001).

In a semi-structured interview, the researcher has a list of questions, often referred to as an interview guide, and the questions are worded according to the interviewer. One problem the semi-structured interview presents is lack of consistency in the way the research questions are asked since questions worded by interviewers may not follow exactly as outlined on the list. Questions that are not on the list may also be asked as the interviewers probe things said by interviewees (Bryman, 2001; Turner, 2010).

A structured interview uses carefully worded questions that are developed before the interview is conducted (Turner, 2010; The International Training and Education Center for Health, 2008). Interviewers always ask identical questions, to minimize the possibility of bias, however, the questions are not so tightly structured so that respondents can express their perspective in their own words (Gall et al., 2003). Turner (2010) explains that standardized open-ended interviews are very popular in researches, since open-ended questions can obtain much detailed information from interviewees and allow researcher to ask follow-up questions.

Usually, the questionnaire survey belongs to a quantitative approach if the data is gathered through scale and analyzed by statistical methods, and the interview represents the qualitative method if it emphasizes the data in the natural setting where they are generated. The post-occupancy evaluation, which combines quantitative and qualitative approaches, is recommended to all public sector building industry clients (Building Research Establishment, n.d.). An industrywide accepted method of POE is still under development; however, in order to make the evaluation process take as little time as possible, the organization of the New Buildings Institute has developed a new POE protocol that includes a facility manager interview and an occupant survey to provide a basic set of performance indicators (Gonchar, 2008).

Several studies use qualitative interviews to determine the interviewees' point of view. Connell (1996) interviewed 12 architects to examine their design process. Additionally, Komas (2005) interviewed 19 respondents with seven open ended questions to gain new insight into archival building documentation in the United States since 1933. One study combined questionnaires and interviews; the researcher used interviews as a supplement to observation results of an on-site walkthrough and questionnaire surveys (Wei, 2002).

3. METHODOLOGY

This chapter describes the methods applied to study the effectiveness of LEED certified healthcare settings. The research design of the study includes the sample selection, questionnaire development, qualitative interview development and procedures of data collection.

3.1 Research Hypotheses

In this study, a quantitative questionnaire survey and qualitative interviews were used. Hypotheses for the quantitative study are as follows:

1. In a hospital case study, a LEED certified building will report higher staff ratings of building performance factors (such as building overall variables; heating; cooling; lighting; noise; personal control over heating, cooling, ventilation, lighting, and noise; comfort overall; and perceived productivity) than a non-LEED certified building.
2. The building performance of LEED certified healthcare settings will have relatively high rank of staff ratings in building performance factors (such as building overall variables; heating; cooling; lighting; noise; personal control over heating, cooling, ventilation, lighting, and noise; comfort overall; and perceived productivity) compared to the buildings in a benchmark database.
3. Building performance variables (such as building overall variables; heating; cooling; lighting; noise; and personal control over heating, cooling, ventilation, lighting, noise; comfort overall; and perceived productivity) will be rated differently for LEED Gold and Silver certification.

4. Building performance variables (such as building overall variables; heating; cooling; lighting; noise; and personal control over heating, cooling, ventilation, lighting, noise; comfort overall; and perceived productivity) will be rated differently between male and female.
5. Building performance variables will have a positive relationship with overall comfort.
6. Building performance variables will have a positive relationship with perceived productivity.

3.2 Research Design

This study measured the overall comfort and perceived productivity of healthcare staff with questionnaires, interviews with facility management, and an evaluation of LEED submittal information. In order to control confounding variables, which include temperature and humidity, the LEED certified healthcare settings included in this study are all in climate zones 2 and 3 shown in Figure 3.1

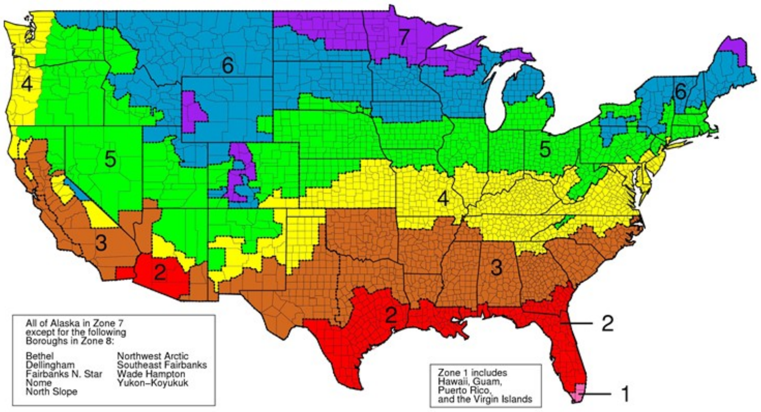


Figure 3.1 Climate zones in the U.S. (Building Energy Codes, n.d.),

3.2.1 Core of this research

My study used questionnaire surveys and interviews as the dominant methods for collecting data, and it employed a case study as a secondary method. The core of this research included four parts:

1) Questionnaire surveys collected data on staff age, gender, overall comfort, perceived productivity, and on the physical building environments in the LEED certified healthcare settings. The survey was distributed to all seven healthcare settings including six LEED certified and one Non-LEED certified buildings.
2) Interviews with facility managers provided their perspective on the buildings' performance. This was conducted for all the six LEED healthcare facilities.
3) A case study was performed for one hospital with two medical buildings (one obtained LEED certification and the other did not). The physical building environmental data were compared for the two buildings.
4) Quantitative data were analyzed with a statistical package, SPSS; qualitative data were analyzed with ATLAS.ti., a computer aided qualitative data analysis software program.

3.2.2 Research procedures

In this study, I used questionnaire surveys and interviews to provide feedback for architects, planners and clients in order to learn the impact of different building design factors and technologies on occupant comfort, satisfaction and productivity. The research procedure involved five phases shown in Figure 3.2:

1) Selected study samples. As of November 1, 2010, nine healthcare settings in climate zone 2 and eight healthcare settings in climate zone 3 had obtained LEED NC certification (USGBC, 2010b). Due to the limited number of site options, the study samples were not randomly selected. Seven healthcare facilities were selected in climate zones 2 and 3 (three in climate zone two and four in zone three). Six of them received LEED NC, one was not LEED certified, and all of them had been in use for at least six months as of November 1, 2010.

First, I searched the entire database of the LEED Registered Project Directory from U.S. Green Building Council using the term "registered healthcare settings." Under the "owner organization" category, the key words: "medical center," "healthcare," "clinic," "hospital" and "cancer center" were used to define the healthcare settings. Second, all healthcare facilities were selected, and their locations were examined on Google map to further screen out those in climate zones two and three. Then, I emailed the designers to confirm the selected healthcare settings' functions. Finally, I contacted the managers, directors, or researchers of these healthcare settings to find the final candidates who were willing to participate in my study.

2) Distributed building evaluation questionnaires. I analyzed the relationship of productivity, comfort and the building performance variables in the survey; and compared the building performance variables between the LEED certified hospital and Non-LEED hospital.

3) Conducted interviews. The pilot study suggested modifications to the original interview questions, which informed the formal interviews with the facility managers in these selected healthcare settings; analyzed data and constructed a theoretical model to discover the facility managers' concerns and views pertaining to their LEED certified healthcare settings.

4) Completed the dissertation with collected data and the results from statistical analyses.

5) Found building performance problems in these healthcare settings, and in terms of the perspectives from the facility managers, possible solutions were sought for these issues.

6) Used the results of the quantitative and qualitative analysis to propose further improvements for healthcare settings, and developed guidelines for effective sustainable strategies for healthcare settings design.

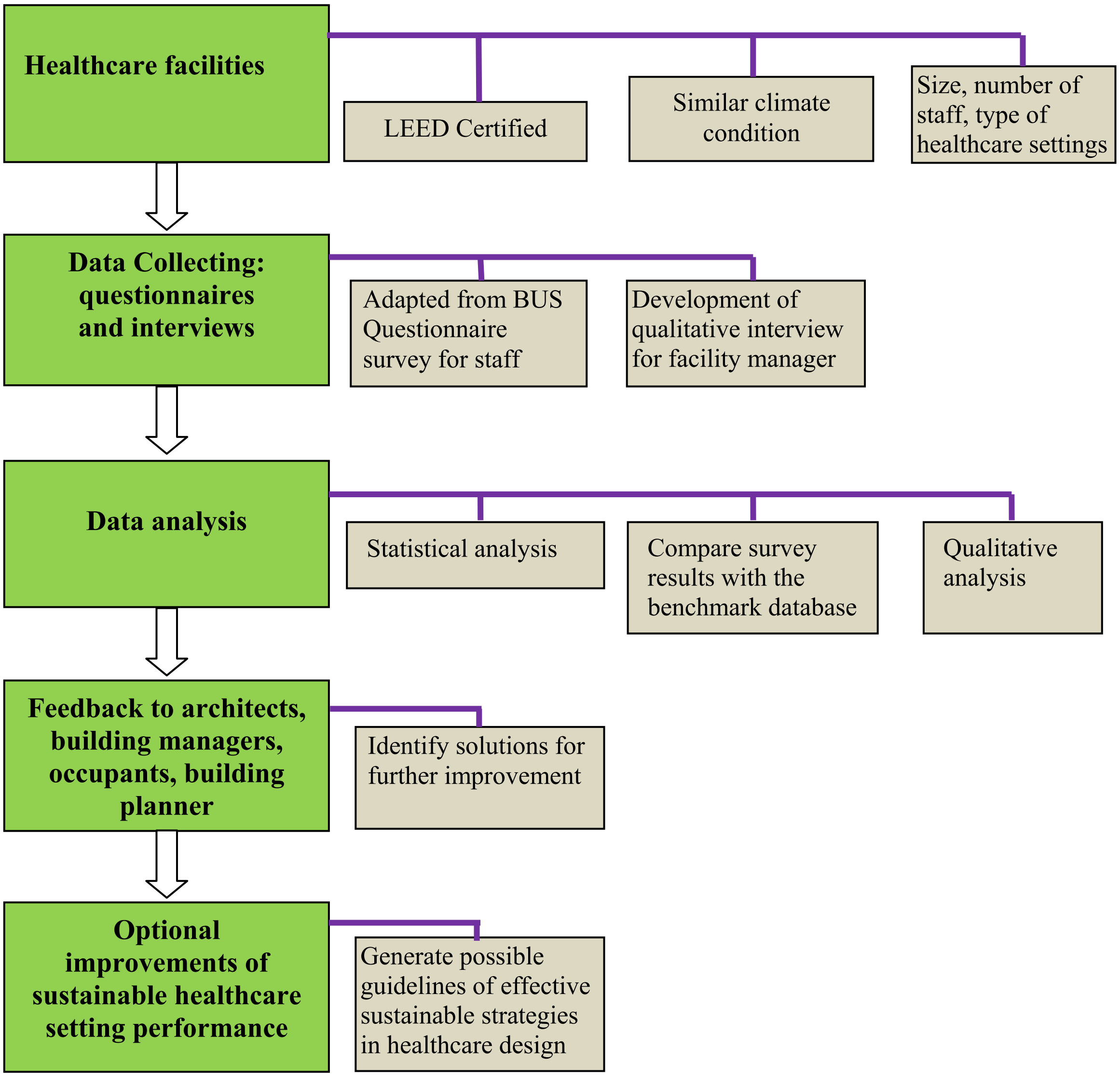

Healthcare facilities
LEED Certified
Similar climate condition
Size, number of staff, type of healthcare settings
Data Collecting: questionnaires and interviews
Adapted from BUS Questionnaire survey for staff
Development of qualitative interview for facility manager
Data analysis
Statistical analysis
Compare survey results with the benchmark database
Qualitative analysis
Feedback to architects, building managers, occupants, building planner
Identify solutions for further improvement
Optional improvements of sustainable healthcare setting performance
Generate possible guidelines of effective sustainable strategies in healthcare design

Figure 3.2 Research and feedback process

3.3 Multiple-Methods Approach

3.3.1 Concept of triangulation

A multi-method approach is to use different data collection methods to improve understandings of research (Williamson, 2005). Mixed qualitative and quantitative strategies usually were considered as a way to enhance the rigor of methodology (Burgess, 1994; Carr, 1994; Mason, 1994; Rose & Webb, 1997). Moreover, some researchers claimed the combined quantitative and qualitative method to be a third research method in addition to quantitative and qualitative method (Bryman, 2004; Creswell, 2003; Tashakkori & Teddlie, 1998).

The concept of triangulation can date back to the 1950s (Campbell & Fiske, 1959). Triangulation is a research strategy using multiple approaches; it can help explain and enhance the process of a research (Olsen, 2004; Sim & Sharp, 1998). The principle behind it is that diverse viewpoints and methods can compensate the weakness of each other and finally improve the quality of data (Sim & Sharp, 1998).

3.3.2 Importance of triangulation

Triangulation has received significant attention among scholars and researchers, why should we use triangulation strategies in research?

Denzin (2009) explained that "Triangulation, or the use of multiple methods, is a plan of action that will raise sociologists above the personalistic biases that stem from single methodologies." (p300) The benefits of triangulation include: increasing researchers' confidence on the research results, creating innovative methods of understanding the problems, uncovering findings, and integrating theories (Jick, 1979).

3.3.3 Types of triangulation

Denzin (2009) described four types of triangulations: data, investigators, theories, and methodological triangulation. Data triangulation means the study uses more than one data source in the same research. And he claimed three types of data triangulation: time, space and person. Time triangulation indicates that data are collected at different time intervals to increase the robustness of the data; space triangulation is to collect the data at diverse sites in order to increase the validity of the findings; and person triangulation means people involved in the data collection can vary the robustness of data collections (Kimchi, Polivka, & Stevenson, 1991).

Investigator triangulation is to use two or more researchers to collect and examine the data in the same study (Denzin, 2009). The aim is to use the strengths of one investigator to balance the weakness of another (Sim & Sharp, 1998).

Theories triangulation is the use of two or more theories to interpret the data collected in the same study (Denzin, 2009).

Methodological triangulation uses more than one method in one study, and each method can compensate the other to increase the validity of research. Methodological triangulation can be classified into within-method triangulation and between-method triangulation (Denzin, 2009). Within-method triangulation is to use more than one method to collect data within the same research approach (Kimchi, et al., 1991) which can be within quantitative or qualitative approaches, but not both (Thurmond, 2001). Between-method triangulation means using both qualitative and quantitative data collection methods (Begley, 1996).

3.4 Quantitative Data

The dominant phase of the proposed study consisted of a web-based survey of full-time enrolled staff in LEED NC certified healthcare settings in climate zones 2 and 3 in the U.S. The full time criterion was defined to satisfy a basic assumption of this study, the full time staff is likely to know their building's performance.

3.4.1 Questionnaire development

In order to define the important factors in building evaluation, a comprehensive literature review was completed and researchers working in this field of specialization were consulted. Finally, the questionnaire for this study was adapted from Building Use Studies (BUS), which collected feedback from building users about how well buildings work (Appendix A).

The BUS survey was developed based on Building Use Studies performed from 1985 through 2008. The two-page BUS questionnaire evolved from a twelve-page version first piloted by Building Use Studies in 1985. (Leaman, 2010). According to Leaman (2009), the BUS is a quick and thorough but not simplistic analysis method. Primarily obtained from building occupants, it provides professional feedback data on building performance.

The BUS is an independent occupant survey that gives an impression of how well a building works in order to investigate or diagnose its functions in more detail (Leaman, 2009). The building evaluation questionnaire has quantitative and qualitative variables. Occupants rate variables on a 7-point questionnaire scale, 1=Unsatisfactory; 7=Satisfactory (Leaman, et al., 2007). The two-page survey obtains detailed diagnostics on human needs in buildings by using 63 variables that cover temperature, air quality, lighting, noise, overall comfort, productivity, health, design, image and workplace needs (Thomas & Baird, 2006).

During the development of the questionnaire, two researchers in one healthcare system (including LEED and Non-LEED hospitals) gave many important suggestions on the variables selection. The staff in a healthcare setting is usually very busy; therefore, the questionnaire needed to be short. Otherwise, the response rate could be very low. I selected the final variables based on the following principles: eliminating redundancies, associating LEED strategies and building evaluation, and changing British English to American English ("cleaning" was changed to "cleanliness"). In order to keep the validity and reliability of the BUS questionnaire, I did not change the order and wording of the questions; however, I removed a few sections of the questionnaire since they were not related to my study. The sections I removed were: items exclude gender and age in background section, work requirement and space, health, response to problems, effect on behavior and travel to work.

Next, I transferred the paper-based survey into a web-based one by using a third party online survey software tool, "SurveyGizmo." It offers an integrated Developer Toolkit to do advanced programming to build custom question types and custom reporting (surveygizmo, 2012). The web-based survey followed Dillman's tailored design method (2007); the questionnaires were anonymous, and no identifiers could be used to trace the participants of the survey.

3.4.2 Variables

The final list included 37 variables that were grouped into nine categories: background, the building overall, temperature, lighting, noise, personal control, importance of control, overall comfort, and perceived productivity. The background portion of the survey included age, gender and department. The building overall category was comprised of building design, ability to meet occupants' needs, space use efficiency image presented to visitors, personal safety in and around building and cleanliness. The temperature section included temperature--overall comfort, temperature—too hot or too cold, and stability of temperature in the winter and summer. The noise portion addressed noise comfort, noise from colleagues, noise from other people, noise from inside and noise from outside. Lighting included lighting comfort, natural light, glare from sun and sky, artificial light and glare from artificial light. Personal control consisted of control over heating, cooling, ventilation, lighting and noise.

The dependent variables were the comfort overall and perceived productivity in each of the healthcare settings. The overall comfort was measured in satisfaction. The perceived productivity was measured in percentage decreased or increased by the environment.

The independent variables were building overall, temperature comfort in winter and in summer, noise comfort, lighting comfort and personal control. Other variables included importance of personal control over heating, cooling, ventilation, lighting and noise in the work environment. Table 3.1 shows the final variables of this study.

Table 3.1 Description of variables

Group	**Variable**	
Productivity	Perceived productivity	Dependent Variables
Comfort	Overall comfort	
Building overall	Building design Ability to meet occupants' needs Space use efficiency Image presented to visitors Personal safety in and around building Cleanliness of building	Independent Variables
Temperature	Comfort	Independent Variables
	Too cold or too hot Stability	
Noise	Noise comfort	Independent Variables
	Noise from colleagues Noise from other people Noise from inside Noise from outside	
Lighting	Lighting comfort	Independent Variables
	Natural light Glare from sun and sky Artificial light Glare from artificial light	
Personal control	Control over heating Control over cooling Control over ventilation Control over lighting Control over noise	Independent Variables
Importance of control	Importance of control over heating Importance of control over cooling Importance of control over ventilation Importance of control over lighting Importance of control over noise	Other Variables
Background	Age Gender Department	

3.4.3 Pre-test of questionnaire

A pilot study was conducted to test the instrument and assess the web interface functionality. The web-based questionnaire was sent to individuals who were selected because of specific qualities. Two staff members in one of the hospitals tested their understanding of the survey and some Master of Architecture students or Ph.D. students in architecture in different U.S. locations examined the web interface. The pilot study indicated that the wording and concepts of the questionnaire were easily understood; and that the web interface worked well with different browsers, as well as in different locations. These participants were not included in the final study.

3.4.4 Data collection

Survey data for this study were collected from three LEED certified healthcare settings in climate zone 2 and three in climate zone 3.

Main study: As the principal investigator, I contacted managers and activity coordinators of the selected six healthcare settings via email and telephone to introduce this study and to ask them to distribute the questionnaire to their staffs. Next, I distributed invitation letters that included both a link to the survey and information sheets to the staff via email. In order to increase the response rate, I followed Dillman's tailored design methods (2007). Before the survey, the managers distributed a pre-notice email, and after the survey, they sent three reminder emails to the staff in each healthcare setting. Dillman (2007) cautions, "Without follow-up contacts, response rates will usually be 20-40 percentage points lower than those normally attained, regardless of how interesting the questionnaire or impressive the mailout package. This fact makes a carefully designed follow-up sequence imperative." (p.177) A total of 146 study participants were recruited from the six LEED certified healthcare facilities in climate zones 2 and 3. Response rates were 10% to 94% in different facilities.

Case study: Two of the seven healthcare settings (one LEED and one Non-LEED) were studied to compare building performance between LEED certified and Non LEED certified healthcare facilities. They belonged to one healthcare system in one city; this made it possible to control confounding variables. Figured 3.3 showed the research model of the main and case study.

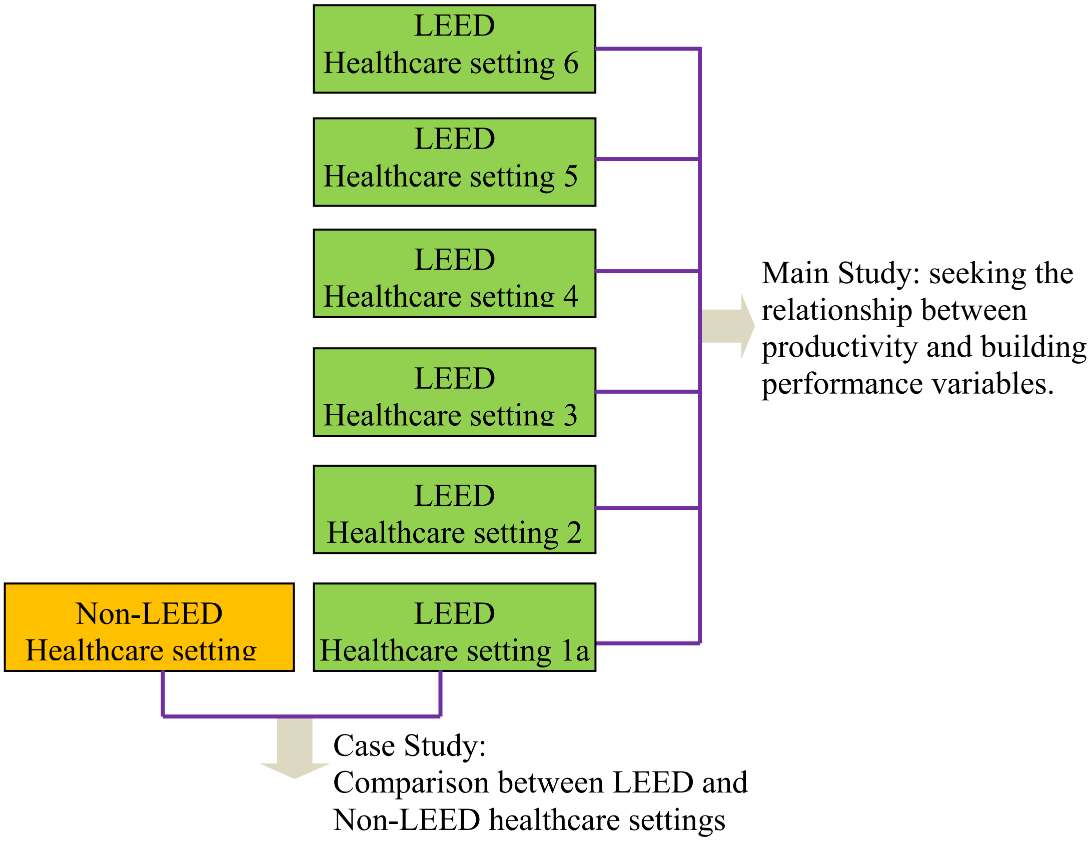

LEED Healthcare setting 6
LEED Healthcare setting 5
LEED Healthcare setting 4
LEED Healthcare setting 3
LEED Healthcare setting 2
Non-LEED Healthcare setting
LEED Healthcare setting 1a
Main Study: seeking the relationship between productivity and building performance variables.
Case Study: Comparison between LEED and Non-LEED healthcare settings

Figure 3.3 Quantitative research frame

3.4.5 Data analysis

The Statistical Package for the Social Sciences (SPSS version 18.0) was used for the quantitative data analysis. Table 3.2 shows the hypotheses and the corresponding statistical methods with descriptions.

Table 3.2 Statistical methods for studies

	Hypotheses	Statistic Methods	Description
Case Study	Hypothesis 1	Independent sample t-test	● Used to examine the difference of variables means of the LEED and Non-LEED healthcare settings.
Main Study	Hypothesis 2	Percentile calculation	Examine the percentile of study buildings in BUS database.
	Hypotheses 3 and 4	MANOVA	● Determine if there was a significant difference between males and females, ● Determine if there was a significant difference between certification levels.
		Two-Way ANOVA	● Compare temperature, noise and lighting comfort variables based on two factors (2 independent variables) LEED certification levels and gender.
	Hypotheses 5 and 6	Multilevel Regression	● Used to establish statistical connections between the variables identified in the hypothesis model and overall comfort; and between variables and perceived productivity. ● It is appropriate in the situation when observations were clustered in a similar situation
	Other Research Focus	Chi Square Test	● A nonparametric chi-square test was used to measure the frequency distribution of cases and examine the association of variables in the temperature, noise and lighting sections. ● All the variables were recoded as category values.

3.4.5.1 Data analysis for case study

Descriptive statistics and independent-sample t-test were used. The descriptive analysis explained the participants' demographic characteristics. The independent-sample t-test emphasized the differences between LEED certified and Non-LEED certified healthcare settings. The hypothesis for this comparison was an LEED certified building will have higher rated building performance factors than a non-LEED certified building.

3.4.5.2 Data analysis for main study

The data analysis for the six LEED certified healthcare facilities included descriptive, correlation and regression statistics. Descriptive explained the mean, standard deviation and the standard error of the mean. It also summarized the frequencies procedures, such as frequency counts, percentages for variables and central tendencies. The description analysis could provide a basic understanding of subjective responses to the performance of LEED certified healthcare settings.

The correlation statistics and multilevel model regression explained the association or relationship among the variables. It included two steps:

The first step was in the temperature, noise and lighting categories. The Chi-square test of independence was employed to study the effect of variables on the temperature overall, noise overall and lighting overall, respectively. This allowed the researcher to find out the statistical relationship between variables under the three categories. The variables were recoded as categorical variables to meet the requirement for statistical analysis. For instance, noise from colleagues was recoded as "1" (too little), “2” (neutral) and “3” (too much), noise overall was transformed into “1” (unsatisfactory), “2” (neutral) and “3” (satisfactory).

The second step was a combination of all the independent and dependent variables. The variables’ mean difference was examined via MANOVA between gender, and certification levels. The purpose of this analysis was to determine if there was a significant difference between male and female, and certification levels in the LEED certified healthcare settings included in this study. The hypothesis was that building performance variables will be rated differently between LEED Gold and Silver certification and between males and females.

The multilevel regression model was used to establish statistical connections between the variables identified in the hypothesis model and overall comfort; and between variables and perceived productivity. The multilevel regression model can analyze the data in a hierarchical structure, that is dependent variables in level-1 and predictors at all levels (Hox, 1995). This model can conduct one model with both an individual level analysis and a group level analysis. It examined the fixed and random effects randomly together in one model (Heck, Thomas, & Tabata, 2010). It is appropriate in the situation when observations were clustered in a similar situation (students in the same class or occupants in one building), the multilevel models can provide more accurate estimation than single (Hox, 2002). The hierarchical linear model (HLM) 6 a professional statistic analysis software package for multilevel model was used to analyze data that is structured hierarchically. The software can create a model in which experimental units are dependent upon variables organized in a nested hierarchy to predict dependent variables with independent variables that account for variations at each level. For my study, there were two levels and I explain the model in the results chapter. The hypothesis was that building performance variables will have a positive relationship with perceived productivity and overall comfort.

3.4.6 Benchmark database

The survey results from the six LEED certified healthcare facilities were entered into the BUS benchmark database to examine mean scores of each individual variable of the benchmark buildings against individual scores for the survey healthcare settings.

The benchmarks are empirically sound as they are based on results from real buildings, not simulations, theories or guesswork (Leaman, 2009). Adrian Leaman confirmed that there were 500 buildings from 17 countries in the full database, but the benchmarks for comparison were comprised of relatively recent studies of between 30 and 100 buildings. For this research, the survey results were compared with 87 buildings (Table 3.3). Leaman said that "they did not use all of them because a) some were old; b) some of the studies had not been carried out to their satisfaction and c) there is a bias toward information from the UK" (A . Leaman, personal communication, April, 7, 2011).

Table 3.3 Full dataset and comparison dataset (A . Leaman, personal communication, April, 7, 2011)

Countries	Full dataset	Dataset for comparison
UK	252	5
Australia	97	11
NZ	34	10
Canada	14	14
USA	8	3
China	7	4
India	8	7
Netherlands	6	6
Ireland	5	3
Malaysia	4	4
Tanzania	2	2
Italy	3	3
Other Countries (7)	13	15

The benchmark database is based on survey results from real buildings which include many types of buildings, mainly offices, schools and university buildings, Healthcare settings were not in the database as a building type, but the comparison was still reasonable and the results seem to be robust to Leaman (A . Leaman, personal communication, April, 5, 2011). Similar studies have been conducted before. Abbaszadeh et al. (2006) obtained survey results of 181 buildings from the Center for the Built Environment at the University of California, Berkeley. They compared 21 green buildings (15 LEED and six self-nominated green buildings) with the remaining 160 conventional buildings. Most of the buildings in the survey were located in the United States, and the remainders were in Canada and Finland. All of these buildings were designated as office buildings, and about one fifth also serve as courthouses, banks, educational facilities, or laboratories. They found that occupants of the green buildings were more satisfied in regards to thermal comfort and air quality than were their counterparts in the conventional buildings. Leaman, Thomas and Vandenberg (2007) compared 22 green buildings with 23 conventional buildings in Australia using data from the BUS benchmark. In their study, the building types included office, educational buildings and libraries.

3.5 Qualitative Data

The second dominant method of collecting data was the semi-structured interview. As the principal investigator, I telephone interviewed the facility managers who knew the building performance well in order to obtain information from their perspective.

3.5.1 Research questions

The research questions for this qualitative section include (1) what building performance elements influence overall comfort and perceived productivity based on the staffs' and facility managers' comments? (2) what are the building performance problems according to the staff and facility managers' comments, (3) and what suggestions for improvement do facility managers offer?

3.5.2 Interview

In-depth, semi-structured interviews were conducted with six facility managers in the selected healthcare settings by telephone. It took around 30 minutes for facility managers to answer interview questions. Several studies were found using semi-structured interview to investigate participants' view related to their research. Interviews in these researches lasted for approximately 30 minutes (Azenkot et al., 2011; Nakahama,2005; Tannock, Hum, Humphries, & Schachar, 2002; Turgut & Irgin, 2009). With the interviewees' permission, the interviews were audio recorded for later analysis. The qualitative interview triangulated the survey and allowed further exploration of the LEED certified healthcare settings' performance. The interview included 15 questions, which were divided into three categories: facility managers' basic information; their perspective on both the building overall and on elements that affect comfort and productivity; and information regarding building performance problems and complaints related to overall comfort and productivity.

3.5.3 Pilot study of interview questions

Performing a pilot study can help a researcher isolate a study's weak points and predict the feasibility of a study's methods and instruments (van Teijingen & Hundley, 2002). The purpose of this pilot study was to assess the interview questions in regards to wording and ease in understanding; to identify the questions that were not easily understood; to examine the questions in light of relevance to this study; and to act as interview training for the principal investigator.

These open-ended questions were discussed at length with a facility manager at Texas A&M University; the discussion lasted about one and one-half hours. He pointed out that some facility managers had engineering rather than architectural backgrounds; therefore, architectural terminologies in some questions were reworked. Some questions were defined as too broad, and were made more specific, for example by providing choices for the questions.

3.5.4 Data collection

Kvale and Brinkmann (2006) defined five hardships when doing an interview. In order to reduce these challenges, they created a linear progression model to help the novice researcher to engage throughout the investigation from the idea to the final report. My study employed their procedures to develop a methodology for interviewing:

1) Thematizing the interview (creating the theme and purpose for the study).

Purpose of the study: to discover the facility managers' concerns and views pertaining to the LEED certified healthcare settings' performance, and to ascertain their awareness regarding factors that support sustainability.

2) Designing the interview.

Recruitment method: first, I contacted the architecture design firm or the hospital directors to get the facility managers' contact information, and then sent them the recruitment email, which included study purpose, interview questions and attached information sheet to ask them if they were interested in participating in the telephone interview. If they agreed to accept the interview, I arranged a time for the telephone interview. If they did not respond to the email, I followed up with another email or a phone call.

3) Number of interviews: According to Kvale and Brinkmann (2006), the number of interviews for common interview studies tends to be about from 5 to 25, based on the law of diminishing returns (with more interviews, less information will be added to the study). Interviews were conducted with the facility manager at each LEED certified healthcare setting, for a total of six interviews. The interviews were not continued, since

the information obtained from the participants was saturated (Lincoln & Guba, 1985). Many studies can be found with limited number of interviews. Madill (2011) conducted 10 semi-structured interviews with members of nine households. Al-Saggaf and Williamson (2004) used online semi-structured interviews to obtain the perceptions of 15 participants. Garland, Plemmons, and Koontz (2006) interviewed six researchers and six practitioners to obtain the perceptions of collaborative process. Ben-Elia, Boeije, and Ettema (2010) conducted semi-structured interviews with 12 participants to study commuters' responses to rewards for rush-hour avoidance. Connell, (1996) and Komas, (2005) interviewed 12 architectural designers and 19 respondents for their dissertation studies respectively.

The number of subjects depends on the purpose of the study. For example, "if the purpose is to statistically test hypotheses about different attitudes of boys and girls toward competition for grades, the necessary sample may be as small as three boys and three girls." (Kvale & Brinkmann, 2009, p.113). As the purpose of the interviews in this study was to triangulate the results of building performance survey, six interviews (one for each LEED certified healthcare setting) are appropriate.

4) Conducting the interview.

Type of questions: interview questions are provided in Appendix B.

Duration of interview: Depending on the responses of the interviewees, the duration of the interviews was from 28 to 36 minutes. The information was kept confidential and no identifiers could be used to track the participants.

5) Transcribing.

The interviews were audio recorded with permission, and transcribed from oral speech to written text. The intended use of the transcript was to convert the facility managers' accounts of the relationship between LEED strategies and building performance into a readable report, rather than to be used as a detailed linguistic or conversational analysis. Therefore, the interviews were transcribed verbatim, except for frequent repetitions, like "uh, hmm," etc.

6) Analysis. The analysis of the qualitative data is explained in the next paragraph.

3.5.5 Data analysis

The study employed the analysis techniques of grounded theory as an analytical method to generate some conclusions based on the qualitative data rather than a theory. This means that the conclusions are derived from the data that have been collected in the study rather than taken from the research literature. Interviews play a significant role in data collection (Leedy & Ormrod, 2005). The qualitative data must consist of the studied participants' perspectives and views (Charmaz, 2002).

According to Strauss and Corbin's (1990, 1998) techniques, the analysis process is: 1) identifying content and examining statements with similar themes, then further identifying subcategories of meaning, 2) making interconnections among themes and subcategories, 3) interpreting results, 4) developing a verbal statement and visual model. As additional information was collected when more participants were interviewed, the first two steps are repeated to refine the categories and their relationships.

Computer-Assisted Qualitative Data Analysis Software (CAQDAS) ATLAS.ti was employed to analyze the qualitative data. It is very user-friendly and it is powerful enough to analyze an immense volume of data. Moreover, it is completely based on the techniques of qualitative analysis used in grounded theory and thus few modifications need to be adapted (Pandit, 1996).

Munirah (2010) stated the basic steps of review of the literature with ATLAS.ti. For the analysis of my interview, the four steps are:

1. Assign the transcription files as 'Primary Documents' or to the ATLAS.ti program.

2. Define the themes of analysis. A theme may be a single word, a phrase, a sentence, a paragraph, or an entire document. For my instance, the theme could be: "lighting," "acoustical environment," "performance problems," and anything you wish to obtain from the research. In ATLAS.ti, the themes are called "Codes."

3. Begin the coding. Coding in Atlas means checking out the transcription, and identifying which word, phrase, sentence and paragraph belong to the specific code. Then highlight the themes, and code the area. In ATLAS.ti the highlighted area of the P-Docs is known as "Quotation."

4. Draw conclusions from the codes. Interpreting the identified themes and their properties, and finding the relationships between codes, quotations. In ATLAS.ti the coded quotations can be retrieved for the write-up.

Several qualitative researches using ATLAS.ti has been published. Pan, Chon, and Song (2008) used ATLAS.ti to analyze 766 articles from travel trade magazines published in 2005. Friese (2011) analyze the financial crisis data with ATLAS.ti. De Gregorio (2009) interviewed 34 individuals and all the interviews were analyzed by ATLAS.ti. And Patrizi (2005) employed ATLAS.ti for the juridical case analysis.

4. RESULTS

4.1 Quantitative Data Analysis

The quantitative data analysis section of this paper includes both the case study and the main study. For the case study, a comparison of LEED (LEED –NC Gold certification) and Non-LEED hospitals addressed the significant differences between the two healthcare settings' performance. For the main study, there are four parts. First, the chi-square analysis for temperature, noise and lighting examined the association of variables under these three categories. This analysis shows that variables under the three categories are associated with the overall comfort of temperature, noise and lighting. In the second part, I compared the mean difference between males and females, and between Silver and Gold certifications. This aim of the analysis was to indicate whether there is a difference in reported indoor environmental factors between males and females, and Silver and Gold certifications. In the third part of the study, correlates of independent variables and dependent variables (overall comfort and perceived productivity) are discussed. This analysis examined the significant predictors for staff comfort and productivity. Finally, in the last portion of the research the study buildings are compared to the BUS Benchmark Database in order to examine their relationship to the broader context of healthcare settings.

4.1.1 Comparison of LEED and Non-LEED hospitals

The data used in the case study were collected in two hospitals, which belong to one healthcare system in climate zone two. After eight weeks, 51 staff members responded from the LEED certified hospital and 113 from the Non-LEED hospital, bringing the total to164 staff that responded to the survey by answering questions regarding building performance, their comfort, and perceived productivity. Figure 4.1 shows the percentage of staff that participated in the two hospitals.

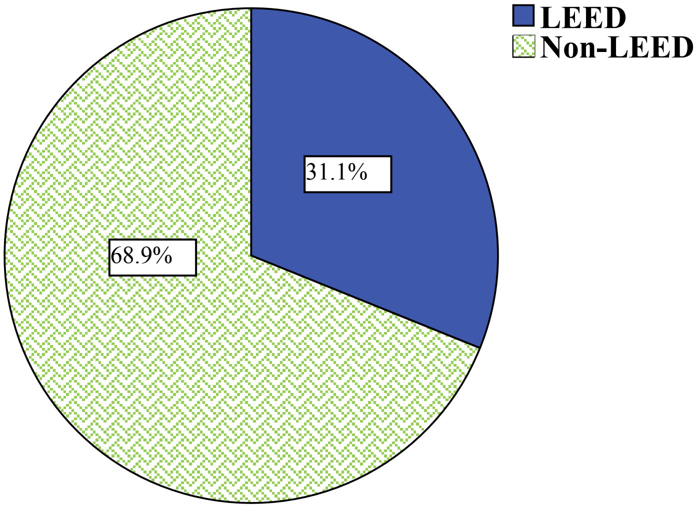


Figure 4.1 Participants in LEED and Non-LEED hospitals

Gender is represented as a dichotomous variable: male and female. In the LEED certified building, the valid survey responses were comprised of 18% males and 82% females. In the Non-LEED building, the percentage is almost the same, 18.2% males and 81.8% females (Figure 4.2).

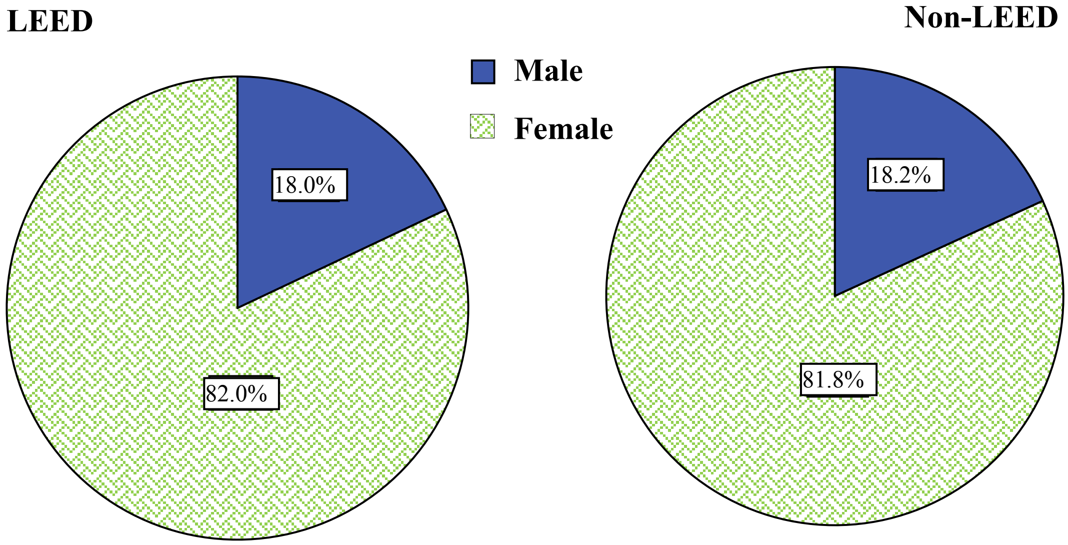


Figure 4.2 Gender of participants in each hospital

The age groups are represented in four categories: under 25, between 25 and 45, between 46 and 65 and over 66. The majority of staff fell in the age group between 46 and 65, the next most populated group was between 25 and 45, then under 25 and finally, over 66. The distribution was the same in both buildings (Figure 4.3).

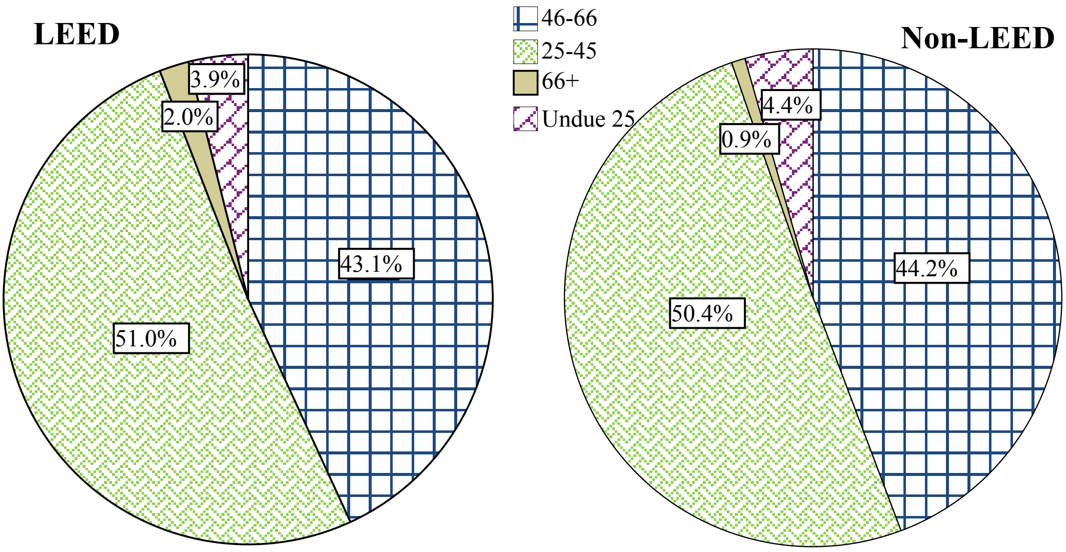


Figure 4.3 Age of participants in each hospital

4.1.1.1 Building overall

In the building overall category, there are six variables: building design, ability to meet occupants' needs, space use efficiency, image presented to visitors, personal safety in and around building and cleanliness. An independent t-test was used to address whether there was a statistical difference between the means of two independent samples (LEED and Non-LEED hospitals). Levene's Test was employed to assess whether the two populations had the same variance. If the variances were equal, then we checked the t-test of the first line “equal variances assumed,” in the SPSS software if the variances were not equal, then we used the t-test from the second line, “equal variances not assumed.”

Table 4.1 showed that all six variables demonstrated significant differences between the two buildings. For the first five variables, the Levene's test for equality of variances was not statistically significant (p-values were above 0.05). This meant that equal variance could be assumed. Hence, the t-value in the line of "equality variances assumed" was used to compare the means for LEED and Non-LEED. For the cleanliness variables, the Levene's test was significant (p-values = 0.002). The t-value of "equal variance not assumed" was used. All six variables' t-values were statistically significant: "Building Design," t(161)=5.868, p-values =0.000; "Ability to meet occupants' needs," t(160)= 4.143, p-values =0.000; "Space use efficiency," t(162)= 3.617, p-values =0.000; "Image presented to visitors," t(160)= 11.129, p-values =0.000; "Personal safety in and around building," t(162)= 3.343, p-values =0.001; "Cleanliness of building," t(162)= 10.119, *p*=0.000. This implied that the means of the six variables for LEED and Non-LEED buildings had significant differences. Cohen's d was used to measure the effect size of the independent t-test; it indicated the amount of difference between the two groups. Cohen (1988) suggested that values of 0.2, 0.5, and 0.8 and above represent small, medium, and large effect sizes respectively. Cohen's d for "Building Design" was 0.997, for "Ability to meet occupants' needs" was 0.699, for "Space use efficiency" was 0.609, for "Image presented to visitors" was 1.92, for "Personal safety in and around building" was 0.57 and for "Cleanliness of building" was 1.606. From the values, the "Building Design", "Image presented to visitors" and "Cleanliness of building" had large difference, and "Ability to meet occupants' needs", "Space use efficiency" and

“Personal safety in and around building” had medium difference. Figure 4.4 showed the means of the variables of LEED and Non-LEED.

Table 4.1 T-test for building overall variables

Independent Samples Test							
		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Building Design	Equal variances assumed	0.018	0.893	5.868	161	0.000	1.542
	Equal variances not assumed			5.937	99.644	0.000	1.542
Ability to meet occupants’ needs	Equal variances assumed	0.022	0.882	4.143	160	0.000	1.151
	Equal variances not assumed			4.084		0.000	1.151
Space use efficiency	Equal variances assumed	0.042	0.837	3.617	162	0.000	1.073
	Equal variances not assumed			3.609	96.053	0.000	1.073
Image presented to visitors	Equal variances assumed	0.892	0.346	11.129	160	0.000	2.699
	Equal variances not assumed			11.48	101.569	0.000	2.699
Personal safety in and around building	Equal variances assumed	0.247	0.62	3.343	162	0.001	0.958
	Equal variances not assumed			3.394	100.102	0.001	0.958
Cleanliness of building	Equal variances assumed	10.284	0.002	9.015	162	0.000	2.495
	Equal variances not assumed			10.119	128.915	0.000	2.495

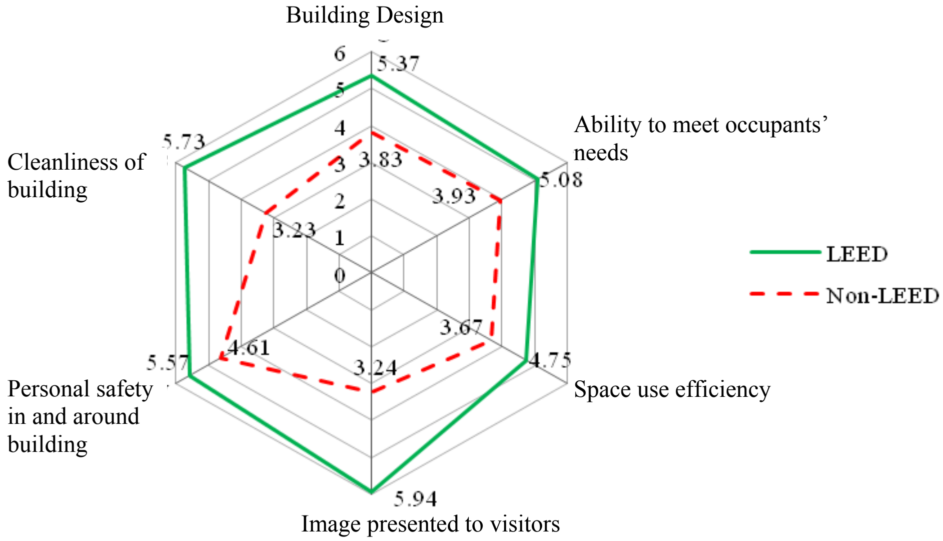


Figure 4.4 Means of building overall variables

4.1.1.2 Environmental comfort

For the four variables in environmental comfort, Levene's test for equality of variances was not significant (significance above 0.05). They used the t-value of "equality variances assumed." Table 4.2 showed that "Temperature Comfort in Winter" (p-value=0.035, Cohen's d =0.35), "Temperature Comfort in Summer" (p-value=0.008, Cohen's d =0.46), "Noise Comfort" (p-value=0.021, Cohen's d =0.39) and "Lighting Comfort" (p-value=0.013, Cohen's d =0.42) had significant difference between LEED and Non-LEED buildings. Cohen's d value showed that the amount of difference was small. Figure 4.5 shows the means of the two buildings and indicates an exceptional result relative to the others. The two lines are almost parallel compared with other figures. This may be because these variables are basic building performance factors.

Usually these basic requirements are met by buildings, so the differences were small or are similar.

Table 4.2 T-test for environmental comfort variables

Independent Samples Test								
		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Temperature Comfort in Winter	Equal variances assumed	3.044	.083	2.128	162	.035	.703
	Equal variances not assumed			2.009	84.670	.048	.703
Temperature Comfort in Summer	Equal variances assumed	.178	.673	2.677	158	.008	.813
	Equal variances not assumed			2.715	95.078	.008	.813
Noise Comfort	Equal variances assumed	.671	.414	2.331	160	.021	.734
	Equal variances not assumed			2.326	96.683	.022	.734
Lighting Comfort	Equal variances assumed	1.102	.296	2.499	160	.013	.790
	Equal variances not assumed			2.563	103.466	.012	.790

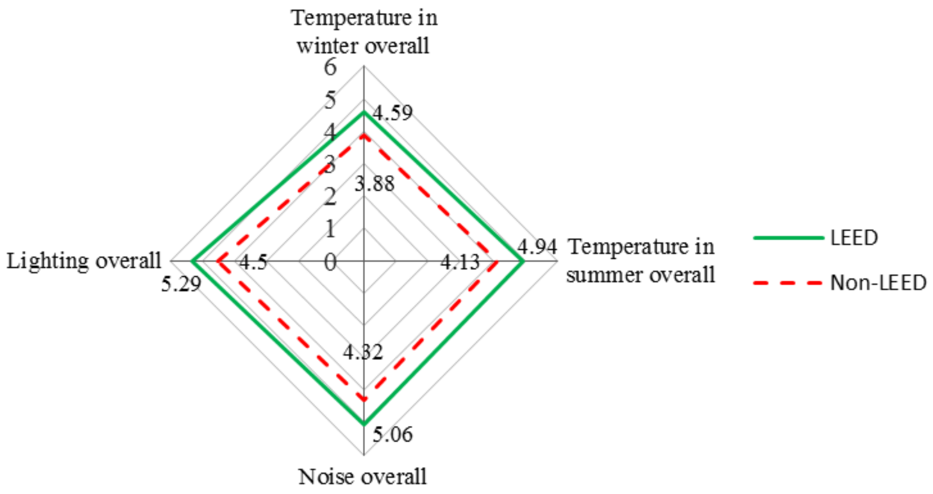


Figure 4.5 Means of environmental comfort variables

4.1.1.3 Controllability

For personal controllability, the means of LEED and Non-LEED were all below the neutral point. This implied that neither of the buildings had good personal controllability for staff (Figure 4.6). The independent t-test (Table 4.3) showed that the "Control over heating" used the t-value from "equal variance not assumed" (p-value of Levene's test=0.01), "Control over cooling," "Control over ventilation," "Control over lighting" and "Control over noise" used the t-value for "Equal variance assumed."

"Control over heating" (p-value=0.004) and "Control over cooling" (p-value=0.007) were statistically significant between LEED and Non-LEED. But for "Control over ventilation" (p-value=0.052), "Control over lighting" (p-value=0.353), and "Control over noise" (p-value=0.174), there was no significant difference between the two hospitals. Further, the value of Cohen's d confirmed that the amount of difference for "Control over heating" (d=0.517) was medium and for "Control over cooling" (d=0.449) was small.

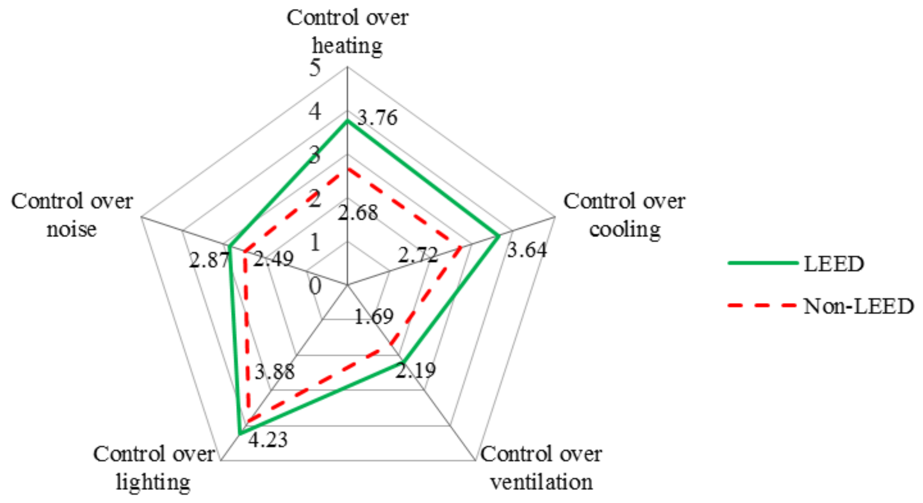


Figure 4.6 Means of personal controllability variables

Table 4.3 T-test for controllability variables

Independent Samples Test								
		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Control over heating	Equal variances assumed	6.880	.010	3.166	161	.002	1.079
	Equal variances not assumed			2.934	79.453	.004	1.079
Control over cooling	Equal variances assumed	3.451	.065	2.721	160	.007	.917
	Equal variances not assumed			2.572	82.990	.012	.917
Control over ventilation	Equal variances assumed	2.219	.138	1.957	154	.052	.503
	Equal variances not assumed			1.857	77.921	.067	.503
Control over lighting	Equal variances assumed	.067	.796	.932	159	.353	.353
	Equal variances not assumed			.931	88.382	.355	.353
Control over noise	Equal variances assumed	2.135	.146	1.366	156	.174	.386
	Equal variances not assumed			1.294	77.243	.200	.386

4.1.1.4 Importance of controllability

The LEED scorecard showed that the LEED hospital obtained the "EQ credit 6.2 controllability of systems: thermal comfort;" this might result in the difference in control over heating and cooling. However, for perceived importance of control, there was no significant difference between the two hospitals (Table 4.4). Although the staff rated controllability low in both hospitals, they ranked the importance of control very high. Figure 4.7 shows the difference in means between the perceived importance of control and real controllability.

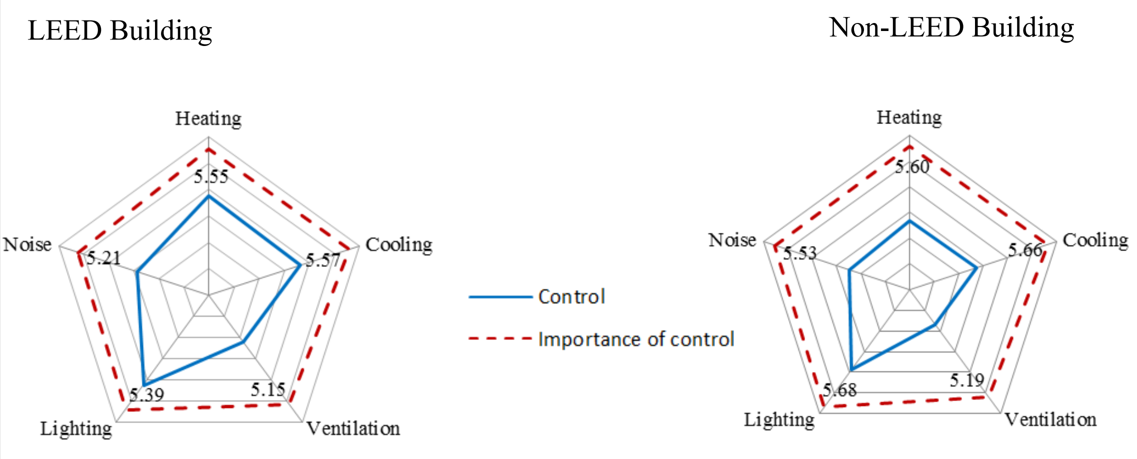


Figure 4.7 Means of control variables and their importance

Table 4.4 T-test for importance of controllability variables

Independent Samples Test							
		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Importance of Control over Heating	Equal variances assumed	.018	.893	-.189	155	.850	-.051
	Equal variances not assumed			-.188	91.292	.852	-.051
Importance of Control over Cooling	Equal variances assumed	.160	.690	-.324	155	.747	-.086
	Equal variances not assumed			-.316	87.878	.752	-.086
Importance of Control over Ventilation	Equal variances assumed	1.948	.165	-.150	154	.881	-.049
	Equal variances not assumed			-.142	79.426	.888	-.049
Importance of Control over Lighting	Equal variances assumed	1.140	.287	-1.033	150	.303	-.288
	Equal variances not assumed			-.965	73.939	.338	-.288
Importance of Control over Noise	Equal variances assumed	1.345	.248	-1.079	152	.282	-.320
	Equal variances not assumed			-1.040	80.983	.301	-.320

4.1.1.5 Comfort overall and productivity

Comfort overall and productivity were compared based on Levene’s test (Table 4.5), “Comfort Overall” and “Productivity” using the t-value for “equality of variances assumed” and “equality of variances not assumed,” respectively.

Both “Comfort Overall” (p-value=0.000) and “Productivity” (p-value=0.004) showed significant differences between the two hospitals according to the staff’s self ratings on building performance variables. The means of these two variables indicated that in both cases, the LEED building had higher staff reported ratings of comfort overall and productivity than Non-LEED building. Value of Cohen’s d indicated that the amount of difference for Overall Comfort (Cohen’s d=0.887) was strong, and the amount for Productivity (0.532) was medium. Figure 4.8 shows the means of these two variables.

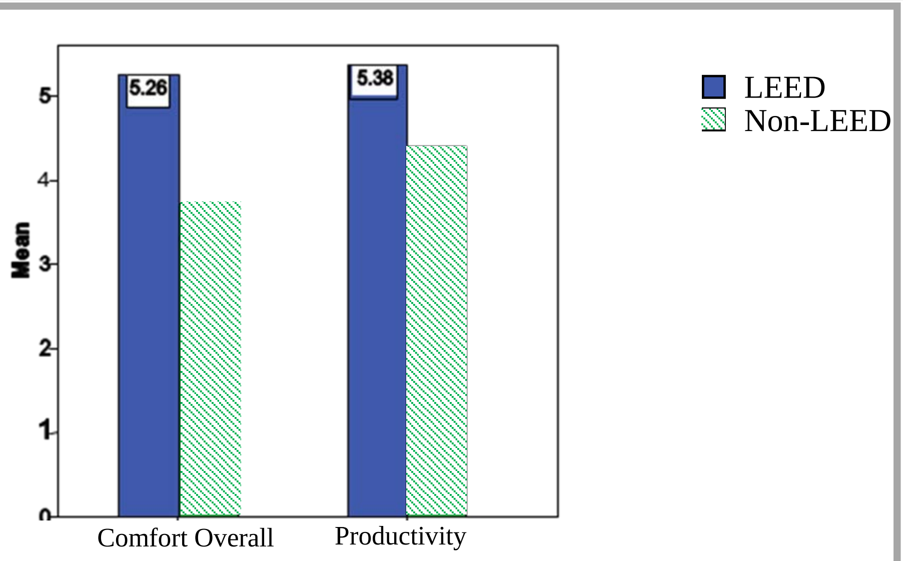


Figure 4.8 Means of comfort and productivity variables

Table 4.5 T-test for comfort and productivity variables

Independent Samples Test								
		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Comfort Overall	Equal variances assumed	1.007	.317	5.353	160	.000	1.429
	Equal variances not assumed			5.145	88.474	.000	1.429
Productivity	Equal variances assumed	7.260	.008	3.315	160	.001	.969
	Equal variances not assumed			2.975	74.656	.004	.969

4.1.1.6 Summary

Through an independent sample t-test, the means of overall comfort, perceived productivity, building overall variables, environmental comfort variables, control over heating and control over cooling demonstrated statistically significant differences; however, control over ventilation, noise, lighting and importance of control were not significantly different. Figure 4.9 illustrates the significant differences between the LEED and Non-LEED hospitals. The higher means of building performance variables in LEED buildings tells us that the staff in LEED hospitals felt more satisfied with building performance variables (building design, ability to meet occupants' needs, space use efficiency, image presented to visitors, personal safety in and around building, cleanliness of building, temperature comfort in winter and summer, noise comfort, lighting comfort, control over heating and control over cooling, comfort overall and productivity) than the staff in Non-LEED hospitals.

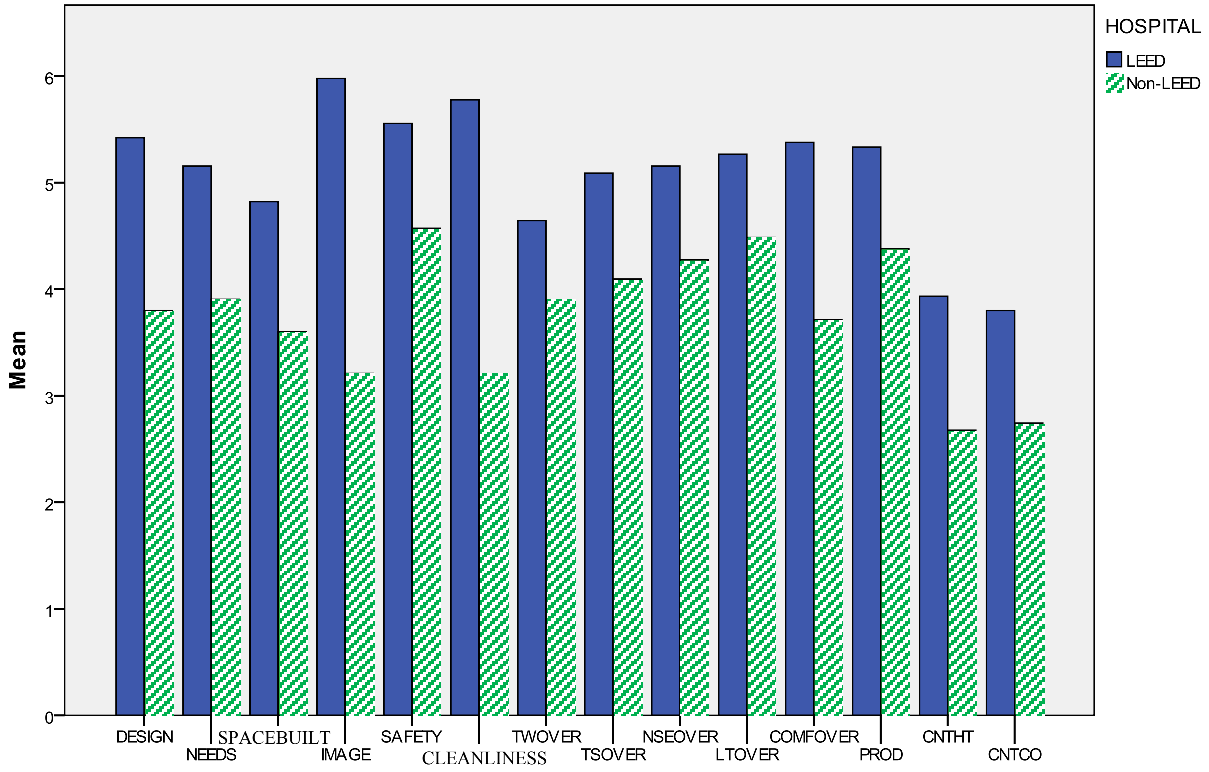


Figure 4.9 Means of variables in LEED and Non-LEED hospitals

4.1.2 Main study survey responses

The data for the main study was collected from six LEED certified healthcare settings, three obtained Silver certification and three were Gold certified. The questionnaire survey was distributed at the end of January 2011. Two months later and after three reminders, a total of 146 responses were obtained from the staff in these healthcare settings; the respondents included many more females (n = 116) than males (n = 26) and four participants who did not indicate gender (still used in the study). As for age groups, most of those who responded were 25 to 45 (n=72) with the 46 to 65 year olds coming in second (n=62), only a few were under 25 (n=6) and even fewer were over 66 years old (n=4) (Figure 4.10).

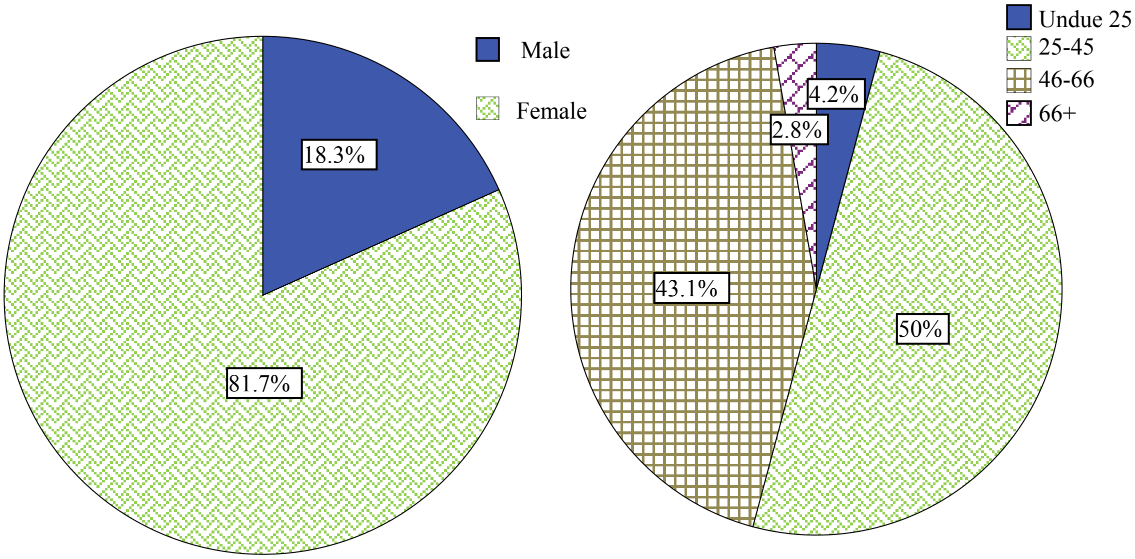


Figure 4.10 Gender and age of participants

The study‘s sample size met statistical analysis requirements using two methods of calculation. First, Bartlett, Kotrlik, and Higgins (2011) stated that according to Cochran’s sample size formula for continuous data, the sample should be more than 118. Second, in the regression model, the optimal ratio of sample size to independent variables was ten to one. When taking the number of independent variables to be entered in the regression and then multiplying it by the number of the ratio, the sample size should exceed 110 based on the 11 independent variables for model 4, which had the most variables (See the table on page 104). Table 4.6 shows the variables' means and standard deviations for results.

Table 4.6 Variables' means and standard deviations for results

Building Performance Factors	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Building Design	1	7	5.08	1.603
Ability to meet occupants' needs	1	7	4.97	1.638
Space use efficiency	1	7	4.66	1.701
Image presented to visitors	1	7	5.78	1.371
Personal safety in and around building	1	7	5.47	1.637
Cleanliness of building	1	7	5.41	1.580
Temperature comfort in winter	1	7	4.42	2.002
Temperature in winter	1	7	4.37	1.454
Temperature stability in winter	1	7	4.17	1.617
Temperature comfort in summer	1	7	4.55	1.768
Temperature in summer	1	7	4.07	1.415
Temperature stability in summer	1	7	4.32	1.611
Noise comfort	1	7	4.62	1.744
Noise from colleagues	1	7	4.23	1.461
Noise from other people	1	7	4.24	1.286
Noise from inside	1	7	4.20	1.389
Noise from outside	1	7	3.58	1.603
Lighting comfort	1	7	5.23	1.780
Natural lighting	1	7	3.62	1.869
Natural lighting glare	1	7	2.93	1.930
Artificial lighting	1	7	4.24	1.313
Artificial lighting glare	1	7	3.29	1.739
Comfort overall	1	7	5.00	1.492
Productivity	1	9	5.52	2.009
Control over heating	1	7	2.55	2.041
Control over cooling	1	7	2.72	2.054
Control over ventilation	1	7	2.24	1.679
Control over lighting	1	7	3.68	2.106
Control over noise	1	7	2.81	1.795

4.1.3 Chi-square analysis for temperature, noise and lighting section

The main study’s first step was to examine the association of variables in the temperature, noise and lighting categories. The chi-square test was used to determine if there was a relationship between the variables and overall comfort of temperature, noise and lighting. Under the temperature section, both “Temperature Comfort in Winter” and “Temperature Comfort in Summer” measured comfort with temperature, both “Temperature in Winter” and “Temperature in Summer” measured temperature, and both “Temperature Stability in Winter” and “Temperature Stability in Summer” measured stability of temperature. The items that measured the same construct should be created as a composite. First from a theoretical point of view, they measured the same construct. Second from a statistical point of view, Cronbach's alpha was used to measure the extent to which these variables were related to each other. Table 4.7 shows that all the Cronbach’s alpha values were greater than the threshold of 0.6 for satisfactory internal consistency reliability (Malhotra & Birks, 2006; Nunnally, 1978). The results indicated that the items in each latent variable formed a reliable composite ($\alpha > 0.6$). (Martensen, Gronholdt, Bendtsen, & Jensen, 2007). The new composite variables were the average of the original raw scores.

Table 4.7 Cronbach's alpha of temperature section

	Cronbach's Alpha	N of Items	Composite variables
Temperature Comfort in Summer	0.773	2	Temperature Comfort
Temperature Comfort in Winter			
Temperature in Summer	0.619	2	Temperature
Temperature in Winter			
Temperature Stability in Summer	0.812	2	Temperature Stability
Temperature Stability in Winter			

Under temperature, noise and lighting categories, better values of some variables' scale are found towards center of scale, "4" equals the best option. For example, the "Temperature" range was from "too hot" to "too cold," and the middle point was the best. Therefore, a nonparametric chi-square test was used to measure the frequency distribution of cases based on these variables, and all the variables were recoded as category values.

4.1.3.1Temperature section

Between "Temperature comfort" and "Temperature," the asymptotic significance of the chi-square statistic was 0.001; therefore, it was safe to say that the relationship observed in the cross-tabulation was real and not due to chance variation, which implied that temperature (too hot, too cold and just about right) resulted in different levels of temperature overall comfort. Phi and Cramer's V values are used to measure the effect sizes in cross-tabulations. Cramer’s V measures the strength of association of two categorical variables when one or both of the variables have three or more levels (Vaske, 2008). Therefore Cramer’s V can be used to measure the effect size in my study. The values of Cramer's V were 0.261 implying a minimal (0.1) to typical (0.3) relationship (Vaske, 2008); the respondents of “just about right” (67.4%) reported statistically higher satisfaction levels than those who rated “too hot” (31.4%) and “too cold” (51.0%). However, for “Temperature Stability” and “Temperature Comfort,” the asymptotic significance of the chi-square statistic was 0.313, so there was no evidence of a relationship between temperature stability and temperature comfort.

4.1.3.2 Noise section

In this section, the relationship between “Noise Comfort” and other noise distraction variables was measured. The chi-square test detected that some cell counts were less than five, so in this situation, the standard test was perhaps not appropriate. Therefore, Fisher’s exact test of independence was used instead (Landau & Everitt, 2004). The test showed that “Noise from Other People” (exact significance value=0.001) and “Noise from Inside” (exact significance value=0.031) had a relationship with “Noise Comfort” and that values of Cramer's V were 0.258 (P-value 0.001); it further indicated that the effect size statistics were significant, which showed that noise from inside impacts the levels of noise overall comfort. However, for “Noise from Colleagues” (exact significance value=0.338) and “Noise from Outside” (exact significance value=0.305), no significant relationship was found with “Noise Comfort”.

4.1.3.3 Lighting section

In this section, association between variables “Natural Lighting,” “Artificial lighting,” “Natural Lighting Glare,” “Artificial Lighting Glare” and “Lighting Comfort” were tested. The chi-square test showed that “Natural Lighting” and “Lighting Comfort” had a statistically significant relationship (significance value=0.009, Phi and Cramer's V=0.009). Respondents who rated too much natural lighting (90.2%) felt statistically higher satisfaction levels than those in the “just about right” (63%) and “too little” (63%) groups. For “Artificial lighting” and “Lighting Comfort,” since two cells have an expected count of less than five, the Fisher's Exact Test was used; the exact significance value was 0.000, and Cramer’s V was 0.311 which indicated a medium effect size relationship between them. Respondents who felt there was “too much” artificial lighting reported higher satisfaction levels (82%) than those in the “too little” (37%) and “just about right” (77.8%) categories. However, for glare from natural and artificial lighting, they did not indicate a significant relationship with lighting comfort.

4.1.3.4 Summary

Under the temperature category, temperature had a significant relationship with temperature comfort, but the temperature stability did not have a significant influence on temperature comfort of the staff. In the noise section, both noise from other people and noise from inside were statistically associated with noise comfort. However, noise from colleagues and outside did not have an influence on noise comfort. In the lighting category, natural lighting and artificial lighting had a significant relationship to lighting comfort, but glare from natural and artificial lighting were not associated with lighting comfort.

4.1.4 Comparison between gender and levels of LEED certifications

Of the six LEED certified healthcare settings, three of them obtained LEED NC 2.2 Silver certification, and three of them achieved LEED NC 2.2 Gold certification. While the LEED Silver certified healthcare settings produced 76 responses, the LEED Gold facilities yielded 70.

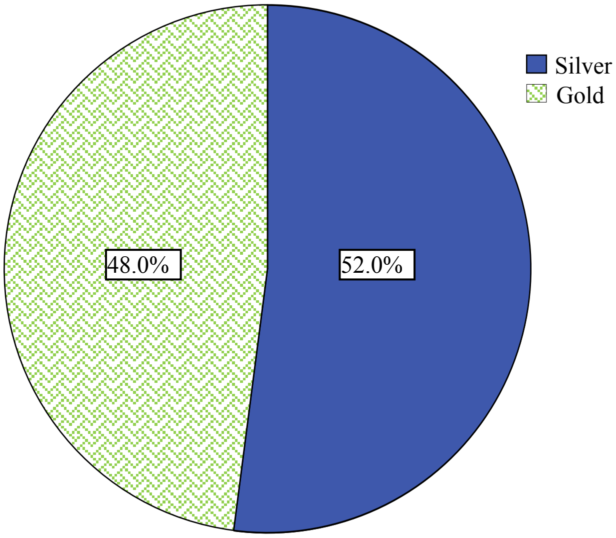


Figure 4.11 Participants in different certification levels

Table 4.8 shows the demographic distribution of participants as well as the response distribution for building variables with mean and percentages among satisfied, neutral and dissatisfied responses. “Building Overall (composite)” had the highest satisfaction percentage in both Silver (73.7%) and Gold (85.7%) buildings. “Lighting Comfort” had the lowest dissatisfaction percentage in Silver (17.3%) and in Gold (11.4%). Interestingly 40.8% of the staff perceived increased productivity in LEED Silver healthcare settings compared with 36.2% in LEED Gold buildings, although there is no significant difference in perceived productivity between the Silver and Gold groups . According to Kats et al. (2003)’s report, 1% productivity could be gained in LEED Certified and Silver certified buildings, and 1.5% productivity could be attributed to LEED Gold and Platinum certified buildings. The report showed that the difference of productivity is very tiny between certification levels.

A multivariate analysis of variance (MANOVA) was used to compare the groups and to determine if there was a significant difference in the means between them on a linear combination of the dependent variables (Pallant, 2007).

Table 4.8 Response distribution of LEED Silver and Gold healthcare settings

		LEED NC 2.2 Silver (BN=3, N=76)	LEED NC 2.2 Gold (BN=3, N=70)
Building Overall (composite)	Mean	5.0	5.5
	Satisfactory	73.7%	85.7%
	OK	1.3%	1.4%
	Unsatisfactory	25.0%	12.9%
Temperature Comfort (composite)	Mean	4.3	4.7
	Satisfactory	48.6%	58.6%
	OK	20.3%	17.1%
	Unsatisfactory	31.1%	24.3%
Lighting Comfort	Mean	5.1	5.4
	Satisfactory	66.7%	77.1%
	OK	16.0%	11.4%
	Unsatisfactory	17.3%	11.4%
Noise Comfort	Mean	4.2	5.0
	Satisfactory	47.9%	70.0%
	OK	20.5%	8.6%
	Unsatisfactory	31.5%	21.4%
Controllability (composite)	Mean	2.5	3.2
	Few control	9.3%	30.4%
	Neutral	6.7%	1.4%
	More control	84.0%	68.1%
Comfort Overall	Mean	4.8	5.3
	Satisfactory	58.1%	69.6%
	OK	23.0%	17.4%
	Unsatisfactory	18.9%	13.0%
Productivity	Mean	5.6	5.4
	Increased	40.8%	36.2%
	Neutral	35.5%	33.3%
	Decreased	18.4%	30.4%
Sex	Male	N=14, 18.4%	N=15, 21.4%
	Female	N=62, 81.6%	N=55, 78.6%
Age	Under 25	N=3, 4%	N=4, 5.7%
	25-45	N=40, 52.6%	N=32, 45.7%
	46-66	N=30, 39.4%	N=32, 45.7%
	66+	N=3, 4%	N=2, 2.9%

A two-way MANOVA was used to test the full model (Appendix C) with all the research-interested variables in order to check for a significant difference between gender and certification levels.

Participants were divided into two groups according to the certification levels (group 1: Silver certification; group 2: Gold certification). The Box's test showed that the significance value was less than 0.05, suggesting that the assumption of homogeneity of variance covariance matrices was not met, and thus the model results were suspect. Then the Pearson correlation was employed to test the multicollinearity among the various dependent variables, and "control over heating" and "control over cooling" were highly correlated, above 0.8. Therefore, they were combined to form a single measure "control over temperature." Further, the Cronbach's alpha for the five variables under controllability was 0.795, and for the six variables under "building overall" was 0.902. Therefore, they were created respectively as a composite to measure "Controllability" and "Building Overall."

A refined model was run using the newly created measures in order to determine the linearity of each pair of dependent variables through a scatter plot (Appendix C).The chart showed that the relationship among "Noise Comfort," "Lighting Comfort" and "Temperature Comfort" was not linear, and that their correlation was low. Hence, they were excluded from the dependent variables and were compared with a separate univariate analysis of variance. The final dependent variables for MANOVA were "Building Overall (composite)," "Overall Comfort," "Productivity" and "Controllability (composite)."

MANOVA is sensitive to outliers, so the univariate and multivariate outliers were examined. A few univariate outliers were found; however, the “5% Trimmed Means” (the new mean of removing the top and bottom 5% of the cases) were very similar to the dependent variables’ mean. Therefore, I retained these cases (Pallant, 2007).

The final MANOVA model was run again, and the significance value of the Box’s test was 0.153, which indicated that the assumption of homogeneity of variance covariance was met. The Levene’s test showed that all of the significance values were larger than 0.05; this indicated that all the variables met the assumption of equality of variance. Then the “Multivariate test” (Table 4.9) showed that the significance level (sig.) of “Pillai's Trace,” “Wilks' Lambda,” “Hotelling's Trace” and “Roy's Largest Root” were all less than 0.05. Consequently, there was a significant difference between certification levels (Silver and Gold). However, the significance value for “sex” and “certification* sex” were 0.151 and 0.589; this indicated that the effect and interaction effect did not contribute to the model.

Given that there is a significant result in the multivariate test, the “Tests of between-subjects effects for final model” (Table 4.10) was used to further examine the difference of Silver and Gold certification levels on all the dependent variables. In the significance column, “Building Overall (composite),” “Comfort Overall” and “Controllability (composite).” recorded a significance value less than 0.05. Hence, the

Table 4.9 Multivariate test for final model

Multivariate Testsb

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.925	395.132	4.000	128.000	.000	.925
	Wilks' Lambda	.075	395.132	4.000	128.000	.000	.925
	Hotelling's Trace	12.348	395.132	4.000	128.000	.000	.925
	Roy's Largest Root	12.348	395.132	4.000	128.000	.000	.925
Certification	Pillai's Trace	.103	3.682	4.000	128.000	.007	.103
	Wilks' Lambda	.897	3.682	4.000	128.000	.007	.103
	Hotelling's Trace	.115	3.682	4.000	128.000	.007	.103
	Roy's Largest Root	.115	3.682	4.000	128.000	.007	.103
sex	Pillai's Trace	.051	1.712	4.000	128.000	.151	.051
	Wilks' Lambda	.949	1.712	4.000	128.000	.151	.051
	Hotelling's Trace	.053	1.712	4.000	128.000	.151	.051
	Roy's Largest Root	.053	1.712	4.000	128.000	.151	.051
Certification * sex	Pillai's Trace	.022	.707	4.000	128.000	.589	.022
	Wilks' Lambda	.978	.707	4.000	128.000	.589	.022
	Hotelling's Trace	.022	.707	4.000	128.000	.589	.022
	Roy's Largest Root	.022	.707	4.000	128.000	.589	.022

Table 4.10 Tests of between-subjects effects for final model

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Certification	Building Overall	7.599	1	7.599	4.656	.033	.034
	Comfort Overall	13.385	1	13.385	7.035	.009	.051
	Productivity	1.586	1	1.586	.393	.532	.003
	Controllability	14.299	1	14.299	7.117	.009	.052

significant differences between Silver and Gold certification levels were on the "Building Overall (composite)," "Comfort Overall" and "Controllability (composite)." Although we know that Gold and Silver groups differed in terms of these factors, we do not know who had the higher scores. Therefore, the means of these variables were checked, the means of "Building Overall (composite)," "Comfort Overall" and "Controllability (composite)" were 5.5, 5.3 and 3.2 in the Gold group compared with 5.0, 4.8 and 2.4 in the Silver group. Although statistically significant, the actual differences between the mean scores were small (fewer than 1 scale point).

Because of the low correlation, "Temperature Comfort (composite)" "Noise Comfort" and "Lighting Comfort" were compared with two-way ANOVA. Table 4.11 suggested that the variance of the dependent variable across the groups were equal (Sig. value greater than 0.05). From the "Tests of between-subjects effects" (Table 4.12), the interaction effect between sex and certification levels was not statistically significant for "Temperature Comfort" F=0.008, p-values =0.929, "Noise Comfort" F=1.811, p-values =0.181 and "Lighting Comfort" F=0.030, p-values =0.862). There was a statistically

Table 4.11 Levene's test of equality of error variances

Dependent Variable	F	df1	df2	Sig.
Temperature Comfort	.228	3	137	.877
Noise Comfort	.633	3	136	.595
Lighting Comfort	1.532	3	137	.209

Table 4.12 Tests of between-subjects effects

Dependent Variable	**Source**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Temperature Comfort	Certification	4.703	1	4.703	1.687	.196	.012
	Sex	11.269	1	11.269	4.042	.046	.029
	Certification * Sex	.022	1	.022	.008	.929	.000
Noise Comfort	Certification	3.263	1	3.263	1.142	.287	.008
	Sex	.436	1	.436	.152	.697	.001
	Certification * Sex	5.173	1	5.173	1.811	.181	.013
Lighting Comfort	Certification	.745	1	.745	.238	.626	.002
	Sex	3.115	1	3.115	.995	.320	.007
	Certification * Sex	.094	1	.094	.030	.862	.000

significant main effect for sex in “Temperature Comfort” (F=4.042, p-values =0.046). For temperature comfort, the mean scores of males was 5.2 and for females 4.4. This indicates that, under the same thermal condition, males tend to feel more satisfied than females. The main effect for certification levels for “Temperature Comfort” F=1.687, p-values =0.196, “Noise Comfort” F=1.142, p-values =0.287, and “Lighting Comfort” F=0.238, p-values =0.626 did not reach statistical significance.

In summary, no significant differences were found for the interaction effect between certification and sex. However, in regards to certification levels, the categories “Building Overall (composite),” “Comfort Overall” and “Controllability (composite)” showed significant higher staff ratings in Gold certified facilities than in Silver facilities. As for sex, statistically significant difference was found in “Temperature Comfort;” it indicates that males feel more satisfactory than females under the same thermal condition.

4.1.5 Building performance and overall comfort and perceived productivity analysis

4.1.5.1 Factor analysis

Prior to using the multiple regression analysis, a factor analysis was used to refine and reduce items and form a smaller number of coherent subscales by looking for groups among the intercorrelation of a set of variables. For example, in this study, a set of five questions were clustered together to measure controllability.

Table 4.13 lists the seven categories contained in the 16 questions. Further, the items in “Building Overall” and “Controllability” were refined by factor analysis. The correlation among the six variables in Building Overall were all above 0.6; the Kaiser-Meyer-Olkin value was 0.876 and the Bartlett's Test of Sphericity was statistically significant (Sig. value was smaller than 0.05), which met the assumption of using factor analysis. The number in table 4.14 indicates loadings of the component matrix. The table shows that one factor was extracted from the six items related to design, needs, space, image, safety and cleanliness. The results show that most staff tend to consider these six concepts as one. From the questionnaire survey, the six variables were also put under the building overall section.

Table 4.13 List of items

Group	**Items**	
Productivity	Perceived productivity	Dependent Variables
Comfort	Overall comfort	
Building Overall	Design	Independent Variable
	Needs	
	Space	
	Image	
	Safety	
	Cleanliness	
Temperature	Temperature Comfort	Independent Variable
Noise	Noise Comfort	Independent Variable
Lighting	Lighting Comfort	Independent Variable
Controllability	Control over heating	Independent Variable
	Control over cooling	
	Control over ventilation	
	Control over lighting	
	Control over noise	
Sex	Female	Independent Variable
	Male	

Table 4.14 Component Matrix. One Component Extracted.
Extraction Method: Principal Component Analysis

Factor	Items	Component
Building Overall	DESIGN	0.906
	NEEDS	0.85
	SPACEBUILT	0.793
	IMAGE	0.821
	SAFETY	0.81
	CLEANLINESS	0.743
Controllability	Control over Heating	0.857
	Control over Cooling	0.87
	Control over Ventilation	0.677
	Control over Lighting	0.659
	Control over Noise	0.628

In addition, one factor was extracted from the five items (Control over Heating, Control over Cooling, Control over Ventilation, Control over Lighting and Control over Noise) under "Controllability." Refined by the factor analysis, the variables for the following multiple regression were "Building Overall (composite)," "Controllability (composite)," "Temperature comfort (composite)," "Noise overall" and "Lighting overall."

4.1.5.2 Multilevel regression model

In multiple linear regression, one important issue is that the observations should be independent of each other. Consequently, special attention must be paid to a regression assumption about the independence of the errors associated with each observation. Violation of this assumption can occur in a variety of situations. For my study, consider the case of collecting data from staff in six different healthcare settings.

It is likely that the staff within each healthcare facility will tend to be more like one another than staff from different healthcare settings, that is, their errors are not independent. Therefore, a multilevel model was used for this study.

A multilevel regression model is appropriate when experimental units are dependent upon variables organized in a nested hierarchy. Even if the groups are established randomly, the group itself will have different influence on results (Corrado & Fingleton, 2011). In a multilevel regression model, there are fixed and random effects. Fixed effects, the primary interest of researchers, can affect population mean and assume observations are independent, while random effects contribute only to the covariance structure of the data associated with sampling procedure and assume some type of relationship exists between observations (SPSS, 2005). For example, in this study, there were two levels of observation: level-1 was the participants and level-2 was the healthcare setting (Figure 4.12). Level-1 was a typical regression model in which "overall comfort" was predicted by a fixed effect of all the level-1 covariates in Table 4.12. The level-1 slope as well as the intercept might be predicted by the random effect of the level-2 grouping variable. Hence, the higher hospitals' level might have different regression slopes and intercepts to predict the "overall comfort" of level-1.

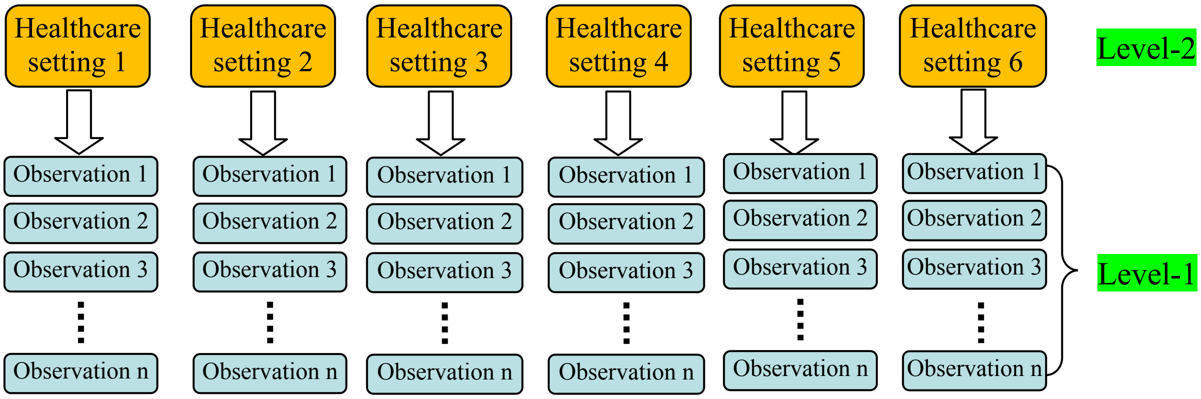


Figure 4.12 Observations nested within each healthcare setting

While a multilevel regression model with random effect between the groups can be replaced by an ordinary regression model with dummy variables, it is still better than multiple regression for two reasons. First, it can function with fewer variables, which is especially helpful when the sample size is limited, and second, it can share information between groups, which will improve the precision of predictions for groups with little data (Buxton, 2008). Many studies have used a multilevel regression model (Alivernini & Manganelli, 2011; Bell, & Dexter, 2000; Cramm, Moller, & Nieboer, 2012; Braun, Jenkins, & Grigg, 2006; Larsen & Merio, 2005; Moineddin, Matheson, & Glazier, 2007; Yusuf, Omigbodun, Adedokun, & Akinyemi, 2011).

Hierarchical Linear and Nonlinear Modeling (HLM 6.0), a software package, was used to analyze the data. HLM is designed to analyze data that is structured hierarchically. The HLM program can generate a linear model to predict dependent variables with response variables that account for variations at each level. Usually, HLM is used in education research because it can solve the problems that present when students are clustered together within classes and classes are clustered together within schools, but it is not limited to educational study. It can be used in any research field that has a hierarchical structure (Scientific Software International, 2012).

The research problem consists of data on staff clustered within healthcare settings; they were i (1…n) level-1 units (staff) nested within j (1…n) level-2 units (healthcare settings). A general model for HLM is given below (equation 4.1 and 4.2):

Level 1: $y_{ij} = \beta_{0j} + \beta_{1j}X_{1ij} + \ldots + \beta_{pj}X_{pij} + e_{ij}$ (4.1)

Level 2: $\beta_{pj} = \gamma_{p0} + \gamma_{p1}W_{1j} + \gamma_{p2}W_{2j} + \ldots + \gamma_{pq}W_{qj} + u_{pj}$ (4.2)

where y_{ij} is the outcome for staff i in healthcare setting j;

β_{pj} is regression coefficients.

X_p is level-1 predictor

e_{ij} is random error in level-1

γ_{pq} is level-2 regression coefficient

W_{qj} is level-2 predictor

u_{pj} is random effect of level-2

For my study, there was no predictor of level-2; equation 4.3 and 4.4 show the specific model:

Level 1: $y_{ij} = \beta_{0j} + \beta_{1j}X_{1ij} + \ldots + \beta_{pj}X_{pij} + e_{ij}$ (4.3)

Level 2: $\beta_{pj} = \gamma_{p0} + u_{pj}$ (4.4)

4.1.5.3 Overall comfort

Four models were analyzed in the following section. Model 1 was an intercept only model. No independent variables were entered into it, and then the predictors were added as fixed effect in Model 2. In Model 3 the independent variables were further added as random effect defined by healthcare groups. These models showed the steps by which I obtained the best model for overall comfort.

4.1.5.3.1 Model 1

First, I analyzed a model with no predicted variables, which was the intercept only model (Model 1, Table 4.15). According to Hox (1995), the intercept only model could give an estimate of the intra-class correlation (level-1 observations from the same level-2 healthcare setting will not be independent but more similar due to the same building environment), and show the deviance to measure the model. It is also used to compare the R^2 with other models. Table 4.15 shows that the "Intercept" is significant (p-value=0.05). This indicates that the intercepts between healthcare settings are different and there are level 2 effects on the model.

Table 4.15 Estimation of variance components for intercept-only model

Random Effect		**Standard Deviation**	**Variance Component**	**df**	**Chi-square**	**P-value**
Intercept	U0	0.34741	0.12069	5	11.01433	0.05
Level-1	R	1.46073	2.13373			

4.1.5.3.2 Model 2

Then a random intercept model with level-1 predictors (Model 1) was analyzed; “Sex,” “Building Overall,” “Temperature Comfort,” “Controllability,” Noise Comfort” and “Lighting Comfort” were entered as fixed effect to predict the dependent variables, but the level-1 intercept was still predicted as a random effect of the level-2 grouping variable. The formula for Model 2 was shown in table 4.16:

Table 4.16 Formula for model 2

Level-1 Model

Y = B0 + B1*(Sex) + B2*(Noise Comfort) + B3*(Lighting Comfort) + B4*(Temperature Comfort) + B5*(Controllability) + B6*(Building Overall) + R

Level-2 Model

B0 = G00 + U0
B1 = G10
B2 = G20
B3 = G30
B4 = G40
B5 = G50
B6 = G60

The p-value from Table 4.17 suggested that “Temperature Comfort” (composite), “Controllability” (composite) and “Building Overall” (composite) were significantly predictors of comfort overall.

Table 4.17 Estimation of fixed effects for model 2

Fixed Effect		**Coefficient**	**Standard Error**	**T-ratio**	**Approx. d.f.**	**P-value**
Intercept	B0	5.166	0.186	27.844	5	0.000
Sex slope	B1	-0.272	0.19	-1.438	125	0.153
Noise Comfort slope	B2	-0.024	0.046	-0.526	125	0.600
Lighting Comfort slope	B3	0.024	0.046	0.514	125	0.608
Temperature Comfort slope	B4	0.235	0.051	4.628	125	0.000
Controllability slope	B5	0.187	0.056	3.347	125	0.001
Building Overall slope	B6	0.688	0.076	9.023	125	0.000

The initial variance component for healthcare settings, from the intercept only model, was 0.121 after level-1 predictors were added, and the between- healthcare setting variance in comfort overall increased to 0.162 (Table 4.18). Controlling for level-1 predictors increased the between-healthcare effect from 5.4% [0.121/(0.121+2.134)] in intercept only model to 19.9% [0.162/(0.162+0.653)]. The between-healthcare effect accounted for 19.9% of the variance in comfort overall scores after level-1 predictors were added.

The variance of comfort overall scores within healthcare settings after adding predicted variables was 0.653 shown in the "level-1" row (Table 4.18). In the intercept only model (Table 4.15), the within healthcare setting variance in comfort overall was 2.134. Therefore, after adding level-1 predicted variables to the model, it reduced within healthcare setting variation of comfort overall by (2.134-0.653)/2.134= 69.4%. This is the estimate of R^2, which indicated that 69.4% of the within healthcare settings variation in comfort overall in the intercept only model was attributable to fixed effects when the level-1 predictors were controlled. Table 4.18 also suggested that after the introduction of level-1 predictors into the model, the variability between healthcare settings were still significant (p-value=0.000).

Table 4.18 Estimation of variance components for model 2

Random Effect		Standard Deviation	Variance Component	df	Chi-square	P-value
Intercept	U0	0.402	0.162	5	29.564	0
Level-1	R	0.808	0.653			

4.1.5.3.3 Model 3

Since some level-1 predictors were significantly related to comfort overall, the third model was analyzed to see if the slope carried across healthcare settings. In model 3, “Sex,” “Building Overall,” “Temperature Comfort,” “Controllability,” Noise Comfort” and “Lighting Comfort” were entered as fixed effect to predict the dependent variables in level-1. These variables, except for “SEX”, were entered as the random effect defined by healthcare groups. From the HLM output (Table 4.19), the formula for model 3 was:

Table 4.19 Formula for model 3

Level-1 Model

Y = B0 + B1*(Sex) + B2*(Noise Comfort) + B3*(Lighting Comfort) + B4*(Temperature Comfort) + B5*(Controllability) + B6*(Building Overall) + R

Level-2 Model

B0 = G00 + U0
B1 = G10
B2 = G20 + U2
B3 = G30 + U3
B4 = G40 + U4
B5 = G50 + U5
B6 = G60 + U6

The “Estimation of fixed effects for model 3” (Table 4.20) showed the average intercept and slope across the six healthcare settings. It illustrated that “Intercept,” “Temperature Overall” (composite), “Controllability” (composite) and “Building Overall” (composite) were significant predictors of comfort overall at level-1. Their coefficients are all positive which indicates that there is a positive relationship between these predictors and comfort overall. According to Field (2005), a predictor that has a smaller p- value and a larger t value will have a greater contribution to the model. Therefore, we find that “Building Overall” (composite) contributed the most to the dependent variable, since it had the smallest p-value (0.000) and biggest t-ratio value (9.1) compared with Temperature Overall” (composite), “Controllability” (composite).

Table 4.20 Estimation of fixed effects for model 3

Fixed Effect		**Coefficient**	**Standard Error**	**T-ratio**	**Approx. d.f.**	**P-value**
Intercept	B0	5.151	0.177	29.141	5	0.000
Sex slope	B1	-0.266	0.184	-1.447	125	0.150
Noise Comfort slope	B2	-0.026	0.044	-0.584	5	0.584
Lighting Comfort slope	B3	0.033	0.046	0.716	5	0.506
Temperature Comfort slope	B4	0.215	0.078	2.764	5	0.040
Controllability slope	B5	0.224	0.067	3.325	5	0.026
Building Overall slope	B6	0.680	0.075	9.100	5	0.000

The random effects are displayed in the “Estimation of variance components for model 3” (Table 4.21). The “Intercept” estimated the between-healthcare settings intercept variation in comfort overall scores. The “LEVEL-1” reflects the within healthcare settings variation in comfort overall scores. The "Noise Comfort," “Lighting Comfort,” “Temperature Comfort,” “Controllability” and “Building Overall” rows represented between-healthcare settings variance in slopes which estimated the strength of the relationships between these variables and comfort overall. The intercept was significant (p-value=0.000); this indicated that the intercept had significant difference between the healthcare settings and that there were level-2 effects on the dependent. However, the slope variance components were not significant (p-value>0.05); this meant that modeling these variables as a random effect of level-2 made no significant effect on the dependent variable.

The “Estimation of variance components” of the intercept only model (Table 4.15) showed that the “Intercept” was significant (p-value=0.05). The “Intercept” in Table 4.21 was significant (p-value=0.000); it indicated that intercepts still had significant variance among healthcare settings after adding level-1 predicted variables as random effects.

The variance component for the intercept of Model 3 was 0.148 compared with 0.162 in Model 2. The ratio was (0.162-0.148)/0.162=0.086, which indicated that adding predicted variables as random effects explained 8.6% of the between-healthcare settings variance in comfort overall.

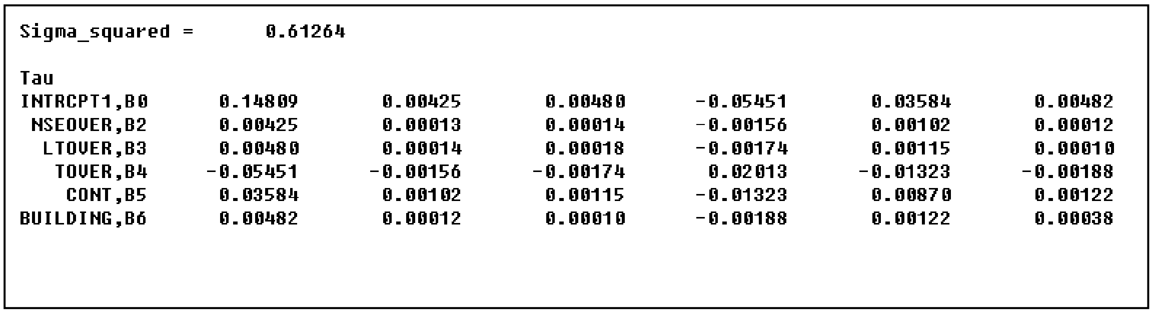
The variance of comfort overall scores within healthcare settings after adding predicted variables was 0.613, as shown in the “level-1” row (Table 4.21). In Model 2, the within healthcare setting variance in comfort overall was 0.653. Therefore, adding level-1 predictors as random effects to the model reduced within healthcare setting variation of comfort overall by (0.653-0.613)/0.653= 0.061. This finding indicated that 6.1% of the within healthcare settings variation in comfort overall in Model 2 could be attributed to between-healthcare setting effects.

The total variance components was the sum of the “level-1” (within-healthcare variance, 0.613) + “intercept” (level-2 intercept variance, 0.148) + level-2 slope variances (0.00013+0.00018+0.0201+0.0087+0.00038) in Table 4.21 + 2* covariances [2*(0.00425+0.0048+ 0.00014 -0.05451-0.00156 -0.00174 + 0.03584 + 0.00102 + 0.00115 -0.01323+0.00482 + 0.00012 + 0.0001-0.00188+0.00122)] in Table 4.22. Therefore the total sum of variance was 0.75, the most variation was from the variation in comfort overall within healthcare settings 0.613/0.75=81.7%. Under controlling for the level-1 predictors, differences in intercepts between healthcare settings accounted for 19.7% (0.148/0.75) of the variation in comfort overall scores, The intra-class correlation indicated that 19.7% of the total variance in comfort overall was due to the between-groups effect on controlling for level-1 predictors.

Table 4.21 Estimation of variance components for model 3

Random Effect		**Standard Deviation**	**Variance Component**	**df**	**Chi-square**	**P-value**
Intercept	U0	0.385	0.148	5	31.013	0.000
Noise Comfort slope	U2	0.011	0.00013	5	3.622	>.500
Lighting Comfort slope	U3	0.013	0.00018	5	2.273	>.500
Temperature Comfort slope	U4	0.142	0.0201	5	7.596	0.179
Controllability slope	U5	0.093	0.0087	5	7.678	0.174
Building Overall slope	U6	0.020	0.00038	5	3.234	>.500
Level-1	R	0.783	0.613			

Table 4.22 Variance components



```
Sigma_squared =       0.61264

Tau
INTRCPT1,B0      0.14809      0.00425      0.00480     -0.05451      0.03584      0.00482
 NSEOVER,B2      0.00425      0.00013      0.00014     -0.00156      0.00102      0.00012
  LTOVER,B3      0.00480      0.00014      0.00018     -0.00174      0.00115      0.00010
   TOVER,B4     -0.05451     -0.00156     -0.00174      0.02013     -0.01323     -0.00188
    CONT,B5      0.03584      0.00102      0.00115     -0.01323      0.00870      0.00122
BUILDING,B6      0.00482      0.00012      0.00010     -0.00188      0.00122      0.00038
```

4.1.5.3.4 Model 4

The "Estimation of fixed effects for model 3" showed that the "Building Overall (composite)" was the predictor that contributed the most to the model. Therefore it was interesting to know what the most important individual factors in this composite variable were in correlation with comfort overall. Therefore, besides the independent variables in Model 2, the six items included in "Building Overall" were also entered into Model 4. From the result of Table 4.21, since independent variables as a random effect of level-2 made no significant effect on the dependent variable. I only kept the intercept as the random effect for the new model. The formula for Model 4 is shown in Table 4.23.

Table 4.23 Formula for model 4

Level-1 Model	
Y = B0 + B1*(Sex) + B2*(DESIGN) + B3*(NEEDS) + B4*(SPACEBUILT) + B5*(IMAGE) + B6*(SAFETY) + B7*(CLEANLINESS) + B8*(Noise Comfort) +B9*(Lighting Comfort) +B10(Temperature Comfort) + B11*(Controllability)+ R	
Level-2 Model	
B0 = G00 + U0	B6 = G60
B1 = G10	B7 = G70
B2 = G20	B8 = G80
B3 = G30	B9 = G90
B4 = G40	B10 = G100
B5 = G50	B11 = G110

The "Estimation of fixed effects for model 4" (Table 4.24) showed that "Intercept," "DESIGN," "SPACEBUILT," "Temperature Comfort" and "Controllability" were significant predictors at level-1 of the level-1 dependent variable. Their positive coefficients indicate there is a positive relationship between these predictors and comfort overall. Therefore, better building design, more efficient space, more satisfaction with temperature, more controllability on building performance will increase staff overall comfort. This result indicates that building design, efficiency of space used, temperature comfort and controllability over building systems play an important role in the staff comfort in LEED certified healthcare settings. The designers, architects, managers and constructors should pay more attention to these building factors and they should be given prioritization for construction expenditures, when the design team wants to improve the staff comfort.

Table 4.24 Estimation of fixed effects for model 4

Fixed Effect		**Coefficient**	**Standard Error**	**T-ratio**	**Approx. d.f.**	**P-value**
Intercept	B0	5.167	0.186	27.846	5.000	0.000
Sex slope	B1	-0.258	0.193	-1.332	120.000	0.186
DESIGN slope	B2	0.308	0.099	3.094	120.000	0.003
NEEDS slope	B3	0.084	0.079	1.062	120.000	0.291
SPACEBUILT slope	B4	0.136	0.065	2.093	120.000	0.038
IMAGE slope	B5	0.027	0.082	0.324	120.000	0.746
SAFETY slope	B6	0.065	0.073	0.897	120.000	0.372
CLEANLINESS slope	B7	0.023	0.072	0.320	120.000	0.749
Noise Comfort slope	B8	-0.004	0.049	-0.090	120.000	0.929
Lighting Comfort slope	B9	0.031	0.047	0.659	120.000	0.511
Temperature Comfort slope	B10	0.227	0.051	4.477	120.000	0.000
Controllability slope	B11	0.174	0.057	3.069	120.000	0.003

4.1.5.4 Perceived productivity

4.1.5.4.1 Model 1

The intercept only model was analyzed for productivity; there were no predictors at level-1 or level-2, but there was random intercept within level-2. The "Estimation of variance components" showed that intercept was not significant (P-value > .500) (Table 4.25), that the random factor healthcare settings would not be significant and an analysis with just fixed effects factors might be possible.

Table 4.25 Estimation of random effects and deviance for model 1

Random Effect		**Standard Deviation**	**Variance Component**	**df**	**Chi-square**	**P-value**
Intercept	U0	0.018	0.00031	5	1.1	>.500
Level-1	R	2.010	4.037			

Statistics for current covariance components model
Deviance = 597.63
Number of estimated parameters = 2

4.1.5.4.2 Model 2

In Model 2, "Sex," "Building Overall," "Temperature Comfort," "Controllability," "Noise Comfort" and "Lighting Comfort" were added as fixed effect, and intercept was entered as a random effect of the level-2 grouping variable. Table 4.26 shows that the intercept is still not significant after adding the level-1 predictors; however, the deviance is 534 with 2 parameters compared to 598 with 2 parameters in the intercept only model. Therefore, Model 2 had a better fit than Model 1.

Table 4.26 Estimation of random effects and deviance for model 2

Random Effect		**Standard Deviation**	**Variance Component**	**df**	**Chi-square**	**P-value**
Intercept	U0	0.0208	0.00043	5	2.338	>.500
Level-1	R	1.684	2.835			
Statistics for current covariance components model Deviance = 534.27 Number of estimated parameters = 2						

4.1.5.4.3 Model 3

In this model, level-1 predictors were also entered as both fixed and random effects. The deviance in this model was 531 (Table 4.27) compared with 598 in model 1 (Table 4.25); the difference is 67. The intercept only model had 2 parameters and this model had 22 parameters, a difference of 20. Looking in a chi-square Table for 20 degrees of freedom, at the .05 significance level the critical value was 31.4 smaller than 67. Therefore, this model was better than the intercept model at a significance level of 0.05, but not quite as good as Model 2.

Table 4.27 Deviance for model 3

Statistics for current covariance components model
Deviance = 530.93
Number of estimated parameters = 22

Therefore, Model 2 was used to analyze the data. The "Estimation of fixed effect for model 2" (Table 4.28) shows that "Lighting Comfort," "Temperature Comfort" and "Controllability" (composite) are significant predictors of perceived productivity. Their positive coefficients indicate that there is a positive relationship between them and perceived productivity. Therefore, as satisfaction of lighting and temperature increases, perceived productivity increases; and as controllability on building system increases, so does productivity. This result shows that lighting comfort, temperature comfort and controllability play an important role in staff perceived productivity in LEED certified healthcare settings. In the design and construction phase, architects, engineers, managers and constructors should try to improve performance of these factors, which are the most important variables to allow for prioritization of construction expenditures in productivity.

Table 4.28 Estimation of fixed effect for model 2

Fixed Effect		**Coefficient**	**Standard Error**	**T-ratio**	**Approx. d.f.**	**P-value**
Intercept	B0	5.478	0.145	37.849	5	0.000
Sex	B1	-0.272	0.393	-0.692	129	0.490
Noise Comfort	B2	0.015	0.094	0.163	129	0.871
Lighting Comfort	B3	0.447	0.097	4.603	129	0.000
Temperature Comfort	B4	0.292	0.103	2.834	129	0.006
Controllability	B5	0.271	0.116	2.343	129	0.021
Building Overall	B6	-0.031	0.153	-0.203	129	0.839

4.1.6 Compare with benchmark database

The last part of the quantitative analysis was a comparison with the BUS benchmark database; the survey results of the six LEED certified healthcare settings were put into the database in order to compare their individual scores to the mean scores of each individual variable of the benchmark buildings.

For these healthcare settings, most of the building performance factors except the controllability factors in the study healthcare settings were higher than the 50th percentile in the benchmark database (see Appendix D). This finding indicated that the study buildings' ranks were relatively high in the benchmark database.

4.2 Qualitative Data Analysis

The telephone interviews were recorded and then transcribed from oral speech to written text. The qualitative data analysis section coded facility managers' narratives to define themes, then interpreted the identified themes and their properties, and linked these codes to networks for theoretical models (organizing codes to build a conceptual or logical relationship between codes, quotations, memos or primary text). The analysis process was implemented using ATLAS.ti, a computer-assisted qualitative analysis software package. According to Grafton (n.d.), ATLAS.ti can generate a conclusion or build a theory. In my study, I used the technique of analyzing qualitative data in grounded theory to generate and visualize a conclusion, rather than generate a theory. To maintain anonymity the settings are referred to as BU, AS, FA, DG, EE, and CL.

4.2.1 Healthcare setting BU

4.2.1.1 Building problems and suggestions

For this healthcare setting, the facility manager described the following building problems: hot water; thermal comfort; acoustics; controllability janitorial. Figure 4.13 shows the conceptual relationship between themes (codes in ATLAS.ti). The blue and purple squares represent the codes related to building performance and the yellow squares, the quotations obtained from the facility manager's narrative.

The facility manager explained that the amount of time it took for water to heat was the problem; the reason for this was a faulty solar panel on the roof that was the primary source of heat for the water. Even though this facility is located in an area which is not cold in winter, the solar panels sustained damage in a hard freeze.

Another problem was thermal comfort. He said, “We get areas that are very populated and create a lot of body heat, so it seems very warm, and then we have some offices and areas that have windows in them that get very cold. So creating a balance in that building is a very difficult task.”

Regarding the acoustics, they did have some issues. There were no established acoustics LEED credits when the building was constructed. The facility manager talked about the acoustic environment:

> There are some complaints, so we try to address them, we have made some corrections to our sound panels. We play some parts there, we have on the acoustical areas we installed some privacy barriers, and things like that.

He further commented:

> We are looking at HIPPA and interaction with social security numbers and thing of that nature. We did go ahead to install some recyclable materials to install some privacy, sound barriers in our intake area, this is an addition to our original construction…. We purchase some sound panels that were basically foamed to absorb sound. I had them covered and they were made out recycle materials and the same paint that we use in the building to try to absorb some of the sound.

Controllability was also a concern. The facility manager’s statement explained the low controllability score on the survey:

> If our sensors do not work it's overridden by a company in CA, we are here in Florida, so we have to contact them and there's a time zone difference, and it's not like we have a readily available assistant person here…, with regards to the lighting, the heating air is remotely controlled … at our facility headquarters, which is in another city. So the staff there do not have the capability to adjust the temperature.

He mentioned that he received numerous complaints about controllability, which resulted in some comfort issues:

> So they cannot control for that is a big complaint area. The system that we put in place as they contact us we can pull it up on a system and look at the different temperatures and different set points, and you know, if there's a problem or not.

The janitorial portion of this facility's management presented an additional challenge. The facility manager said, "Finding the best possible certified green chemical to clean our building with has been a struggle." Figure 4.13 illustrates the building problems in BU in purple squares.

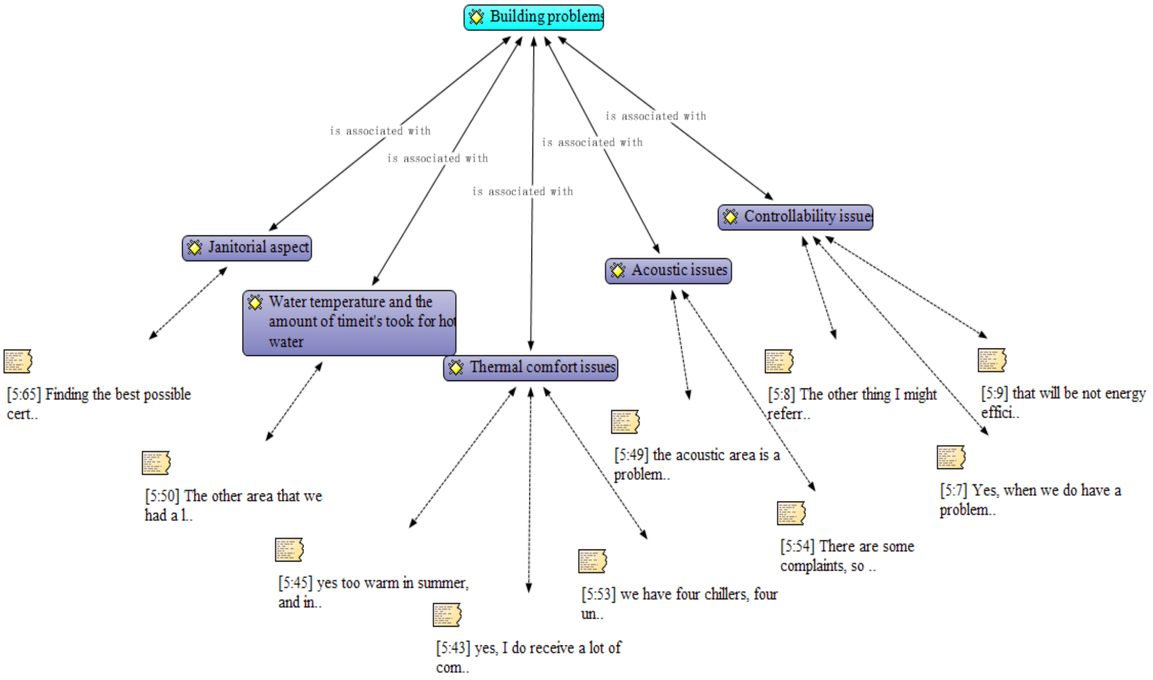

Building problems
is associated with
is associated with
is associated with
is associated with
is associated with
is associated with
Janitorial aspect
Water temperature and the amount of timeit's took for hot water
Thermal comfort issues
Acoustic issues
Controllability issue
[5:65] Finding the best possible cert..
[5:50] The other area that we had a l..
[5:45] yes too warm in summer, and in..
[5:43] yes, I do receive a lot of com..
[5:53] we have four chillers, four un..
[5:49] the acoustic area is a problem..
[5:54] There are some complaints, so ..
[5:8] The other thing I might referr..
[5:9] that will be not energy effici..
[5:7] Yes, when we do have a problem..

Figure 4.13 Network model of building problems in BU (ATLAS.ti)

Based on the facility manager's experience and perspective, he gave some suggestions on healthcare building design (Figure 4.14): do not use overhead paging system; do use appropriate HVAC; and do meet with cleaning supplies provider.

Besides the normal noise, healthcare settings also have equipment noise. In order to reduce this noise, the facility manager said, "We do not use is a paging system overhead, I don't know other healthcare facility to do that. You know this a noise factor, you don't hear a lot of paging stuff going on." As for thermal comfort, he mentioned, "When we design our HVAC system, we will look at the total square footage of the building, take into account the climate, the number of windows and how many people will occupy in the space and then change the BTUs." For the janitorial aspect, he thought the cleaning supplies provider should meet with the healthcare setting management to discuss and recommend appropriate chemicals that will not only do a good job but also will be kind to the environment.

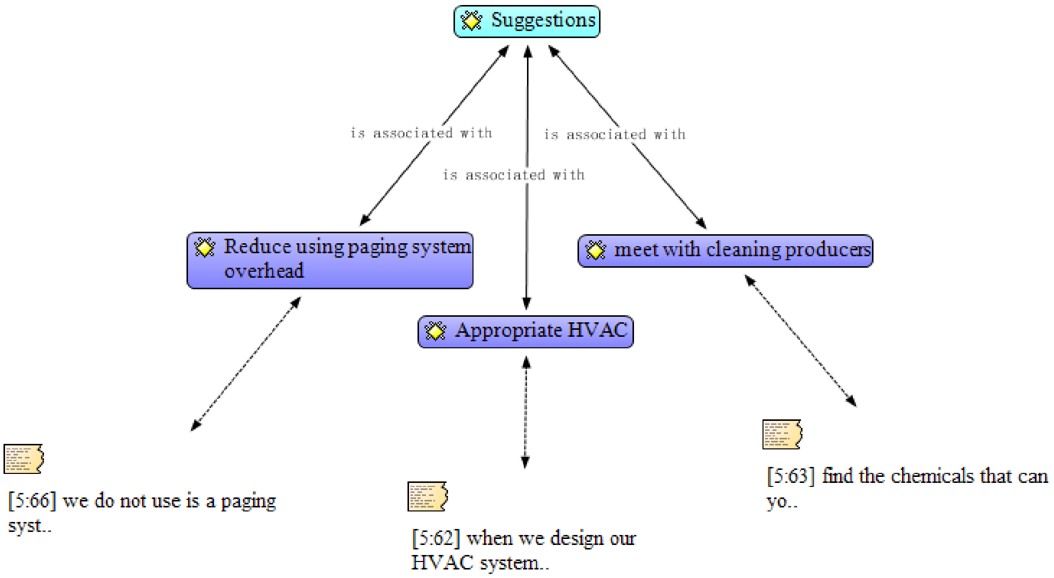

Suggestions
is associated with
is associated with
is associated with
Reduce using paging system overhead
meet with cleaning producers
Appropriate HVAC
[5:66] we do not use is a paging syst..
[5:62] when we design our HVAC system..
[5:63] find the chemicals that can yo..

Figure 4.14 Network model of suggestions in BU (ATLAS.ti)

4.2.1.2 Overall comfort and productivity

Regarding overall comfort and productivity, the facility manager shared that in his opinion, heating and cooling were the most important factors. He also rated lighting as a critical factor to comfort, and suggested that a connection to landscaping and nature could contribute to both productivity and comfort (Figure 4.15).

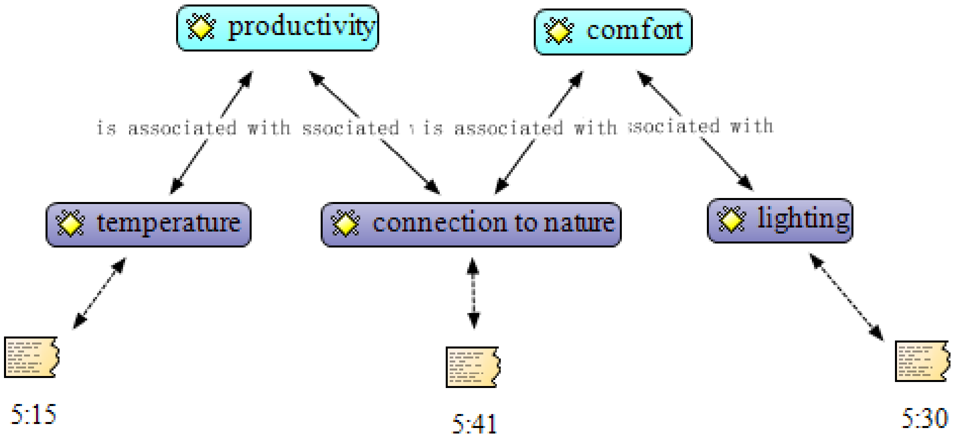


Figure 4.15 Network model of comfort and productivity in BU (ATLAS.ti)

4.2.1.3 Staff's comments from the questionnaire

Comments from the staff were also collected from the comments area in the survey questionnaire. Some of the comments related closely to the performance problems shown in the following:

- Comfort aspect: "Hard to keep clean"; "The intake desks need more space. Either expanded into the clerical area or out into the lobby."
- Lighting: "Sunlight in hall going in the exit area is horrible"; "My office doesn't have windows; light isn't a issue for me."

- Acoustic aspect: “The halls echo extremely loud. You can hear an entire conversation from somebody on the other end of the hall. It is not too bad when there are doorways separating halls, but it can be very annoying. There are also pipes that bang regularly when somebody flushes toilets, which can be very loud and distracting when counseling clients.”; “People in the lobby can hear anything that is said in the clerical area, even though it is said quietly, the sound seems to reverberate”; “The water pipes keep knocking.”
- Productivity: “The work space in the intake and exit area is horrible whoever designed it did and bad job and there is not enough space to work in.”; “When the building is extremely cold it's difficult to work and be productive. Time is wasted trying to get comfortable.”

4.2.2 Healthcare setting AS

4.2.2.1 Building problems and suggestions

In this healthcare setting, the facility manager was concerned with the following performance issues: air changes, recyclable materials, equipment noise, and difficulty attaining LEED credits (Figure 4.16).

He mentioned that a lot of energy was required in order to maintain good air quality. They tried to save energy by utilizing re-circulated air and a filtration system.

Regarding green materials, he said they did not use a lot of “recyclable materials” in the building. They had a problem similar to the previous healthcare setting, since they had problems acquiring recyclable materials that would withstand the rigors of a healthcare facility. Since there were fewer choices in green materials, their use of them was limited.

When we talked about the noise issues, the facility manager said that in a hospital, noise problems could be due to equipment issues rather than to building issues. He said: "It's an equipment issue, all of our equipment has alarms, buzzers, beepers and phones on it. That's what generates the issue that's what keeps people up."

Another issue was about trying to get LEED credits. He said they tried to become more sustainable, but the new ideas they implemented created problems in terms of operation, and they were not sure whether it would pay off in the end. Figure 4.16 illustrates the factors associated with building problems in AS.

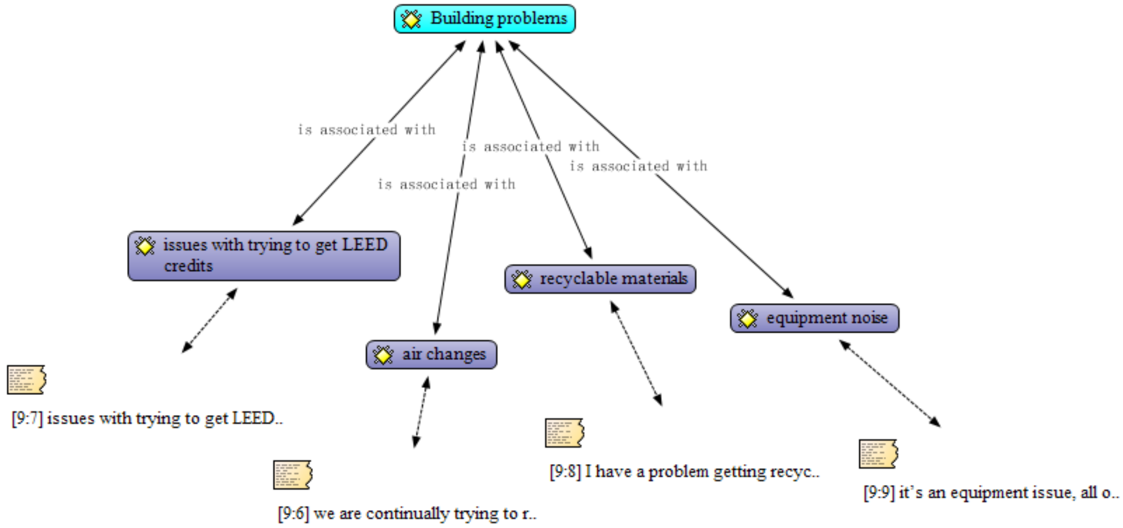

Building problems
is associated with
is associated with
is associated with
is associated with
issues with trying to get LEED credits
recyclable materials
equipment noise
air changes
[9:7] issues with trying to get LEED..
[9:8] I have a problem getting recyc..
[9:9] it's an equipment issue, all o..
[9:6] we are continually trying to r..

Figure 4.16 Network model of building problems in AS (ATLAS.ti)

The facility manager shared some of his building's successes in design (Figure 4.17), such as using large exterior windows to obtain more daylighting, and using automated blinds outside the curtain wall, which reduced the glare in patient rooms. They also used indirect lighting and different controls for the patient areas.

Regarding acoustic issues, he said that "The problem we have is all material that absorbs sound also absorbs germs." He did not suggest using carpet on the floor, or soft, sound absorbing material on the walls. Instead, the ceiling is a good place to install sound absorbing material. He said, "Most of the noise is generated from the equipment," and that finding a way to reduce equipment noise was important in hospital.

He also mentioned that they had several area with views and connections to nature. The staff made positive comments on these areas, saying that they made them feel better, calmer. Figure 4.17 shows the facility manager's suggestions in AS.

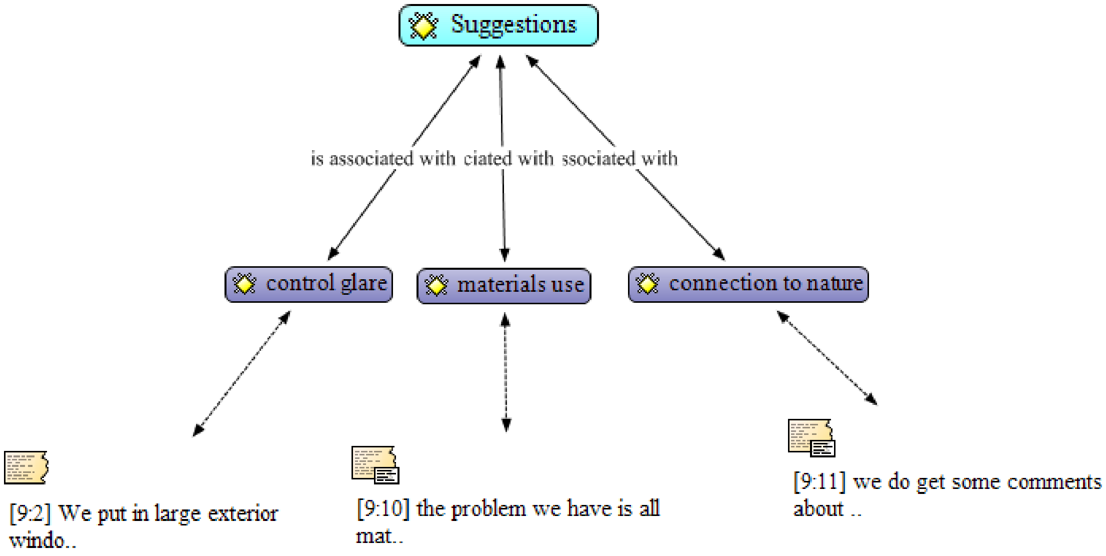

Suggestions
is associated with
ciated with
ssociated with
control glare
materials use
connection to nature
[9:2] We put in large exterior windo..
[9:10] the problem we have is all mat..
[9:11] we do get some comments about ..

Figure 4.17 Network model of suggestions in AS (ATLAS.ti)

4.2.2.2 Overall comfort and productivity

Based on the facility manager's perspective, general lighting was important to occupants' productivity, energy performance related to air conditioning systems was important to the overall comfort, and control over temperature contributed to both comfort and productivity. He said they were in a hot and humid area, and the ability to control temperature could have great impact on occupants. He explained further: "The energy performance of the building is related to air conditioning systems, and you don't do it right, you will have a lot of complaints with the building…. If you do not put enough energy in the building to manage the air conditioning systems, then you got hot and humid. Then you get air quality problems and upset patients and upset staff." Figure 4.18 illustrates the factors associated with productivity and comfort.

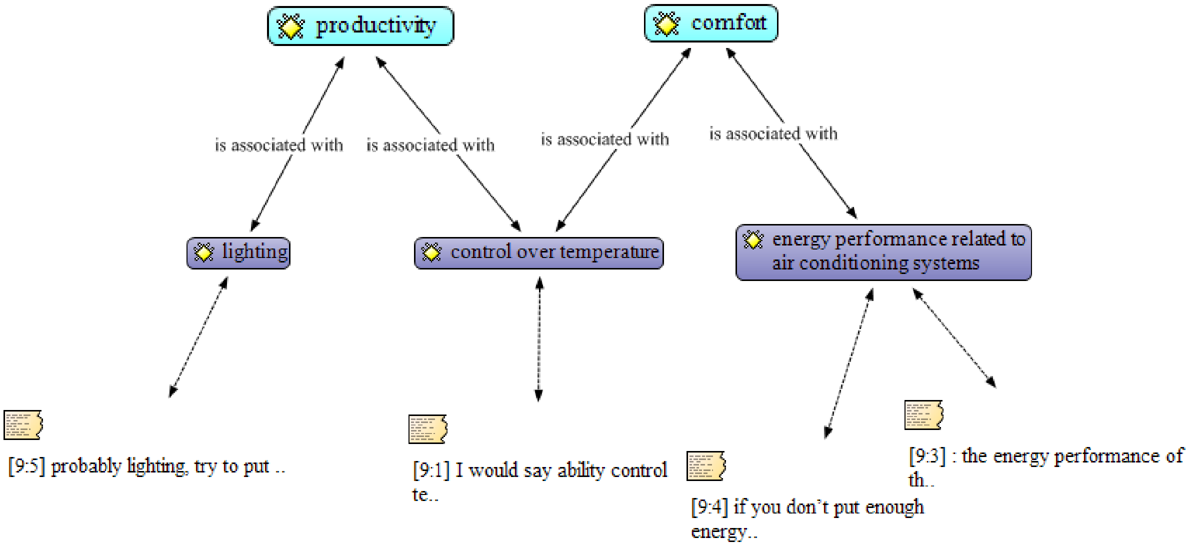

productivity
comfort
is associated with
is associated with
is associated with
is associated with
lighting
control over temperature
energy performance related to air conditioning systems
[9:5] probably lighting, try to put ..
[9:1] I would say ability control te..
[9:4] if you don't put enough energy..
[9:3] : the energy performance of th..

Figure 4.18 Network model of comfort and productivity in AS (ATLAS.ti)

4.2.2.3 Staff's comments from the questionnaire

- Comfort aspect: "Clerk areas are very small not space… office area are very small to have two worker"; "I think it is a disservice to patients not to provide more seating in the lobby. When we first opened it was boasted that our lobby would look like a hotel not a hospital, patients could not sit in the lobby waiting for a ride, etc. I have personally seen a patient with his leg in a full cast sitting on the ground waiting for his ride… We need to realize this is a hospital and not a hotel and focus on the needs one might have as a sick patient not a healthy traveler."; "Need more work space and windows. Walls need cleaning and/or painting."; "computers hung under counters perfectly placed to crack kneecaps"; "counters at wrong heights that create back strain".
- Lighting aspect: "At times the artificial light at the computer alcoves is glaring"; "Sitting by a window makes all the difference in the world. I'll take the glare and higher temperatures any day over an interior cube."; "The nurses' station is so dark in areas that you can't read. The lights in the alcoves are so small you have to move the papers around to see from top to bottom."; "We have had to tape cardboard and paper to the windows to combat the afternoon son."; "Window looking west; gets very warm in the afternoon."
- Noise aspect: "Pneumatic tube system was very loud when tubes drop or take off."; "Room does not have proper sound insulation. Many types of equipment creating high level of ambient noise. Talking has to be loud to hear over it.";

“The noise is mostly from the patients and their kids, their kids will be screaming and crying …”

- Productivity:”Lots of walking to get the supplies”; “The long halls increase my walking time to the RN station to get labels, tube specimens, answer call lights, go to the staff restroom”; “The med rooms are far away from a lot of the patient rooms. The halls are so long that it takes extra time to get to the kitchen, nurses station, med rooms, etc.”

4.2.3 Healthcare FA

4.2.3.1 Building problems and suggestions

For this healthcare setting, the facility manager did not have performance problems or receive any complaints related to comfort and productivity. He said, “We addressed pretty much every single one of these issues, we implemented daylighting, HVAC was designed to provide local control and also designed to be quiet during its normal operation. Every space has an ability to control the own lighting and every space that would be normally occupied could have openable windows. As far as giving the most flexibility to the local user, to the occupants.”

He shared suggestions on LEED and healthcare setting design (Figure 4.19) He thought that ongoing maintenance and operations were important aspects, but that LEED did not have much to do with those things. Instead, LEED should be more focused on the future operational characteristics of buildings.

Their healthcare setting was a small one, and they designed the building to be 40% better than the National Energy Code. For a small project that might be the envelope dominated building, he thought focusing on the high efficiency envelope, insulation system, and windows would have a positive effect on occupant comfort. He said, “When we do thing like that, what you doing is reducing the heating and cooling load so that we don’t get big temperature swing.” He pointed out that effective use of exterior light shelves could contribute to comfort as well; occupants could control the daylighting as well as the overheating. He shared that “Then you don’t have to work as hard to control heating and cooling systems, because they are not struggling to heat the building or cool the building to overcome inadequate building envelop issues.”

The facility manager said some of the building performance problems resulted from the complexity of using the building being greater than the ability of building’s occupants to use it, and that there was not enough education on how to use the system correctly. Therefore, they used simple heating and cooling systems with simple thermostats, “because those could be easily maintained, managed locally. So I think lots of issues are where your expectation is not met by the system that was designed.”

He mentioned that remaining sustainable was important; they implemented a green cleaning program after they obtained LEED certification, and trained the janitorial staff to use the green cleaning materials. He said, “You don’t want turn around and put toxic chemical into your building to clean it after you spent all this money putting in healthy materials.”

As for the acoustical environment, the facility manager thought it was a necessary element for healthcare design. He suggested having multiple levels and strategies of acoustic environments: “Permanently occupied spaces or rooms that you see patients in, those spaces should perhaps get a higher level of acoustic quality than say public spaces where people are going to use them intermittently." He believed this could limit the cost impact. Figure 4.19 illustrates the suggestions from facility manager in FA.

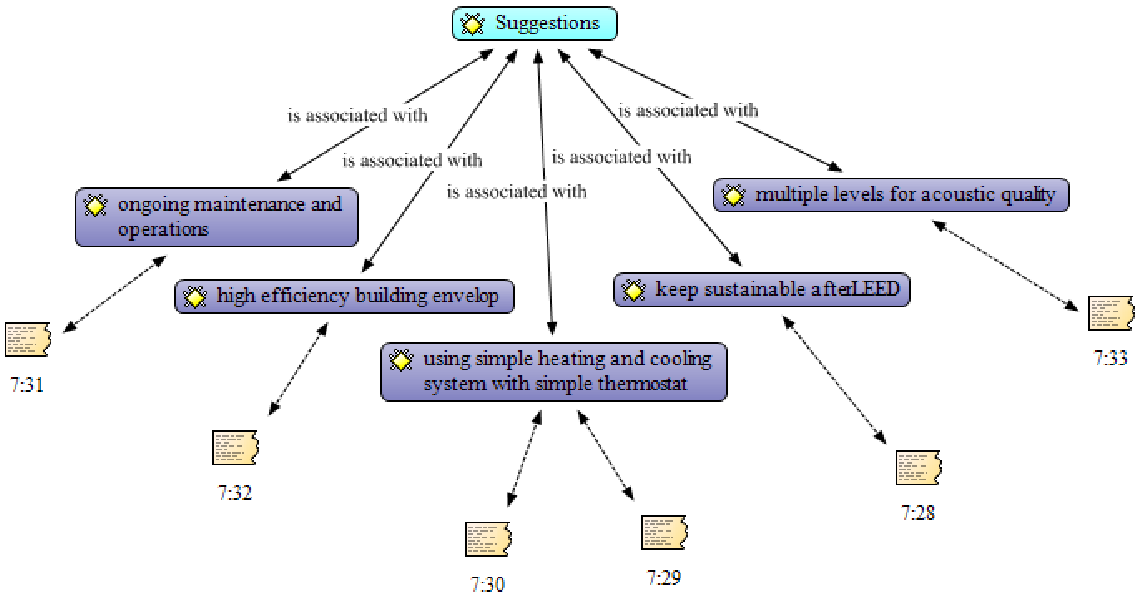

Suggestions
is associated with
is associated with
is associated with
is associated with
is associated with
is associated with
ongoing maintenance and operations
multiple levels for acoustic quality
high efficiency building envelop
keep sustainable afterLEED
using simple heating and cooling system with simple thermostat
7:31
7:32
7:30
7:29
7:28
7:33

Figure 4.19 Network model of suggestions in FA (ATLAS.ti)

4.2.3.2 Overall comfort and productivity

The facility manager thought that HAVC comfort, daylighting and the flexibility of space could significantly affect occupants' productivity. He especially emphasized the flexibility of building space. Building the building a little bigger gave them room to add personnel and still have plenty of work spaces; he said "that I think really gives them a lot of flexibility and I think that improves their productivity." A comfort survey could examine the issues after occupancy, which gives an opportunity to find the problems and fix them.

He said the optimize energy performance credit was an indirect, but related LEED credit that could affect comfort. They used high efficiency envelope, insulation system, windows and exterior shelves to reduce heating and cooling loading, which also prevented the big temperature swing. This kept facility managers from working hard to control heating and cooling systems to overcome the envelope issues. Figure 4.20 shows the factors that can affect productivity and comfort in facility manager's perspectives.

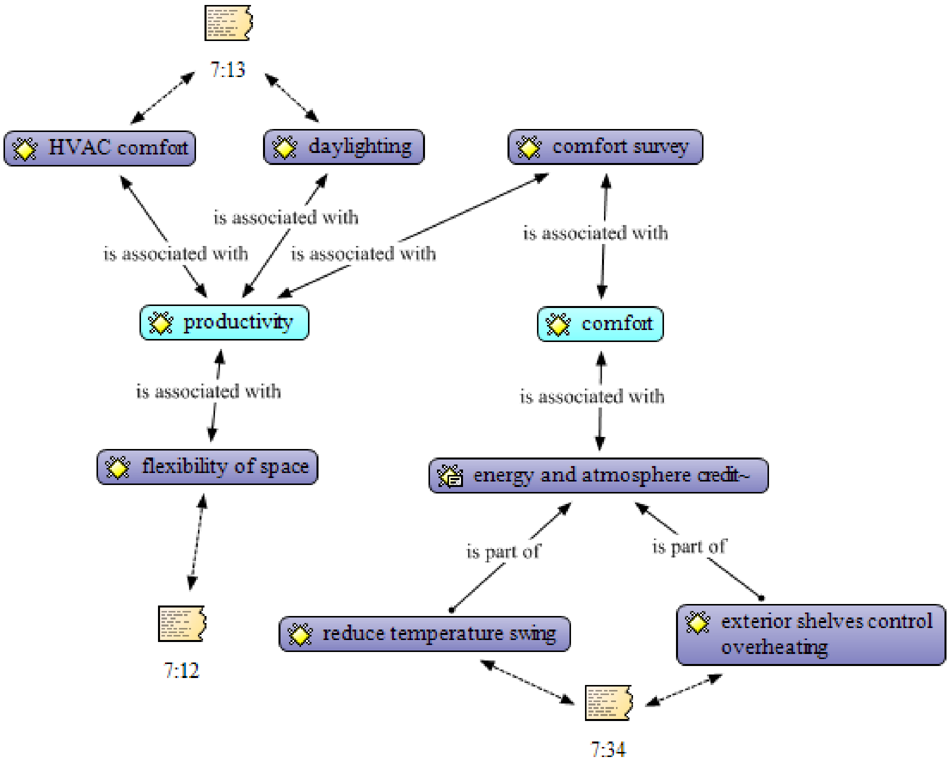


Figure 4.20 Network model of comfort and productivity in FA (ATLAS.ti)

4.2.4 Healthcare setting DG

4.2.4.1 Building problems and suggestions

The facility manager shared several building performance problems (Figure 4.21). He said that the walls in the lobby were two floors high, and that the housekeeping staff complained that it was very hard to clean such a tall wall. He maintained that the difficulty of cleaning a two-story wall should have been considered during the design phase. Another issue related to the two-story lobby wall was that during the summer, whenever the entrance door opened, hot air entered and went upstairs which could increase energy costs. The facility manager said in the first year, they found that the HVAC system was under sized; hence, they struggled with adequately cooling the building. The facility manager mentioned that they had issues related to the complex system, which was also a concern of the facility manager in healthcare setting FA. He said they were not familiar with the lighting system, and that the biggest difficulty was to learn the system better. Besides the major problems already mentioned, he said the adobe finish on the outside of the building gave them troubles, since it cracked a lot.

One suggestion he had for healthcare design was using air conditioning systems with humidity controls. He explained further, “Most healthcare facilities have to pump so much outside air into the facility which makes it hard to control the humidity, keep it clean, and things like that.” He was glad that they had the air conditioning system with humidity controls that were able to assist them in minimizing the use of outside air. “Being able to run those systems with humidity condensers can minimize that so we can sometime close down the amount of outside air we’re bringing in depending on humidity," he said. Figure 4.21 illustrates the factors associated with building problems and facility manager's suggestions.

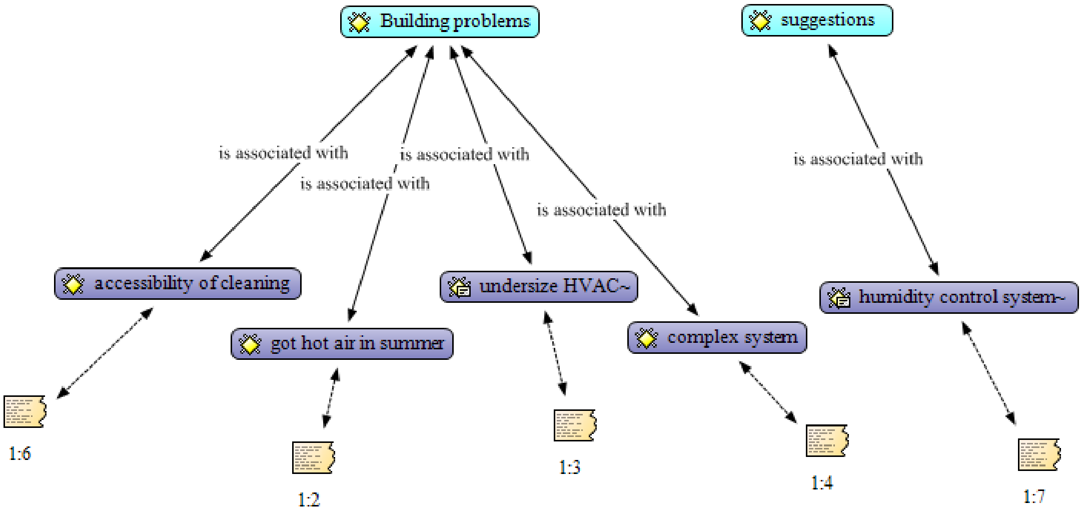


Figure 4.21 Network model of building problems and suggestions in DG (ATLAS.ti)

4.2.4.2 Overall comfort and productivity

The facility manager commented that natural views played an important role in occupant comfort: "…can look out this full sized wall window at our pond scene, which has a walking path and a lot of forest there, and it's really relaxing and make a big difference how they feel…". Air conditioning systems also contribute to comfort and productivity, but the system should be appropriately sized in the design phase. Figure 4.22 shows the facility manager's concerns that is associated with productivity and comfort.

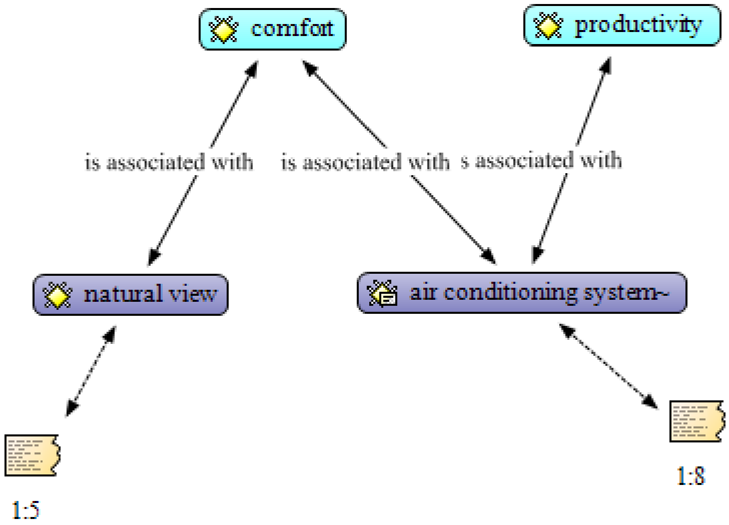


Figure 4.22 Network model of comfort and productivity in DG (ATLAS.ti)

4.2.5 Healthcare setting EE

4.2.5.1 Building problems and suggestions

In this building, the facility manager mainly focused on two performance problems, which are related to design and operation and maintenance (O&M) issues: time waiting for hot water (design) and appropriate green material (O&M) (Figure 4.23). He said they had problems in choosing appropriate green materials, which was also mentioned by the facility manager in healthcare setting in BU. They started out using a green floor wax, which was insufficient as a coating and the floors looked bad. They were struggling to find an appropriate alternative green material, when at last they decided on using a non- green floor wax, which met their requirement.

Another concern was hot water issues, which was also a problem at another healthcare setting. The facility manager said, “We have to run the water to get hot water even though we have hot water circulations systems, they are insufficient as to the design.” He suggested that LEED should quantify or specify some strategies to overcome these flaws (Figure 4.23). In his building, a lot of water was wasted while waiting for it to heat up. He suggested:

> LEED might need to quantify things like to say you have hot water within 30 seconds, or you have hot water within 45 seconds or something. That would force me to design a system that is moving a fair amount of hot water, in large volume through the buildings, so you only have to worry about the stand pipe down to the sink as far as the quantity of hot water goes.

A similar suggestion he gave was to specify lumens, using some efficient lighting systems like LEDs could help obtain LEED credit, but the LEDs might not perform well. Therefore, he thought LEED should quantify some credits. Figure 4. 23 illustrates the building problems and suggestions in healthcare setting EE.

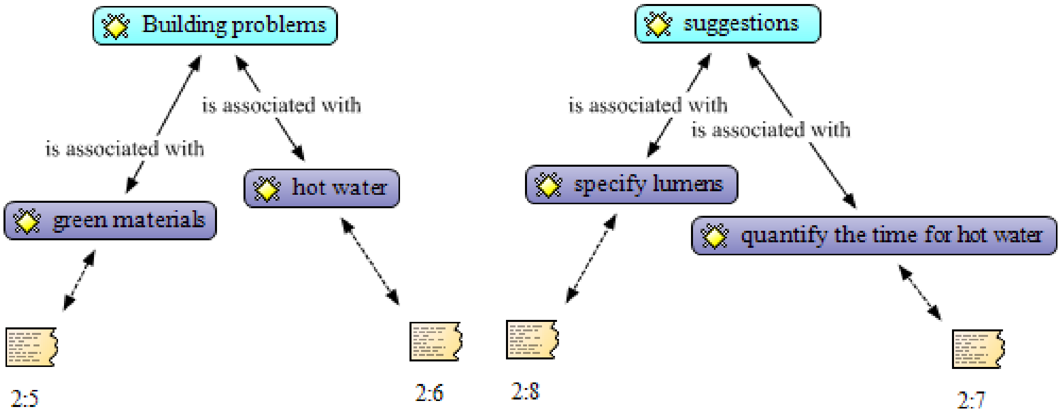


Figure 4.23 Network model of building problems and suggestions in EE (ATLAS.ti)

4.2.5.2 Overall comfort and productivity

The facility manager thought that heating, venting and air conditioning was important to productivity and comfort especially, in hot or cold climate zones. He also mentioned that lighting, acoustics, heating and venting could affect occupant comfort and lighting was especially important to productivity. Figure 4.24 shows the factors associated with productivity and comfort.

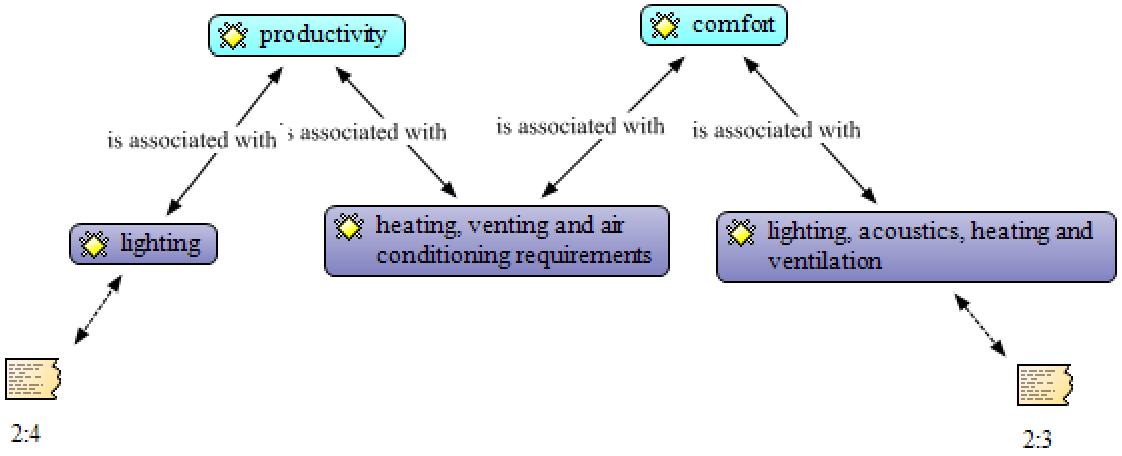


Figure 4.24 Network model of comfort and productivity in EE (ATLAS.ti)

4.2.5.3 Staff's comments from the questionnaire

- Comfort aspect: "Temperature is a constant frustration."
- Lighting aspect: "Wish we had skylights. Do not like artificial lighting as it gives me a headache"; "These lights tend to give me many headaches. I feel that they're too bright."
- Noise aspect: "All conversations are overheard and sometimes are a HIPAA violation"; "Break room is very noisy. No door to filter out noise and everyone does not take break/lunch at the same time."; "Slamming door throughout day from front lobby area to patient area."

4.2.6 Healthcare setting CL

4.2.6.1 Building problems and suggestions

According to the facility manager, this setting had two major problems: cracks in walls and foundation; and controllability issues with HVAC, which resulted in hot and cold spots in his building. For these problems, which were not easy to fix, he said the best solution was not to let them happen in the first place. The HVAC control system was the cause of most of the complaints from staff, since they had problems in controlling the heat and air handlers. They replaced the control system with one that was more functional and served the facility better.

Another suggestion he shared was to “look carefully at your exterior material and what you’re using for your building envelope. And making sure it doesn’t cause problems if it cracks or anything.” He also proposed that keeping the building positive pressure could contribute to cleanliness. It was less likely to get dirt coming in from outside. He specifically mentioned that acoustic environment related to privacy concerns and was important to healthcare design. He explained: “When a patient is in a room discussing something with their doctor that they can feel comfortable knowing that what they’re talking about is not escaping to the outside world.” Figure 4.25 illustrates the two problems and facility manager’s suggestions in CL.

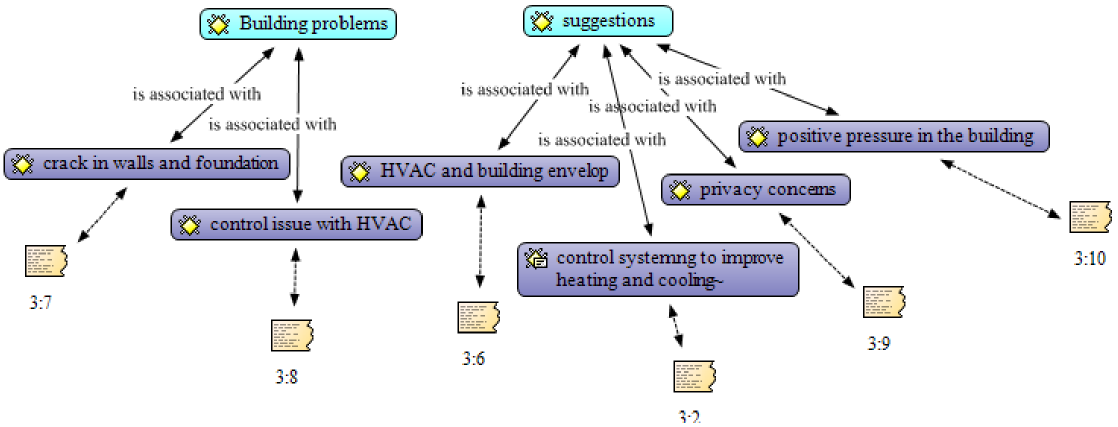


Figure 4.25 Network model of building problems and suggestions in CL (ATLAS.ti)

4.2.6.2 Overall comfort and productivity

The codes and quotations extracted from the narratives are shown in Figure 4.26 which illustrates the factors associated with productivity and comfort. The facility manager thought the indoor environmental quality was the most important factor affecting comfort, and he also claimed energy and atmosphere strategies could affect comfort, “If you have a more efficient building, the heating extremes, because of it being well insulated, are a lot less, so it’s easier to keep the building temperature comfortable for the occupants.” He thought heating and cooling were definitely the most significant elements affecting occupant comfort. Regarding productivity, he thought that building performance factors like noise, lighting and temperature were all important, and that people would be productive if they were comfortable with the environment.

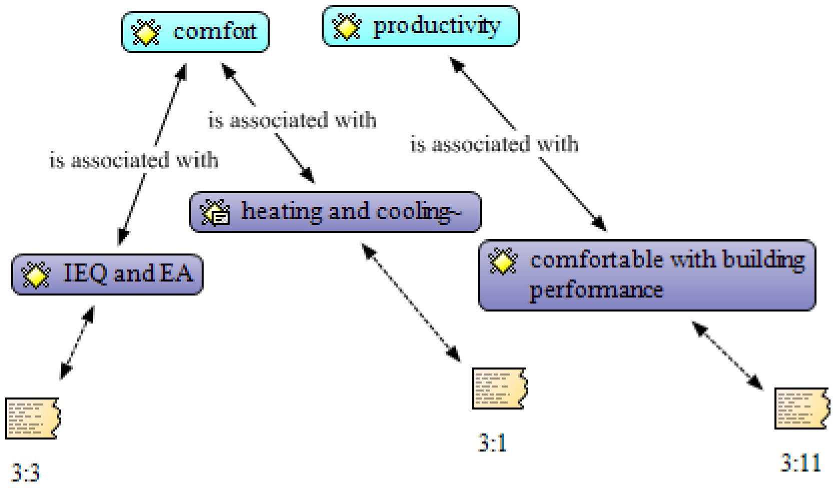


Figure 4.26 Network model of comfort and productivity in CL (ATLAS.ti)

4.2.6.3 Staff's comments from the questionnaire

- Comfort aspect: "Furniture, desks are very uncomfortable. Shelves too high and no step ladders to access them."
- Noise aspect: "Air handlers are very noisy and annoying;" "I work next door to pediatrics and you hear kids screaming all day;" "Too much overhead paging by employees."
- Productivity aspect: "Seems we spend a lot of time doing a lot of walking to get things. Supplies are not convenienly placed near the nurses;" "The area I work in is constantly busy and noise, sound and temp are always a varying factor."

5. DISCUSSION

The discussion chapter compares the quantitative and qualitative data and tries to explain some of the extreme scores in the questionnaire surveys. In addition, the two types of results are summarized, and both the research hypotheses and the research questions are discussed.

5.1 Comparison of Data from Survey and Interview

In this section, the scores from the staff questionnaires were supported by the facility managers' narratives to see whether the staff ratings and the facility manager comments were consistent. Researchers often combined semi-structured interview and structured questionnaire in their studies to obtain confirmative results (Harris & Brown, 2010). Questionnaires and interviews have complementary strengths and weaknesses. Questionnaires can be used to provide findings with large samples, and in-depth interviews are used to collect detail perspective and view of the interviewee (Harris & Brown, 2010; Kendall, 2008). Harris and Brown (2010) examined studies that used both questionnaire and interview methods, and they found that majority of the studies reviewed demonstrated positive levels of similarity between this two methods. Although there is no industrywide accepted POE method, the organization of the New Buildings Institute has developed a new POE protocol that includes a facility manager interview and an occupant survey to provide a basic set of performance indicators (Gonchar, 2008).

Some extreme and uncommon scores were examined to determine the reason for the variance. "Building design," "space use efficiency," "temperature comfort (composite)," "lighting comfort" and "controllability over building system (composite)" were addressed, since from the result chapter, they were significant factors for productivity and overall comfort.

Scores of "building design" and "space use efficiency" were above "4," the neutral point, on the staff questionnaires and the facility managers highly rated these two factors as well. However, one facility had relatively low scores ("building design" 4.09, "space use efficiency" 4.03), which were just above the neutral point. The reason might be evident from the staff's comments: "Seems we spend a lot of time doing a lot of walking to get things. Supplies are not conveniently placed near the nurses;" "We have an increased number of patients, increasing constantly. Poor seating for walk-ins in the main hallway."

The performance factors' means showed that most of the factors were rated above the neutral point (comfort, productivity, building design, ability to meet occupants' needs, space use efficiency, image presented to visitors, personal safety in and around building, cleanliness of building, temperature comfort in winter and summer, noise comfort, lighting comfort), which meant "satisfactory." However, the controllability of building systems was rated the lowest among the performance factors in all the healthcare settings. The facility managers' statement confirmed why the staff rated the controllability low. According to the facility managers (Table 5.1), two buildings had systems controls for staff; that might be the reason these two buildings had a relatively higher score than the others. Staff in one healthcare setting did not have controllability, and they rated the controllability low; however, they still obtained the

LEED credit of controllability, since the facility manager could control the building's system remotely. When the staff were not satisfied with the temperature, they asked the facility manager to change it. From both the surveys and the interviews, I found that none of the buildings were designed well in the area of personal controllability. This issue should be addressed since the results showed that controllability was an important predictor for both occupants' overall comfort and perceived productivity. Other studies have also showed that controllability over building system plays an important role in occupants' comfort and productivity (Chartered Institute of Building Services Engineers, 1999; Frontczak &Wargocki, 2010; Leaman, 1999).

The other two factors that fell below the neutral point were the temperatures in summer and the temperatures in the winter in one of the healthcare settings; this was confirmed by the staff and facility manager who explained the low scores (Table 5.2).

In regards to lighting comfort, which was a significant predictor for productivity as shown in the results chapter, almost all the facility managers gave a high evaluation on their lighting, and the staff also rated light above "5." However, one healthcare setting obtained a lower score than the others (Table 5.3). According to the facility manager's statement, their lighting was excellent, and they used LED lights, which were energy efficient.

Table 5.1 Controllability results from surveys and interviews

Healthcare Facilities	**Controllability Performance**	**Survey Mean**	**Staff Comments**	**Facility Manager Comments**
Healthcare EE	Control over cooling	1	No comments	"I do the control remotely, but staff does not control all that."
	Control over heating	1		
	Control over noise	1.29		
	Control over lighting	2.14		
	Control over ventilation	1.14		
Healthcare DG	Control over cooling	1.33	No comments	"We did have some staff control, but very little."
	Control over cooling	1.6		
	Control over noise	2.8		
	Control over lighting	2.8		
	Control over ventilation	1.7		
Healthcare FA	Control over cooling	3	No comments	"Pretty much. You know with the certain limit."
	Control over heating	2.89		
	Control over noise	3.33		
	Control over lighting	3.89		
	Control over ventilation	4.22		
Healthcare AS	Control over cooling	3.51	"Temperature control is the only issue."	"They can control their temperature and turn off light switches."
	Control over heating	3.69		
	Control over noise	2.75		
	Control over lighting	4.15		
	Control over ventilation	2.15		

Table 5.2 Temperature results from surveys and interview

Healthcare Facility	Temperature Performance	Study Mean	Staff Comments	Facility Manager Comments
Healthcare BU	Temperature in summer	3.73	· "When the building is extremely cold it's difficult to work and be productive. Time is wasted trying to get comfortable." · "This being a new building air and heat should work correctly."	·"I do receive a lot of complaints about the temperature in the building." ·"Too warm in summer, and in the winter months, it is too cold."
	Temperature in winter	3.53		

Table 5.3 Lighting comfort results from surveys and interview

Healthcare Facility	Performance	Study Mean	Staff Comments	Facility Manager Comments
Healthcare EE	Lighting	4	·"Some days the lights make a headache worse." ·"These lights tend to give me many headaches. I feel that they're too bright." ·"Wish we had skylights. Do not like artificial lighting as it gives me a headache."	· "My lighting is excellent." · "We are using LED lights, which are called "xx," which are energy efficient." · "They're on various timers and things like that, so that all has worked very well."

There was a difference between the staff rating and the facility managers' comments; the manager contended that even though the lighting system was excellent and energy efficient, the occupants still were not satisfied with it. This problem might result from the use of LED lights. A similar situation occurred in a Dutch building that installed energy efficient LED lights; the lighting seemed to cause headaches for the occupants (Information on the health risks of energy saving lamps, 2009). The reason LED lighting may actually cause headaches is a phenomenon called flicker. Wilkins, Veitch, and Lehman (2010) demonstrated that existing technologies in LED lighting sometimes provide flicker at frequencies that might cause headaches and impaired visual performance.

In regards to noise comfort, two healthcare settings obtained low scores which are just the neutral point; this was confirmed by the facility managers' statements and staff comments (Table 5.4).

Table 5.4 Noise results from surveys and interviews

Healthcare Facility	**Performance**	**Survey Mean**	**Staff Comments**	**Facility Managers Comments**
Healthcare EE	Noise	4	· "All conversations are overheard and sometimes is a HIPAA violation." · "Break room is very noisy. No door to filter out noise and everyone does not take break/lunch at the same time."	"From one exam room to the next though, we are getting noise transmission."
Healthcare CL	Noise	4.09	·"Too much overhead paging by employees." ·"We still do not have patient confidentiality in some areas." ·"I work next door to pediatrics and you hear kids screaming all day." ·"Being open to pediatrics, you hear crying most of the day."	"It's definitely something that you'd want to consider in the process of your design."

In regards to personal safety, a very important factor in healthcare design, almost all the facility managers gave their buildings good evaluations (Table 5.5). This was confirmed by the survey results.

Table 5.5 Safety results from survey and interview

Healthcare Facility	**Performance**	**Average Survey Mean**	**Staff Comments**	**Facility Managers Comments**
Mean of Six Healthcare Settings	Safety	5.68	"The fire alarms are extremely loud and the decibel levels verge on being unsafe."	·"We have very few incidents in the building." ·"Personal safety is very excellent." ·"It's obviously I think a little bit safer than the old side." ·"It's a real safe building."

Other than the areas mentioned, the facility managers received no other complaints. Generally, facility managers were satisfied with these LEED healthcare settings except some minor problems. They all stated that, even with some problems, they still felt satisfied with the buildings performance overall.

5.2 Summary of Study Results

The research hypotheses for the quantitative study were:

1. In a hospital case study, a LEED certified building will report higher staff ratings of building performance factors (such as building overall variables; heating; cooling; lighting; noise; personal control over heating, cooling, ventilation, lighting, and noise; comfort overall; and perceived productivity)

than a non-LEED certified building.

2. The building performance of LEED certified healthcare settings will have relatively high rank of staff ratings in building performance factors (such as building overall variables; heating; cooling; lighting; noise; personal control over heating, cooling, ventilation, lighting, and noise; comfort overall and perceived productivity) compared to the buildings in a benchmark database.
3. Building performance variables (such as building overall variables; heating; cooling; lighting; noise; and personal control over heating, cooling, ventilation, lighting, noise; comfort overall and perceived productivity) will be rated differently for LEED Gold and Silver certification.
4. Building performance variables (such as building overall variables; heating; cooling; lighting; noise; and personal control over heating, cooling, ventilation, lighting, noise; comfort overall and perceived productivity) will be rated differently between males and females..
5. Building performance variables will have a positive relationship with overall comfort.
6. Building performance variables will have a positive relationship with perceived productivity.

The research questions for the qualitative interview methodology included (1) what building performance elements influence overall comfort and perceived productivity based on the staffs' and facility managers' comments? (2) what are the building performance problems according to the staff and facility managers' comments,

(3) and what suggestions for improvement do facility managers offer? Research question one was answered with the hypotheses five and six, and questions two and three were in the 5.2.6 section. Table 5.6 shows the sections for research hypotheses and questions.

Table 5.6 Sections for research hypotheses and questions

Sections	Research Hypotheses	Research Questions
5.2.1	Hypothesis 1	
5.2.2	Hypothesis 2	
5.2.3	Hypothesis 3	
	Hypothesis 4	
5.2.4	Hypothesis 5	Research 1
5.2.5	Hypothesis 6	
5.2.6		Research 2
		Research 3

5.2.1 Research hypothesis one

The survey results showed that based on 95% confidence level, the staff in LEED healthcare settings reported higher ratings than the staff in non-LEED healthcare facilities in the following building performance factors: building design, ability to meet occupants’ needs, efficient space use, image presented to visitors, personal safety in and around building, cleanliness of building, temperature comfort in winter and summer, noise comfort, lighting comfort, controllability over heating and cooling, and overall comfort and perceived productivity. This indicates that the staff feel that building performance in the LEED building is better than the performances in the Non-LEED building. Here I carried out a two-tailed test, since there is no prior opinion regarding the direction of a possible group difference in the building performance variables. The means of these factors in the two facilities are shown in Table 5.7.

Among these factors, the image presented to visitors had the largest effect size (d=1.92), which indicated the biggest difference between the two groups; building design, cleanliness of the building, and comfort overall also displayed a strong difference (d>0.8) between the two buildings.

Table 5.7 Means of LEED and Non-LEED facilities

Performance Factors	LEED Mean	Non-LEED Mean
building design	5.4	3.8
ability to meet occupants' needs	5.1	3.9
efficient space use	4.8	3.7
image presented to visitors	5.9	3.2
personal safety in and around building	5.6	4.6
cleanliness of building	5.7	3.2
temperature comfort in winter	4.6	3.9
temperature comfort in summer	4.9	4.1
noise comfort	5.1	4.3
lighting comfort	5.3	4.5
controllability over heating	3.8	2.7
controllability over cooling	3.6	2.7
overall comfort	5.3	3.7
perceived productivity	5.4	4.4

5.2.2 Research hypothesis two

The study results showed that most of the study building’s performance factors were higher than the 50th percentile in the benchmark database from Building Use Studies (BUS) in UK. (Appendix D). The report (obtained from BUS) of the results with benchmarks is based on my survey data. Figure 5.1 shows the example of the report.

The results indicated that the average percentiles of the study buildings were somewhat higher in the benchmark database. To some extent, it meant these buildings serviced the occupants relatively well compared to the buildings used for the benchmark. For temperature in winter, the average percentile was 36 (low compared to other factors). For some of the study healthcare settings, the staff complained that they felt cold, especially in winter. This might explain the low percentile of this factor. The controllability factors in all the healthcare settings were low since, basically, the building systems were controlled by the facility managers remotely rather than the staff. The average mean and percentile of the performance factors were calculated by adding the values in Appendix D and divided by six. Table 5.8 shows the average scores and average percentile of the six healthcare settings in comparison to the benchmark, the order is based on the average percentile from high to low.

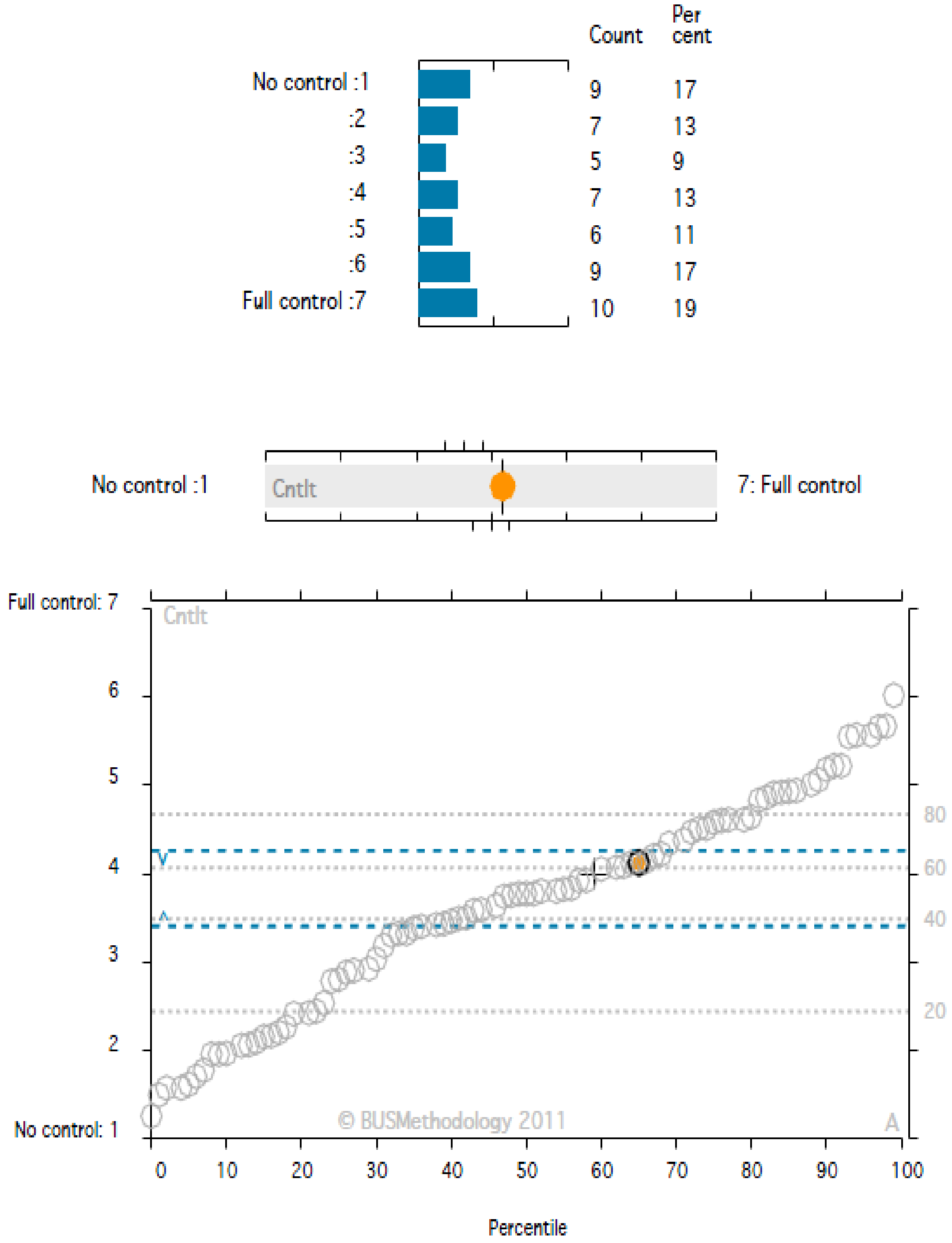


Figure 5.1 Example of benchmark report

Table 5.8 Average percentile of the healthcare settings in the benchmark database

Performance Factors	Average Study Mean	Benchmark Mean	Average Percentile
Productivity	6.15	3.84	67
Cleanliness of building	5.52	5.1	65
Temperature comfort in summer	4.59	4.2	65
Comfort overall	5.16	4.95	64
Image presented to visitors	5.98	5.57	64
Building design	5.23	5	58
Lighting comfort	5.16	5.06	56
Personal safety in and around building	5.68	5.77	55
Ability to meet occupants' needs	5.16	5.1	52
Space use efficiency	4.97	4.89	52
Control over noise	2.65	2.59	52
Noise comfort	4.57	4.55	47
Control over lighting	3.35	3.63	42
Control over cooling	2.26	2.81	37
Temperature comfort in winter	4.37	4.77	36
Control over heating	2.17	2.77	35
Control over ventilation	2.27	3.12	31

5.2.3 Research hypotheses three and four

Survey results were examined to compare the means for the third research hypothesis. The study results showed that “Building Overall,” “Comfort Overall” and “Controllability” had significant differences between the Silver and Gold certifications.

According to mean scores in figure 5.2, we found that staff in the Gold group reported higher scores for “Building Overall,” “Comfort Overall” and “Controllability” than staff in the Silver group which indicates that the staff feel the building performances related to “Building Overall,” “Comfort Overall” and “Controllability” are better in the Gold group than the performances in Silver group. In regards to the “Partial Eta Squared” effect size statistics, it evaluates the importance of the impact of certification levels on “Building Overall,” “Comfort Overall” and “Controllability” and indicates the proportion of variance of the dependent variable (“Building Overall,” “Comfort Overall” and “Controllability”) explained by the independent variable (certification levels). Table 5.9 shows the effect size and Partial Eta Squared value (Pallant, 2007).

Table 5.9 Effect size and Partial Eta Squared value
(Pallant, 2007, p208)

Size	Partial Eta Squared Value
Small	0.01
Medium	0.06
Large	0.138

The “Partial Eta Squared” value for “Building Overall,” “Comfort Overall” and “Controllability” in certification levels was 0.034, 0.051 and 0.052 (Table 4.10), which indicated that 3.4%, 5.1% and 5.2% of the variance in these variables scores can be explained by certification levels (small effect).

As for gender, statistical significant differences was found in “Temperature comfort” however, “Partial Eta Squared” value (Table 4.11) indicated that it did not contribute very much to the model. It also indicated that males and females had different thermal comfort levels while in the same temperature. Men were slightly more satisfied than women in regards to temperature. Study found that females were more sensitive to the thermal comfort than males (Karjalainen, 2006). Figure 5.2 showed the means of these performance factors in certification levels and gender.

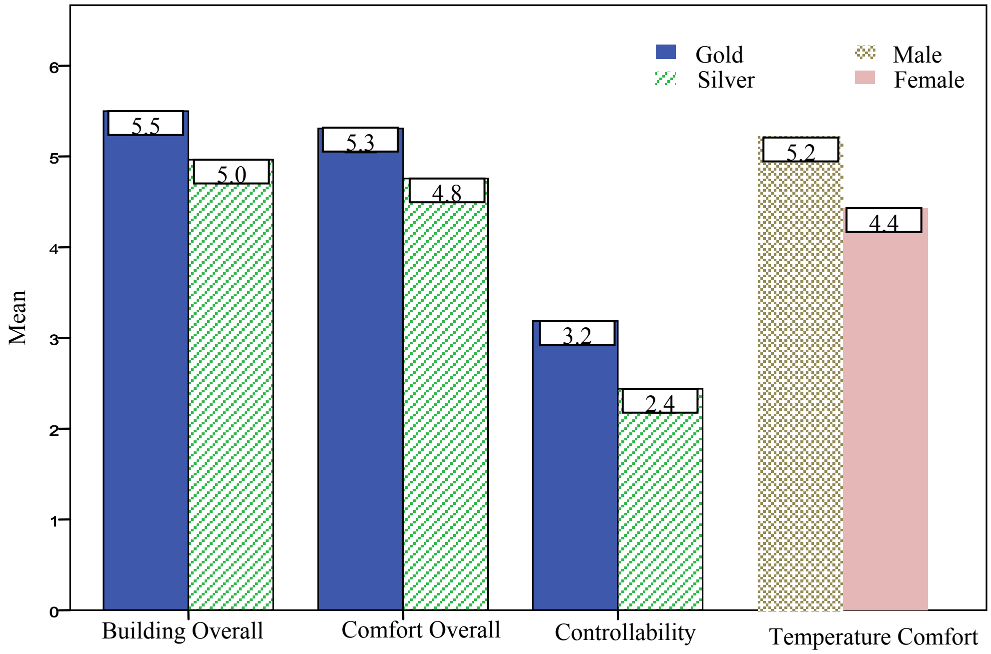


Figure 5.2 Means of performance factors with significant difference

5.2.4 Research hypothesis five

A multilevel regression model was conducted to measure the relationship between overall comfort and building performance predictors. The study results showed that building design, space use efficiency, temperature comfort (composite) and controllability over building system (composite) were significant predictors for staff overall comfort (Table 5.10).

Table 5.10 Predictors for overall comfort

predictors	coefficient	P-value
building design	0.31	0.003
space use efficiency	0.14	0.038
temperature comfort	0.23	0.000
controllability over building system	0.17	0.003

The qualitative data results on the same theme generated similar findings. According to the facility managers' narratives, heating, cooling, lighting, view and connection to nature, acoustics, and controllability of building system can affect overall comfort. The staff's comments indicate that space use, temperature, acoustics, lighting, and controllability affect their comfort.

5.2.5 Research hypothesis six

The sixth hypothesis also employed a multilevel regression model to examine how well the building performance variables were able to predict perceived productivity. The results showed that lighting comfort, temperature comfort (composite) and controllability over building system (composite) had a significant relationship with perceived productivity (Table 5.11).

Table 5.11 Predictors for perceived productivity

predictors	coefficient	P-value
lighting comfort	0.45	0.000
temperature comfort	0.36	0.001
controllability over building system	0.24	0.040

The qualitative data generated similar findings on perceived productivity. In the interviews, facility managers thought that heating, venting and air conditioning (HVAC), connection to nature, lighting, control over temperature, and flexibility of space had a significant impact on productivity. The staff commented that feeling cold, too much walking, noise, not enough space, and no ergonomic work areas had a negative effect on their productivity. Conversely, appropriately designed space, natural light, openness of the space had a positive effect on productivity. In these comments, too much walking was mentioned many times; staff said they had to walk long distances to get supplies, labels and answer call lights, which made them exhausted and reduced productivity. Walking is one of the major time consumers for nurses (Hendrich & Chow, 2008). Hendrich, Marilyn, Skierczynski and Lu (2008) measured the nurses' travel distance, and demonstrated that unit organization and design could improve the effectiveness of nursing care. Table 5.12 indicates the sources of the factors that have an impact on comfort and productivity.

Table 5.12 Source of factors for comfort and productivity

Healthcare Facility	**Dependent Variables**	**Significant predictors from Statistical Results**	**Factors from Staff Comments**	**Factors from Facility Manager Comments**
All six LEED Healthcare Settings	Comfort Overall	building design space use efficiency temperature comfort controllability over building system	work space, control over temperature , heating and cooling, acoustics, lighting comfort, view of nature, ergonomic working space.	heating and cooling, lighting, controllability over building systems, noise, view and connection to nature.
	Perceived Productivity	lighting comfort temperature comfort controllability over building system	heating and cooling, natural light and openness of space, walking distance, noise.	control over temperature and lighting, heating and cooling, connection to nature, flexibility of space.

5.2.6 Research questions two and three

In the interviews, the facility managers discussed several building performance problems. Some of these issues had happened in two, or more than two, healthcare settings. The number is shown in the parentheses after each item. The problems discussed included:

- difficulty in finding appropriate green materials that would withstand the rigorous requirements in healthcare settings (3);
- too much equipment noise (2);
- length of time to get hot water (2);
- HVAC system issues (controllability and undersized) (2);

- complex building system that are difficult to use (2),
- cracks in walls (2) and foundation.
- noise complaints from staff;
- little controllability for staff;
- too much energy required to maintain air quality;
- accessibility of janitorial staff for cleanliness;

Based on these performance issues as well as on both their experience and perspectives, the facility managers gave the following suggestions on design and the LEED system:

- Reducing the use of paging system overhead or using noiseless paging system. Ulrich (2003) demonstrated that using a noiseless paging system could reduce noise in hospital.
- Taking full consideration of building size, number of occupants, number and type of windows, shading device, weather etc. when designing HVAC. Right Size of HVAC systems can ensure efficient operation (Graham, 2009).
- Meeting with green product producers to find appropriate materials. According to Froeschle (1999), gathering information directly from product producers is the first step of green product selection.
- Using more daylighting and designing blinds to reduce glare. Daylighting can reduce stress, length of stay and medication for pain (Ulrich, et al., 2004). Morning daylighting could reduce agitation of aged patients with dementia (Lovell, Ancoli-Israel, & Gevirtz, 1995). Walch, et al. (2005) found that

patient exposed to increased amounts of sunlight had less stress, pain, and took less analgesic medication. And patient exposed to sunlight in the morning had a shorter hospital stay (Benedett, Colombo, Barbini, Campori, & Smeraldi, 2001). Blinds, louvers and fins can be mounted internally or externally to reduce glare (Osterhaus, n.d.). Hultgren & Knave (1974) demonstrated that discomfort glare was one of the main causes of the complaints in office environment.

- Incorporating view and a connection to nature inside the building (positive comments from staff). Studies showed that natural view could reduce stress (Ulrich, 1999) and could reduce the length of stay (Ulrich, 1984).
- Including high efficiency envelop, insulation system in the design of small healthcare settings
- Paying more attention to ongoing maintenance and operations in LEED certified healthcare facility
- Using effectively indirect lighting and exterior light shelves (control daylighting and overheating)--indirect lighting could also improve staff rated productivity (Hedge, Sims, & Becker, 1995)
- Suggesting use of a simple building system--if using a complex system, more education should be provided to staff
- Keeping sustainable after LEED-- train staff to use green materials
- Suggesting using air conditioning system with humidity controls in hospitals in order to control humidity and reduce using outside air

- Quantifying or specifying some LEED strategies (time for hot water, lumens for lighting, etc.). According to Klein (2008), the most efficient hot water distribution system should use least materials for pipes, mechanical engineers should make sure that the hot water locations are close to the appliances. He mentioned that in order to reduce the time for hot water, the length of the pipe serving one fixture needs to be reduced.
- Being careful to avoid problems that were not easy to fix (cracks in walls and foundation) through preventive maintenance
- Keeping the building slightly positive pressure which could contribute to cleanliness (It would be less likely for dirt to come in from outside). Positive pressure can prevent particle contamination from entering the area (BPA, n.d.), and can keep infiltration of air from adjacent areas (Bhatia, n.d.).
- Designing an acoustic environment that takes into consideration the importance of privacy in the healthcare settings. The Health Insurance Portability and Accountability Act (HIPPA) of 1998 has showed the importance of protecting the confidentiality and privacy of patients (Ulrich, et al., 2004).One study observed the hospital staff in elevators for the inappropriate comments, the researchers found that hospital employees often made comments that violated patients' confidentiality and privacy in elevator rides (Ubel, Zell, & Miller, 1995). Another study conducted in an emergency department at a university hospital showed that all the doctors and nurses committed confidentiality and privacy breaches (Mlinek & Pierce, 1997).

Barlas, Sama, Ward and Lesser (2001) measured the patients' perceived privacy in emergency department area with curtains and walls, and they found that patients with curtains perceived less auditory and visual privacy compared with the area with walls.

Table 5.13 shows the building problems and suggestions from facility managers. And table 5.14 summarizes the results of study hypotheses.

Table 5.13 Building performance problems and suggestions

Building Performance Problems	**Facility Managers' Suggestions**
Time for getting hot water	·quantify LEED strategies
Noise complaints	·using sound absorbing ceiling; ·do not use soft, sound absorbing walls and carpet; ·reducing equipment noise;
Complex building system	·using simple building system to have easier maintenance and operation; or more education on staff
Difficult to choose appropriate green material that would withstand the rigors in hospital	·meeting with producer
Too much energy maintaining air quality	·using air conditioning system with humidity controls

Table 5.14 Summary of the results for hypotheses

Hypotheses		Hypotheses Test	Building Performance Factors
1	In a hospital case study, a LEED certified building will report higher staff ratings of building performance factors than a non-LEED certified building.	Factors that have significant difference (LEED are higher than Non-LEED)	Building design, ability to meet occupants' needs, space use efficiency, image presented to visitors, personal safety in and around building, cleanliness of building, temperature comfort in winter and summer, noise comfort, lighting comfort, control over heating and cooling, comfort overall and productivity.
		Factors that do not have significant difference	Control over ventilation, control over lighting, control over noise, importance of controllability over heating, cooling, ventilation, lighting, noise.
2	The building performance of LEED certified healthcare settings will have relatively high rank of staff ratings in building performance factors compared to the buildings in a benchmark database.	Factors that are above 50 percentile	Productivity, cleanliness of building, temperature comfort in summer, comfort overall, image presented to visitors, building design, lighting comfort, personal safety in and around building, ability to meet occupants' needs, space use efficiency, control over noise
		Factors that are below 50 percentile	Noise comfort, control over lighting, control over heating, cooling and ventilation, temperature comfort in winter
3	Building performance variables will be rated differently for LEED Gold and Silver certification.	Factors that have significant difference (Gold group are higher than Silver group)	Building overall (composite), comfort overall and controllability (composite)
		Factors that do not have significant difference	Productivity, noise comfort, lighting comfort, temperature comfort
4	Building performance variables will be rated differently between males and females.	Factors that have significant difference	Temperature comfort
		Factors that do not have significant difference	Noise comfort, lighting comfort, building overall (composite), comfort overall, controllability (composite) and productivity
5	Building performance variables will have a positive relationship with overall comfort.	Factors that have significant positive relationship	Building design, space use efficiency, temperature comfort, controllability (composite)
		Factors that do not have significant relationship	Ability to meet occupants' needs, image presented to visitors, personal safety in and around building, cleanliness of building, noise comfort, lighting comfort
6	Building performance variables will have a positive relationship with perceived productivity.	Factors that have significant positive relationship	Lighting Comfort, temperature comfort and controllability (composite)
		Factors that do not have significant relationship	Noise comfort, lighting comfort, building overall (composite)

5.3 Results Discussion

The results discussion is based on the research hypotheses and questions. The study findings showed that within the same healthcare system, the LEED facility was superior to the non-LEED facility in the following categories. It had better overall building design, personal safety, image to visitors, cleanliness, temperature comfort, noise comfort, lighting comfort, overall comfort, perceived productivity, more control over heating, cooling, met staff's needs better and used space more efficiently. These results may be explained by some existing studies.

LEED certification enhances a facility's public image; Fuerst and McAllister (2011) explain that it has reputational benefits and that LEED certified office buildings could charge 3%-5% more in rent. Silin (2009) demonstrated that LEED strategies could protect the environment as well as the occupants' health; they could also contribute to the occupants' safety. Occupants in LEED-certified buildings had higher satisfaction in cleanliness, thermal comfort and maintenance quality than those in non-LEED certified buildings (Lee & Kim, 2008). Green facilities had easier reconfiguration of space, which resulted in less downtime (Miller, Spivey, & Florance, 2008). Further, LEED used sustainable strategies to improve quality of lighting and use of daylighting (Kats, 2003), and Birt and Newsham (2009) reported that occupants' satisfaction for lighting and acoustics was higher than for non-LEED buildings. LEED certified buildings could also increase employee productivity (Landa, 2010; Thomsbury, 2010; Welsh, 2008).

The superiority of the LEED facility might also be explained by the LEED strategies it employs. Based on the LEED scorecard, it obtained IEQ Credit 2, increased ventilation, IEQ Credit 6, control over lighting system, IEQ credit 6.2, control over thermal comfort system, IEQ Credit 7.1 thermal comfort design and IEQ Credit 7.2 thermal comfort verification. This might have influenced staff suggest higher ratings for temperature, lighting comfort, controllability of heating and cooling, overall comfort and productivity. Also, EQ credit 4.1-4.4, low-emitting materials and credit 5, indoor chemical & pollutant source control might improve the occupants' safety and the building's cleanliness.

The study findings indicated the LEED Gold certified healthcare settings were rated higher in "building overall factors (composite)," "overall comfort" and "controllability over building systems" than the Silver certified group. Some studies focused on the cost difference between the four LEED certification levels (Kats, Alevantis, Berman, Mills, & Perlman, 2003; Syphers, Baum, Bouton, &Sullen, 2003; Miller, et al., 2008). However, very few studies can be found that examine from the staff's perspective building performance differences according to certification levels. Lee (2011b) found a positive relationship between environmental satisfaction, in regards to thermal comfort quality and indoor air quality, and LEED Gold and Silver certification levels. The Gold building group tended to have lower lighting and acoustic quality than other certification levels (Lee, 2011a). Certified and Silver level green buildings achieved 55% and Gold level LEED buildings achieved 88% of possible LEED credits related to low emitting materials and indoor chemical and pollutant source control (Kats, 2003).

The reason the Gold facilities showed significantly higher ratings in overall comfort and controllability of building systems over the Silver facilities might be due to the credits related to controllability and IEQ. The total number of controllability of system credits in the Gold group was four and for the Silver facilities, it was two. Gold facilities obtained 32 credits in indoor environmental quality while Silver facilities earned 27 credits. Indoor environmental quality plays an important role in occupants' health and comfort (Abdou, Kholy, & Abdou, 2006), and buildings with good IEQ can be marketed as a comfortable environment (Arhire, n.d.).

The results also showed a slight gender difference in temperature in healthcare settings; male staff tended to be more satisfied with temperature than female staff. Karjalainen (2006) demonstrated that a small difference between genders was found in preferred temperature and thermal comfort, and that females seemed to be more sensitive to the deviation from the optimum temperature. In the laboratory study, Parsons (2002) found a small difference in the thermal comfort responses of males and females with the same clothing insulation and activity level, but in cool conditions, females seemed to be cooler than males.

Regarding overall comfort and productivity, the study findings showed that temperature comfort and controllability over building systems were important factors to both of them. Building design and efficiency of the space could also affect overall comfort. Further, productivity could be impacted by light comfort.

Wineman (1982) indicated that the staff's satisfaction with design factors like arrangement of interior space and office size were particularly important to architects and designers. He mentioned that workspace design, space layout, size of the workspace and adequacy and arrangement of work spaces could affect staff's satisfaction and performance. Tidiness also had a strong effect on a visitor's comfort and feelings (Morrow & McElroy, 1981). Frontczak and Wargocki (2010) claimed that providing occupants the ability to control the environment could improve satisfaction with the indoor environment. Personal control over building systems could provide the optimum conditions for comfort (CIBSE, 1999). Leaman (1999) reported that comfort and perceived productivity were greater in buildings where occupants have more control over the building systems. From the architects' perspectives, they ranked daylight and views, controllability of systems and thermal comfort as the top items that could enhance staff productivity (Hepner & Boser, 2007). Lan, Lian and Pan (2010) demonstrated that thermal discomfort had a negative impact on office staff productivity. Studies indicated that lighting was an important factor on occupants' productivity (Heerwagen, 2000; Chung & Burnett, 2000).

5.4 Conclusion

Through comparing the data of interview and questionnaire survey, the results of the survey were confirmed by the facility managers' statements. The six hypotheses were tested with different statistic methods and research questions were also answered. The study results were discussed, literature review showed that the study results were supported by previous studies.

6. CONCLUSION

This chapter will address the limitations of this study and give a possible future research direction. Following this, the findings presented in the results chapter are combined and guidance for healthcare design is generated.

6.1 Summary

The LEED for healthcare rating system represents a seven-year collaboration between the Green guide for Healthcare (GGHC) and the USGBC (USGBC, 2010a). It incorporates many concepts and strategies from the GGHC (Zimmerman, 2011).

LEED HC is important to sustainable healthcare design as the facility managers in LEED NC certified healthcare facilities explain:

- "Prior to LEED for healthcare, it didn't make sense in some cases, it was difficult for them to take a specialized building, like a hospital, and fit it into the LEED package, so LEED for healthcare gives a little easier way to integrate some of those ideas."
- "It will get more realistic in the systems and we'll realize that the healthcare environment is different from an office environment or any other church structures anything like that because of different nature."
- "The healthcare environment seems to be extremely rigid with regards to many things…So it's great to have a recognizable alternative system that allows hospital designers and developers and health care industries to shift their emphasis to a newer standard which will be the LEED HC."

The only newly added LEED HC credits in the categories “Sustainable Sites” and “IEQ” are SS credit 9.1 and 9.2: “Connection to the Natural World,” and for IEQ, credit 2: “Acoustic Environment.” According to the facility manager and staff comments, these two aspects are important to healthcare design. If the building design connects to and provides a view of nature, the facility managers receive many positive comments from staff. Providing staff with a connection and view of nature can relieve their stress as well (Ulrich & Gilpin, 2003). Occupants preferred the building environments that provided a connection to, and view of, nature (Orians & Heerwagen, 1992). Confirmed by Bayo, Garcia, & Garcia, (1995)’s study, staff rated that high noise levels could interfere with their work. Noise could also be a cause of staff burnout in hospitals (West, 2008). Biley (1994) suggested that wearing soft-soled shoes and separating areas with high noise levels could create a better environment for staff in hospitals.

The research results showed that controllability of building systems, temperature comfort, lighting comfort, building design and the use of space were significant factors impacting staff comfort and perceived productivity. Gold certified healthcare facilities that obtained more controllability credits and LEED IEQ credits had a significantly higher rating in composite building overall factors, overall comfort, and controllability of building systems, than those in Silver certified facilities. Besides the differences between the various certification levels, the LEED and non-LEED healthcare facilities in one healthcare system also had significant differences in building design, ability to meet occupants’ needs, efficiency of space use, image presented to visitors, personal safety in and around building, cleanliness of the building, temperature comfort in winter and summer, noise comfort, lighting comfort, controllability over heating and cooling, overall comfort and perceived productivity.

6.2 Limitations of the Studies

The study only considered the healthcare settings in climate zones two and three in the U.S.; the results cannot be generalized to other climate zones. In different climate zones, the recommendations for building design are also different, such as the envelope, lighting and HVAC system (Bonnema, Pless, & Debber, 2010). These recommendations might have an impact on the feeling of occupants which might result in different research results.

Due to lack of interest in the study, not meeting the requirements of the study (at least 6 months after occupation, used as healthcare, in climate zone 2 and 3), difficulty in obtaining permissions for study sites, the number of sites is limited. As a result, the healthcare settings in the study were not randomly selected, and were limited by the number of organizations willing to participate.

Another limitation was that the size and number of staff were not the same in the two healthcare settings in the case study. The difference in size and number of staff might be confounding variables that might bias the results,

The study used only the questions in the BUS questionnaire survey. It is possible that other uncollected data may have important correlates with comfort and productivity in healthcare facilities. Other correlates might have included administration policy, the work type of the staff, or job satisfaction.

6.3 Recommendations for Future Studies

Although the limitations constrain the application of research results, they imply potential directions for future studies. Future studies should continue to try to gather data from randomly selected healthcare settings in other climate zones, and the methods outlined in this study should be replicated with additional population samples, such as patients.

Future studies should also:

- Increase the response ratio of staff. Although the sample size of this study was adequate for statistic analysis, larger samples may generate results that are more robust. In addition to interviewing facility managers, it is necessary to interview randomly selected staff to obtain deeper feedback that further triangulates the data and provides more evidence in the qualitative section.
- Limit healthcare setting samples to similar size, function of healthcare settings, and number of staff; for example, only select inpatient, outpatient, assisted living facilities, etc. as study samples. They should also generate design guidance for each type of healthcare setting.
- Obtain the cooperation of healthcare settings of all LEED certification levels, and compare the building performance among the different certification levels. Use LEED scorecards or onsite measurement to verify the results.

- Study the effectiveness of healthcare settings that obtained LEED for Healthcare certification. Compare the effectiveness between LEED NC and LEED HC.

6.4 Recommended Design Guidelines

This study hopes to provide insight on the design of healthcare settings based on the perceptions of staff and facility managers in relation to building performance. Current findings seek to be used as guidance and benchmarks for future studies as well as add to the growing body of research on sustainable design and occupants' perception of IEQ in healthcare settings.

Combining the quantitative and qualitative findings and previous research on building performance and sustainability in healthcare design, design recommendations are proposed for future sustainable healthcare design regarding four main aspects: general recommendations, reducing building performance problems, improving the LEED system for healthcare, and improving the staff comfort and productivity.

Most of the building problems or suggestions were mentioned by several facility managers, or by a facility manager and staff, however, a few of them were mentioned by only one facility manager. Those building problems which were mentioned by one facility manager did exist, as demonstrated by a facility manager at Texas A&M University in the pilot study and provide valuable information which can improve design. The facility manager is the individual the most familiar with the building performance; their first-hand experience and information related to building performance are valuable to the design of future buildings.

6.5 Design Recommendations

6.5.1 General recommendations for healthcare design

Incorporate sustainable strategies into healthcare design. Based on the results of comparison between LEED and Non-LEED healthcare facilities and comparison between Gold certified and Silver certified healthcare settings, I found that staff in the healthcare facility that incorporated LEED credits had a higher satisfaction level regarding building performance. Gold certified facilities with more IEQ credits (such as credits related to controllability and indoor environment comfort) demonstrated better building performance regarding controllability and comfort overall based on staff ratings. Vittori (2011) demonstrated that green healthcare facilities not only operate more efficiently than conventional healthcare settings, but also improve medical outcomes and reduce staff turnover. Architects, designers, LEED APs and constructors should take responsibility for informing healthcare managers of the benefits of incorporating sustainable strategies into the healthcare design. Currently, healthcare managers are most worried about the cost of sustainable healthcare facilities. Actually, sustainable healthcare facilities may not be significantly more expensive to construct. With incentives, the maximum increase of the premiums is about 3.8% (Houghton, Vittori, & Guenther, 2009). Fortunately, according to the 2010 Energy Efficiency Indicator survey conducted by Johnson Controls Institute for Building Efficiency, the American Society for Healthcare Engineering (ASHE), and the International Facility Management Association (IFMA), the percentage of healthcare organizations that intend to incorporate sustainable approaches in their new projects has been increasing since 2008 (Institute for Building Efficiency, 2010).

6.5.2 Recommendations for improving building performance

In the interviews and staff comments in the survey, both facility managers and staff expressed their opinion and perspectives regarding performance of their healthcare facilities, which indicated their building performance problems, which building performances should be improved, and complaints of staff.

1) Meet with green materials producers to find easily obtained green cleaning materials that are recyclable and can withstand the rigors of healthcare settings. This aspect was mentioned by three facility managers, which indicated that half of my study healthcare settings had this building performance problem. Green cleaning products have become popular since they protect the environment and are safe for the user (Johnson, n.d.). In a healthcare facility, this is especially important for the fragile patients. Markkanen, Quinn, Galligan, and Bello (2009) suggested one of the important components for promoting safer and more environmentally sound cleaning materials in the hospitals is to assess the effectiveness of each new cleaning product. Through meeting with the green materials producers, facility managers will obtain firsthand information about the materials and the producer can evaluate which kinds of material are best for the healthcare facility.
2) Use simple systems such as simple heating and cooling systems with simple thermostats. If complex systems are used, more education needs to be provided

for users. This suggestion was mentioned by two facility managers who received many complaints about complicated building system from occupants. Staff commented that sometimes the buildings employ complex systems (such as complicated thermostats) that are difficult for them to use. In this situation, the control system cannot work appropriately, therefore it is important to make the building system simple. If complex systems are used, users should be educated to use the systems.

3) Carefully select the materials for the building envelope to prevent cracks. Two facility managers talked about crack problems, which are common in many buildings. According to Nehdi (n.d.), most of the cracks are caused by deformations rather than materials. Although it is impossible to prevent building movement, the designers still can reduce the occurrence of cracks by proper selection of materials. Nehdi demonstrated that materials that can prevent occurrence of cracks have the following properties: low thermal expansion, low shrinkage and creep coefficient. In Nehdi's study, he summarized the properties of some common building materials, examples are shown in Figure 6.1.

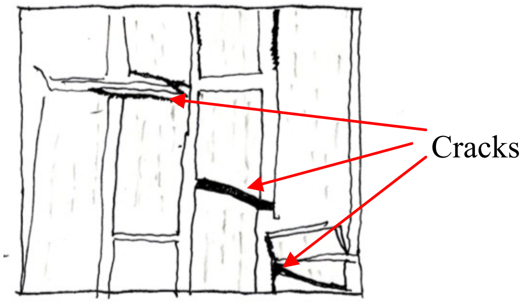


Figure 6.1 Cracks on the wall

Table 6.1 Properties of building materials. Source: Nehdi (n.d.)

Material	**Modulus of elasticity [MPa x 10^3]**	**Shrinkage (initial drying) [mm/m]**	**Creep Coefficient (|)**
Plain Concrete			
Normal Weight	30	0.5	3
Glass	70	0	0
Clay	-	-0.2	1
Wood			
Radial	1	30	Practice avoided
Metal			
Aluminum	70	0	0
Steel	200	0	0
Natural Stone			
Marble	35	-	0

4) Take full consideration (size, number of occupants, windows, etc.) when designing the HVAC system, which is a very important system affecting occupants' comfort. Two facility managers commented they had HVAC problems and staff also complained that sometimes the temperature is not comfortable in the buildings. They mentioned that when the HVAC was undersized, they received many complaints on temperature from staff.

5) Effectively use indirect lighting and exterior light shelves, which can control daylighting and overheating. One facility manager gave this suggestion based on his experience and the occupants' positive comments. Staff in the building also like the lighting in the building. Indirect lighting could improve staff rated productivity compared with parabolic downlighting systems (Hedge, Sims, & Becker, 1995). Figure 6.2 shows exterior light shelves and indirect lighting.

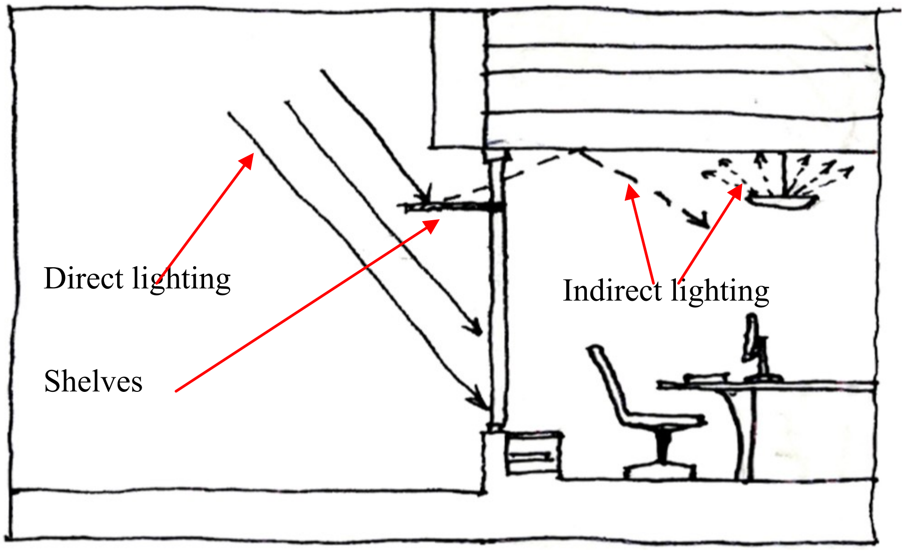


Figure 6.2 Exterior shelves and indirect lighting

6) Improve accessibility for housekeeping staff when cleaning. One facility manager said that janitorial staff complained that the two-story wall in the atrium was very tall, making it hard to clean. Cleanliness in buildings is very important, especially in healthcare settings. Cleanliness is an essential factor that can provide a safe environment, reduce the nosocomial infections, and help retain

staff (Noble, 2002). Figure 6.3 illustrates the situation that janitorial staff may have difficulty in cleaning walls. Therefore, when designers focus on the attractive appearance and function of the buildings, they also need to determine how to clean the building.

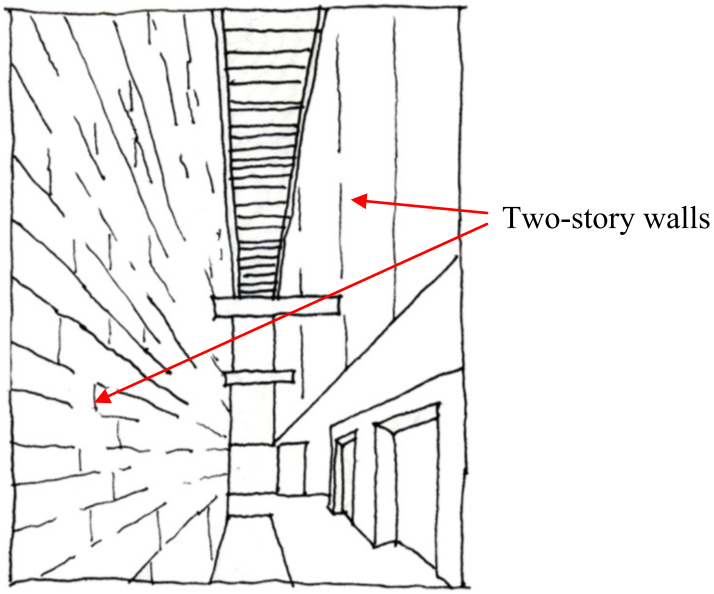


Figure 6.3 High walls difficult to clean

7) Equip the air conditioning system with humidity controls; this can help reduce the amount of outside air that has to be used in buildings. One facility manager said that pumping so much outside air into the facility makes it hard to control the humidity and keep it clean. "Being able to run those systems with humidity condensers can minimize that so we can sometimes close down the amount of

outside air we're bringing in depending on humidity." Usually, hospitals have a minimum requirement for the outside air. In such a case, facility manager should make sure to pump enough outside air.

8) Keep the building under positive pressure as this can contribute to cleanliness. When one facility manager was asked about his perspective on building cleanliness, he suggested that it is less likely to get dirt coming in from outside, when the building is kept under positive pressure.

6.5.3 Recommendations for LEED strategies

1) Keep supporting sustainable strategies after obtaining LEED certification, for example, training staff to use green, recyclable materials and cleaning products. All six facility managers think that maintaining sustainability is very important in LEED certified healthcare facilities. As one facility manager said, "You don't want turn around and put toxic chemical into your building to clean it after you spent all this money putting in healthy materials."
2) Pay more attention to ongoing maintenance and operations in LEED certified healthcare facilities. All six facility managers think that it is very important to track and maintain the building performance after the building has obtained LEED certification. In the newly released *LEED for Healthcare*, I did not find any credits related to ongoing maintenance and operations. Healthcare facilities are a special type of building. Facility managers in healthcare settings suggested that the ongoing maintenance, operations and problems of the LEED healthcare facility should be closely addressed.

3) Quantify or specify some LEED strategies, such as the length of time to get hot water and lumens for lighting. In LEED, you can obtain credits for using an efficient lighting system such as LEDS, but it still could be insufficient. Two facility managers commented that they received many complaints from staff that the time to get hot water is too long. Klein (2008) demonstrated that the most efficient hot water distribution system should use the least materials for pipes. Designers should place the hot water sources close the appliances (Figure 6.4). When the length of pipe serving the fixture is reduced, the time for hot water can be reduced consequently.

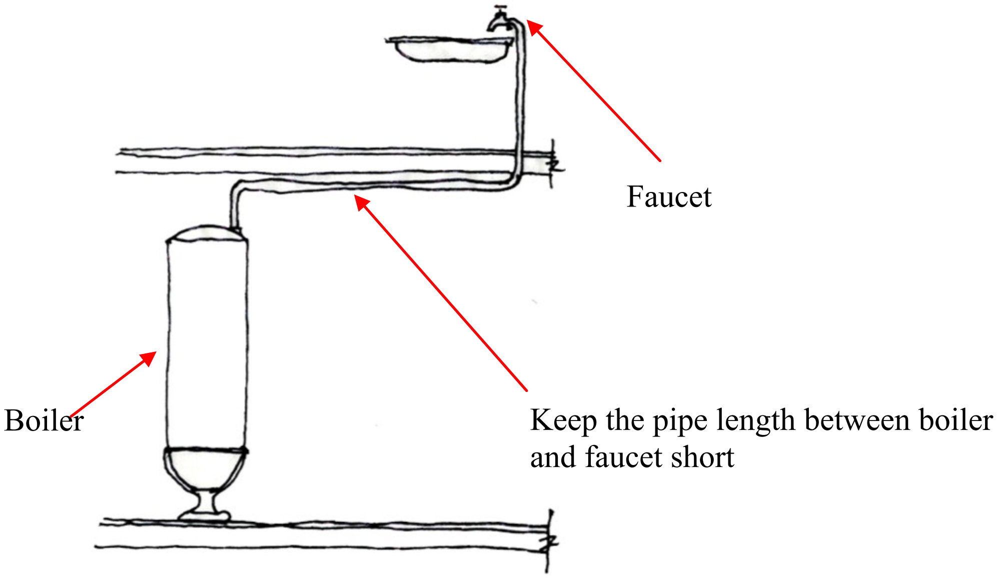


Figure 6.4 Hot water source and appliance

4) Give thoughtful consideration to the Innovation & Design credits. Operations, maintenance and whether they can return the investment should be considered before applying the credits. For the innovation credit, one facility manager said "that it created some problems in terms of operation; you know, it's something we tried to do in order to be more sustainable, but I am not sure it'll pay off in the end." Obtaining LEED certification is just a good beginning, it does not mean the building is sustainable for a lifetime. Managers, designers and LEED APs should carefully evaluate the strategies employed in the building and make sure they will be operated, maintained properly.
5) Create multiple levels of strategies for acoustic environments in healthcare facilities. One facility manager suggested that spaces like patient rooms should have a higher level of acoustic quality and control than some public spaces that are used only intermittently; this could limit the cost. However, this issue has already been addressed in the LEED HC system. In the *Sound and Vibration Design Guidelines for Health Care Facilities* (2010), there are multiple design criteria for room noise levels; the public areas have a lower criterion than private rooms and wards.

6.5.4 Recommendations for improving of staff comfort and productivity

The guidelines for staff comfort and productivity evolved out of the facility managers' responses to the interview questions, staff comments on the survey questionnaire, and the findings from the statistical analysis.

1) Improve personal control of building systems in healthcare settings. According to the statistical findings in the results chapter, controllability is significant predictor for both comfort and productivity which means controllability of building systems plays an important role in occupants' comfort and productivity; however, based on the staff reported low scores of controllability, it does not get much attention from designers and managers. In addition, the study results comparing Gold and Silver groups showed that LEED healthcare facilities with more controllability credits had significantly higher ratings in personal control than those with fewer controllability credits. Therefore, the designers, managers, LEED APs, and constructors should carefully consider the building and provide controllability for more occupants in the building.
2) Particular attention should be paid to the building design, space used, lighting comfort and temperature comfort in the healthcare settings. The quantitative study findings in the results chapter showed that these factors play an important role in staff's comfort and productivity. Architectural design and quality of space design are important in the healing process (Horsburgh, 1995). The spatial requirements in healthcare facilities are different from those in public buildings. In the healthcare settings addressed in this study, staff commented that efficiency of space is important; many of them commented that too much walking was required for getting the medical stuff. Horsburgh (1995) demonstrated that the quality of design in hospitals affected the outcome of medical care. He also mentioned that good spatial qualities could provide patients with better care.

3) Improve the acoustic environment in healthcare settings. All six facility managers think a good acoustic environment has a positive impact on staff comfort and performance. Many staff commented in the survey questionnaire that noise from the pediatrics department had a negative impact on their work. This would likely be true for all inpatient areas where patients are highly stressed or in pain. For the areas close to pediatrics and similar departments, try to block out the noise (crying and screaming). As discussed in the results chapter, it was noise from inside and other people rather than from colleagues and outside that were significantly associated with noise comfort. Through the survey of 295 staff in a hospital, Bayo, et al. (1995) revealed that the most important noise sources were located primarily inside the hospital. Two facility managers mentioned that staff in the building complained that there was too much noise from medical equipment. Medical equipment is one of the main noise sources in healthcare settings. Biley (1994) suggested that wearing soft-soled shoes, separating areas with high noise levels and choosing quieter equipment could create a better environment for staff in hospitals.
4) Provide staff with a view and connection to nature from inside the building (positive comments from staff). All six facility managers commented that views and connection to nature play an important role in healthcare design. Several facility managers said that natural views and connection to nature always get positive comments from staff. Many studies have been conducted on views and connection to nature, which has a positive impact on patients and staff (Cooper-

Marcus and Barnes; 1995; Parsons & Hartig, 2000; Ulrich, 1984; Ulrich, 1991; Ulrich, 1999). Designers should try to incorporate design with natural views in healthcare settings (figure 6.5).

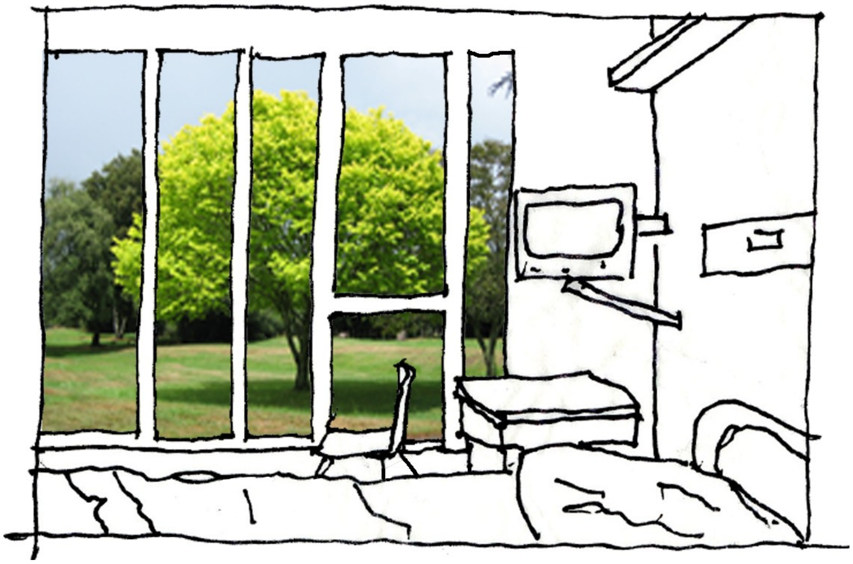


Figure 6.5 Natural view in patient room

5) Use more daylighting throughout building design and equip blinds to reduce glare effectively. All six facility managers commented that using daylighting can reduce energy consumption and have a positive impact on staff and patient. One facility manager mentioned that equipping blinds to control daylighting is also very important in healthcare design and many staff complained that there is too much glare in the afternoon, blinds or louvers can solve this problem easily. Daylighting can reduce stress, length of stay and medication for pain (Ulrich, et

al., 2004). Walch, et al. (2005) found that patients exposed to increased amounts of sunlight had less stress, pain, and took less analgesic medication. Blinds, louvers and fins can be mounted internally or externally to reduce glare (Osterhaus, n.d.), which could result in fewer complaints in office environment (Hultgren & Knave, 1974). Staff and patients can control daylighting by manually adjusting the blinds. Figure 6.6 shows a sketch of blinds in a hospital corridor.

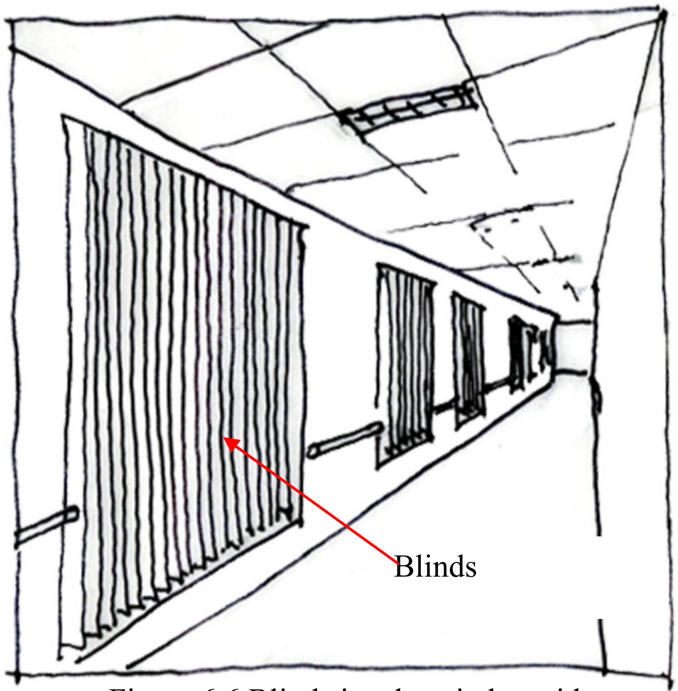


Figure 6.6 Blinds in a hospital corridor

6) Reduce walking distance for staff. Many staff commented on the survey questionnaire that they spent a lot of time doing a lot of walking to get materials and supplies which decreases their productivity. Supplies should be conveniently placed near the nurses. Avoid long halls in healthcare design, and medicine rooms should not be far from the nurses' station and patient rooms. Figure 6.7 and 6.8 illustrate the design concepts on reducing nurses' walking distance by allocating a room for supplies close to centralized nurse station and adding an alcove for supplies and automated medication dispensing cabinets on corridor close to decentralized nurse station.

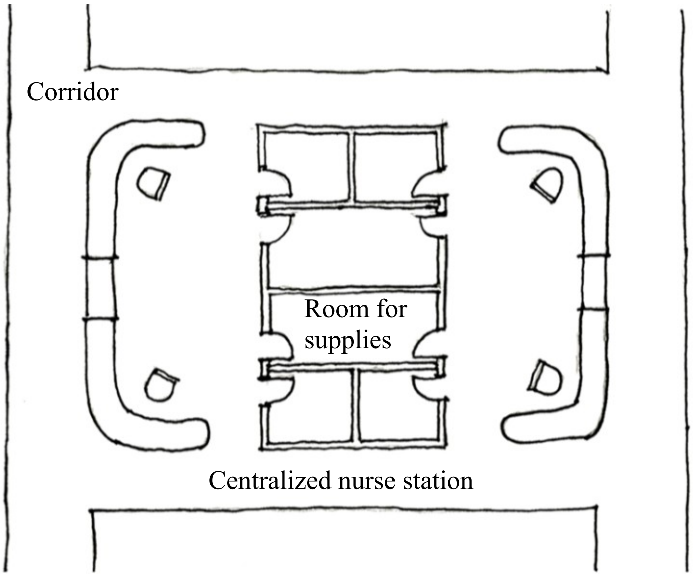


Figure 6.7 Room for supplies in nurse station

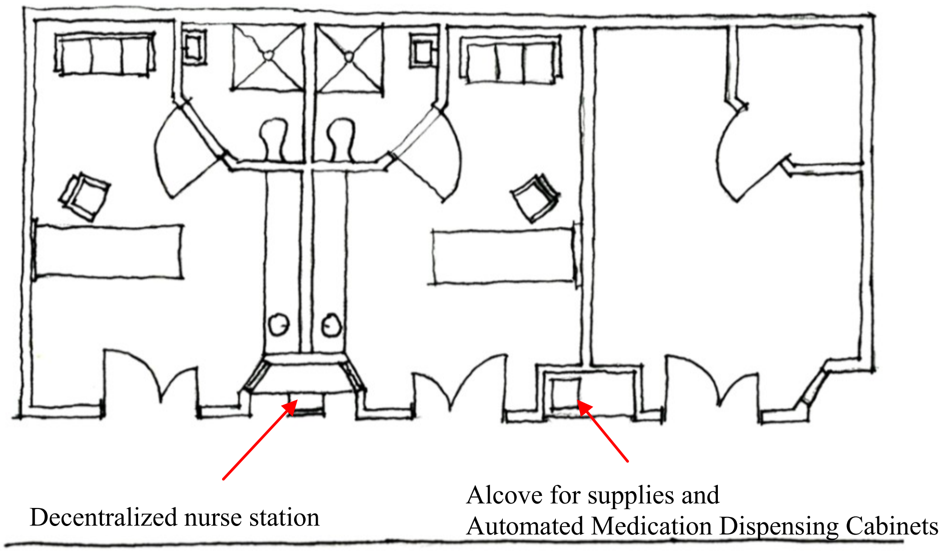

Decentralized nurse station
Alcove for supplies and
Automated Medication Dispensing Cabinets

Figure 6.8 Alcove for supplies on corridor

7) Carefully select an energy efficient lighting system such as LEDs. The facility manager in one healthcare setting was satisfied with the energy efficient lighting system, however, staff in the building commented in the survey questionnaire that the lighting gave them headaches. Selecting the appropriate lighting system is important, since some LEDs might cause headaches due to flicker (Wilkins, Veitch, and Lehman, 2010). For the managers who are in charge of selecting energy efficient lighting systems, they should contact the lighting system producers and obtain the system's detailed specifications, and make an appropriate choice for both energy savings and occupant comfort.

6.6 Conclusion

Healthcare facilities as a special building type are different from public buildings. Healthcare facilities are places for healing, and are in operation 24 hours a day, 7 days a week, and 365 days a year. There are always patients, staff or visitors inside the building.

This study shows that in climate zones 2 and 3, LEED certified healthcare setting will outperform Non-LEED healthcare setting; healthcare settings with Gold certification will outperform the ones with Silver certification; and building performance are positively related with staff overall comfort and perceived productivity.

Sustainable development is intended to create and maintain harmonious social, economic, and ecological systems. The LEED rating system is a sustainable standard which makes buildings energy saving, safe and comfortable. LEED for Healthcare has been released recently to help design better healthcare facilities. It provides a more appropriate way to integrate strategies into healthcare design. Research on exploring the effectiveness of LEED certified healthcare settings needs to be added to the agenda.

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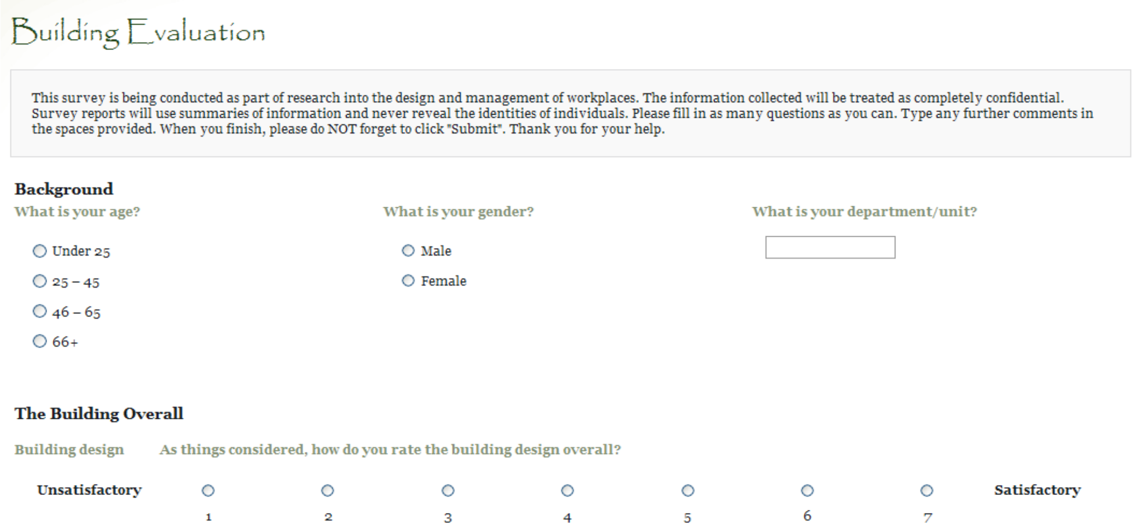
APPENDIX A

Example Questions for Staff



Building Evaluation

This survey is being conducted as part of research into the design and management of workplaces. The information collected will be treated as completely confidential. Survey reports will use summaries of information and never reveal the identities of individuals. Please fill in as many questions as you can. Type any further comments in the spaces provided. When you finish, please do NOT forget to click "Submit". Thank you for your help.

Background

What is your age?	What is your gender?	What is your department/unit?
○ Under 25	○ Male	☐
○ 25 – 45	○ Female	
○ 46 – 65		
○ 66+		

The Building Overall

Building design As things considered, how do you rate the building design overall?

Unsatisfactory	○	○	○	○	○	○	○	**Satisfactory**
	1	2	3	4	5	6	7	

The full questionnaire may be obtained on license from BUS Methodology, copyright 1985-2012 www.usablebuildings.co.uk

APPENDIX B

Telephone Interview Questions for Facility Managers

[1] How long have you been a facility manager at this healthcare setting?

[2] What is your experience as a facility manager at other healthcare facilities? Were any healthcare facilities LEED certified? If yes, what other healthcare facilities were LEED certified? and how do you compare this LEED certified one with the previous ones?

[3] How do you rate design of your LEED healthcare facility overall?
How efficient are the spaces in your LEED healthcare setting?
How do you rate the quality of safety in your LEED healthcare setting?
How do you rate the cleanliness of your LEED healthcare setting?

[4] What elements of your LEED certification building do you think affect the way the public perceives the building?

[5] From the list below (temperature, daylighting, noise, controllability of lighting, heating, cooling, noise and ventilation), which are the most significant elements that affect staff comfort and productivity?

[6] How effective is the building performance in achieving proper lighting and controllability of building systems in your hospital/clinic?

[7] In the case of your healthcare facility, do you receive any complaints about performance affecting comfort? If yes, what are they? Which LEED credits do you think can significantly affect the occupant's comfort?

[8] In the case of your healthcare facility, do you receive any complaints about performance affecting productivity? If yes, what are they? Which LEED credits do you think can significantly affect the occupant's productivity?

[9] Based on your experience as a facility manager in healthcare facility, what would you do in healthcare facility that might promote green strategies and sustainability?

[10] What are the current building performance problems in your hospital/clinic? (could be LEED or other). What in your opinion is the good way to solve these problems?

[11] There were no LEED credits about acoustics when your building was built. Do you think noise is an important factor in sustainable healthcare design?

[12] Is there a "connection to the natural world-places of respite" in your healthcare building? If yes, how is this achieved? What types of comment do staff make about comfort and productivity related to the "natural world-respite" amenities?

[13] How important is it to track the healthcare building's performance and maintain the building's design performance after it has obtained LEED certification?

[14] LEED for Healthcare was released recently. Are you familiar with LEED HC? If you are aware of the contents of this document, what do you think the impact of the new LEED HC will be?

[15] Are there any other topics that you would like share with me regarding LEED and building performance?

APPENDIX C

Full Model for MANOVA

Between-Subjects Factors

		Value Label	N
Certification	1.00	Silver	60
	2.00	Gold	59
sex	1	MALE	22
	2	FEMALE	97

Box's Test of Equality of Covariance Matrices

Box's M	222.907
F	1.346
df1	136
df2	27260.340
Sig.	.005

Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.959	146.419	16.000	100.000	.000	.959
	Wilks' Lambda	.041	146.419	16.000	100.000	.000	.959
	Hotelling's Trace	23.427	146.419	16.000	100.000	.000	.959
	Roy's Largest Root	23.427	146.419	16.000	100.000	.000	.959
Certification	Pillai's Trace	.210	1.661	16.000	100.000	.067	.210
	Wilks' Lambda	.790	1.661	16.000	100.000	.067	.210
	Hotelling's Trace	.266	1.661	16.000	100.000	.067	.210
	Roy's Largest Root	.266	1.661	16.000	100.000	.067	.210
sex	Pillai's Trace	.127	.906	16.000	100.000	.565	.127
	Wilks' Lambda	.873	.906	16.000	100.000	.565	.127
	Hotelling's Trace	.145	.906	16.000	100.000	.565	.127
	Roy's Largest Root	.145	.906	16.000	100.000	.565	.127
Certification * sex	Pillai's Trace	.168	1.264	16.000	100.000	.235	.168
	Wilks' Lambda	.832	1.264	16.000	100.000	.235	.168
	Hotelling's Trace	.202	1.264	16.000	100.000	.235	.168
	Roy's Largest Root	.202	1.264	16.000	100.000	.235	.168

Levene's Test of Equality of Error Variances

	F	df1	df2	Sig.
DESIGN	.553	3	115	.647
NEEDS	.753	3	115	.523
SPACEBUILT	1.393	3	115	.249
IMAGE	4.742	3	115	.004
SAFETY	1.572	3	115	.200
CLEANING	3.453	3	115	.019
Noise Comfort	.649	3	115	.585
Lighting Comfort	2.977	3	115	.035
Comfort Overall	1.892	3	115	.135
Productivity	.266	3	115	.850
Control over Heating	8.927	3	115	.000
Control over Cooling	2.659	3	115	.052
Control over Ventilation	.801	3	115	.496
Control over Lighting	.821	3	115	.485
Control over Noise	1.273	3	115	.287
Temperature Comfort	.411	3	115	.745

Refined model for MANOVA

Between-Subjects Factors

		Value Label	N
Certification	1.00	Silver	68
	2.00	Gold	66
sex	1	MALE	24
	2	FEMALE	110

Box's Test of Equality of Covariance Matrices

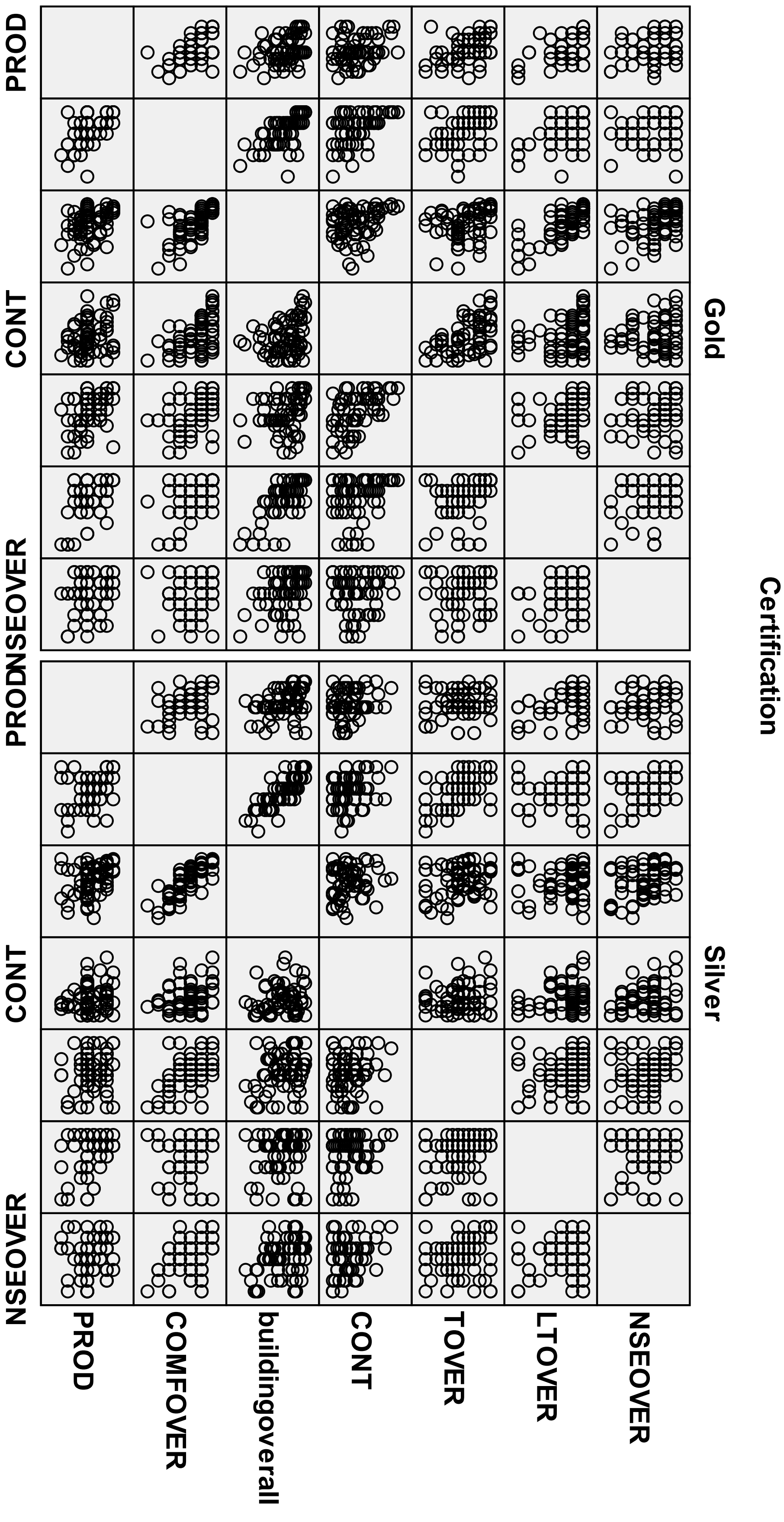
Box's M	145.369
F	1.380
df1	84
df2	3450.489
Sig.	.013

Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.936	260.784	7.000	124.000	.000	.936
	Wilks' Lambda	.064	260.784	7.000	124.000	.000	.936
	Hotelling's Trace	14.722	260.784	7.000	124.000	.000	.936
	Roy's Largest Root	14.722	260.784	7.000	124.000	.000	.936
Certification	Pillai's Trace	.102	2.022	7.000	124.000	.057	.102
	Wilks' Lambda	.898	2.022	7.000	124.000	.057	.102
	Hotelling's Trace	.114	2.022	7.000	124.000	.057	.102
	Roy's Largest Root	.114	2.022	7.000	124.000	.057	.102
sex	Pillai's Trace	.058	1.084	7.000	124.000	.378	.058
	Wilks' Lambda	.942	1.084	7.000	124.000	.378	.058
	Hotelling's Trace	.061	1.084	7.000	124.000	.378	.058
	Roy's Largest Root	.061	1.084	7.000	124.000	.378	.058
Certification * sex	Pillai's Trace	.068	1.296	7.000	124.000	.258	.068
	Wilks' Lambda	.932	1.296	7.000	124.000	.258	.068
	Hotelling's Trace	.073	1.296	7.000	124.000	.258	.068
	Roy's Largest Root	.073	1.296	7.000	124.000	.258	.068

Levene's Test of Equality of Error Variances

	F	df1	df2	Sig.
Noise Comfort	.568	3	130	.637
Lighting Comfort	1.533	3	130	.209
Comfort Overall	1.946	3	130	.125
Productivity	.560	3	130	.643
Temperature Comfort	.110	3	130	.954
Building Overall	1.013	3	130	.389
Controllability	.936	3	130	.426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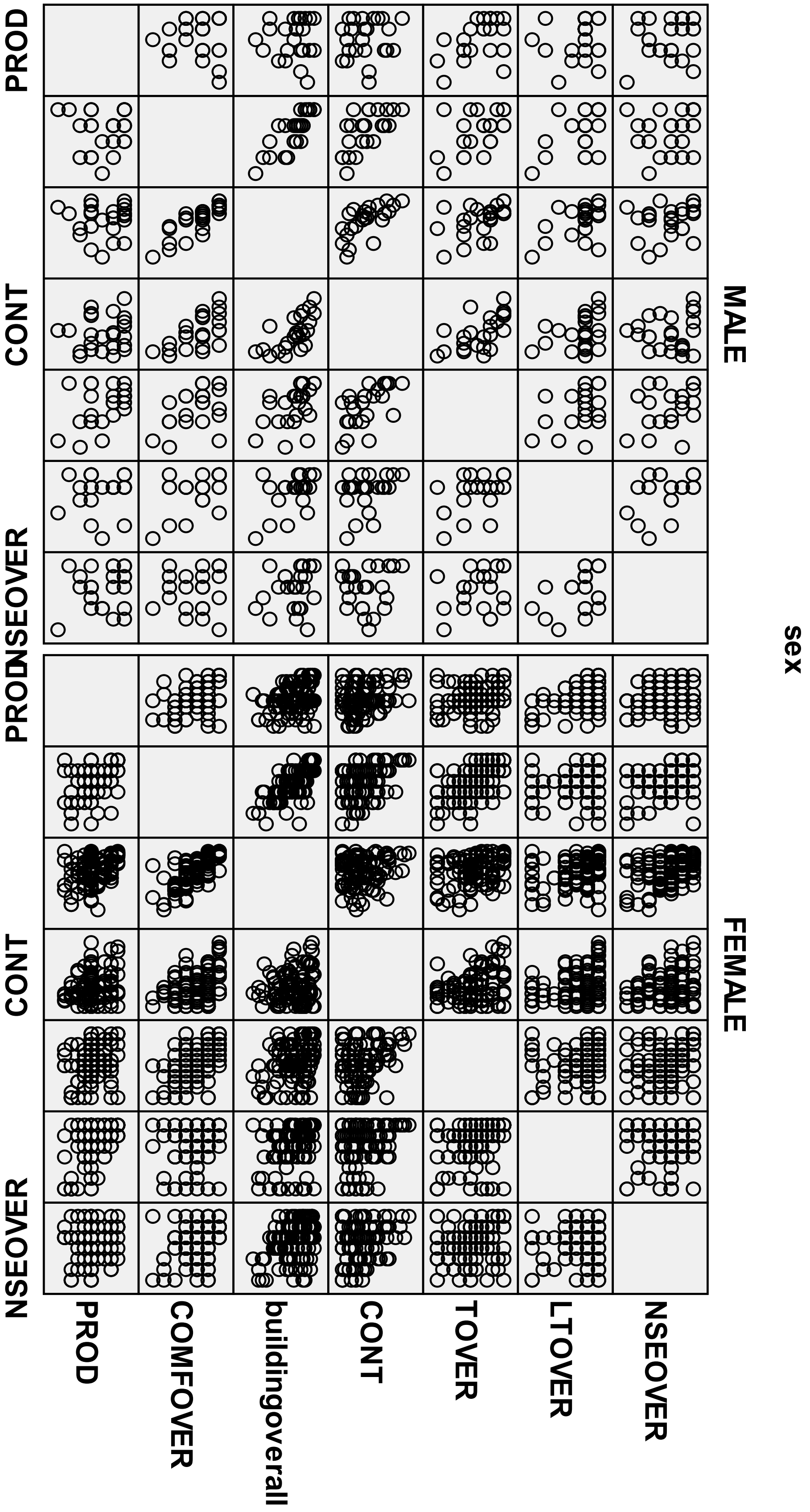
Certification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APPENDIX D

Healthcare setting AS

Performance Factors	Study Mean	Benchmark Mean	Percentile
Comfort overall	5.18	4.95	70
Productivity	10	7.68	65
Design	5.33	5	62
Needs	5.09	5.1	44
Space	4.77	4.89	42
Safety	5.54	5.77	42
Image	5.8	5.57	55
Cleanliness	5.47	5.1	67
Temperature in summer	4.98	4.2	77
Temperature in winter	4.57	4.77	44
Noise overall	4.96	4.55	68
Lighting overall	5.37	5.06	59
Control over cooling	3.51	2.81	73
Control over heating	3.69	2.77	74
Control over noise	2.75	2.59	54
Control over lighting	4.15	4.95	65
Control over ventilation	2.15	7.68	29

Healthcare setting BU

Performance Factors	Study Mean	Benchmark Mean	Percentile
Comfort overall	5.06	4.95	62
Productivity	14.54	7.68	67
Design	5.32	5	62
Needs	5.03	5.1	44
Space	4.56	4.89	33
Safety	5.44	5.77	34
Image	5.91	5.57	56
Cleanliness	6.12	5.1	89
Temperature in summer	3.73	4.2	24
Temperature in winter	3.53	4.77	5
Noise overall	4.38	4.55	38
Lighting overall	4.94	5.06	38
Control over cooling	2.41	2.81	42
Control over heating	1.65	2.77	17
Control over noise	2.94	2.59	66
Control over lighting	3.68	3.63	49

Healthcare setting CL

Performance Factors	Study Mean	Benchmark Mean	Percentile
Comfort overall	4.35	4.95	21
Productivity	8.12	7.68	59
Design	4.09	5	19
Needs	4.36	5.1	17
Space	4.03	4.89	21
Safety	4.88	5.77	19
Image	4.94	5.57	23
Cleanliness	3.82	5.1	12
Temperature in summer	4.66	4.2	71
Temperature in winter	5.12	4.77	71
Noise overall	4.09	4.55	24
Lighting overall	5.5	5.06	73
Control over cooling	2.32	2.81	36
Control over heating	2.18	2.77	40
Control over noise	2.78	2.59	58
Control over lighting	3.44	3.63	38
Control over ventilation	2.12	3.12	29

Healthcare setting DG

Performance Factors	Study Mean	Benchmark Mean	Percentile
Comfort overall	5.2	4.95	70
Productivity	10	7.68	65
Design	4.5	5	27
Needs	4.8	5.1	36
Space	5	4.89	45
Safety	6	5.77	74
Image	6.2	5.57	72
Cleanliness	5.8	5.1	64
Temperature in summer	4.5	4.2	67
Temperature in winter	4.5	4.77	41
Noise overall	4.3	4.55	34
Lighting overall	5.5	5.06	73
Control over cooling	1.33	2.81	5
Control over heating	1.6	2.77	15
Control over noise	2.8	2.59	60
Control over lighting	2.8	3.63	27

Healthcare setting EE

Performance Factors	Study Mean	Benchmark Mean	Percentile
Comfort overall	5.29	4.95	70
Productivity	20	7.68	81
Design	6.14	5	92
Needs	6	5.1	91
Space	5.57	4.89	79
Safety	6	5.77	74
Image	6.57	5.57	91
Cleanliness	6.43	5.1	97
Temperature in summer	4.57	4.2	67
Temperature in winter	4.14	4.77	21
Noise overall	4	4.55	24
Lighting overall	4	5.06	10
Control over cooling	1	2.81	1
Control over heating	1	2.77	1
Control over noise	1.29	2.59	1
Control over lighting	2.14	3.63	18
Control over ventilation	1.14	3.12	1

Healthcare setting FA

Performance Factors	Study Mean	Benchmark Mean	Percentile
Comfort overall	5.88	4.95	89
Productivity	11.12	7.68	65
Design	6	5	88
Needs	5.67	5.1	81
Space	5.89	4.89	91
Safety	6.22	5.77	84
Image	6.44	5.57	87
Cleanliness	5.5	5.1	62
Temperature in summer	5.11	4.2	84
Temperature in winter	4.33	4.77	33
Noise overall	5.67	4.55	95
Lighting overall	5.67	5.06	84
Control over cooling	3	2.81	64
Control over heating	2.89	2.77	60
Control over noise	3.33	2.59	74
Control over lighting	3.89	3.63	56
Control over ventilation	4.22	3.12	79

APPENDIX E

IRB Approval for Questionnaire Survey

TEXAS A&M UNIVERSITY
DIVISION OF RESEARCH AND GRADUATE STUDIES - OFFICE OF RESEARCH COMPLIANCE

1186 TAMU, General Services Complex
College Station, TX 77843-1186
750 Agronomy Road, #3500

979.458.1467
FAX 979.862.3176
http://researchcompliance.tamu.edu

Human Subjects Protection Program

Institutional Review Board

DATE:	13-Dec-2010
MEMORANDUM	
TO:	XUAN, XIAODONG 77843-3578
FROM:	Office of Research Compliance Institutional Review Board
SUBJECT:	Initial Review
Protocol Number:	2010-0974
Title:	Exploring the Effectiveness of LEED strategies in LEED Certified Hospitals in Climate Zone 2 and 3
Review Category:	Exempt from IRB Review

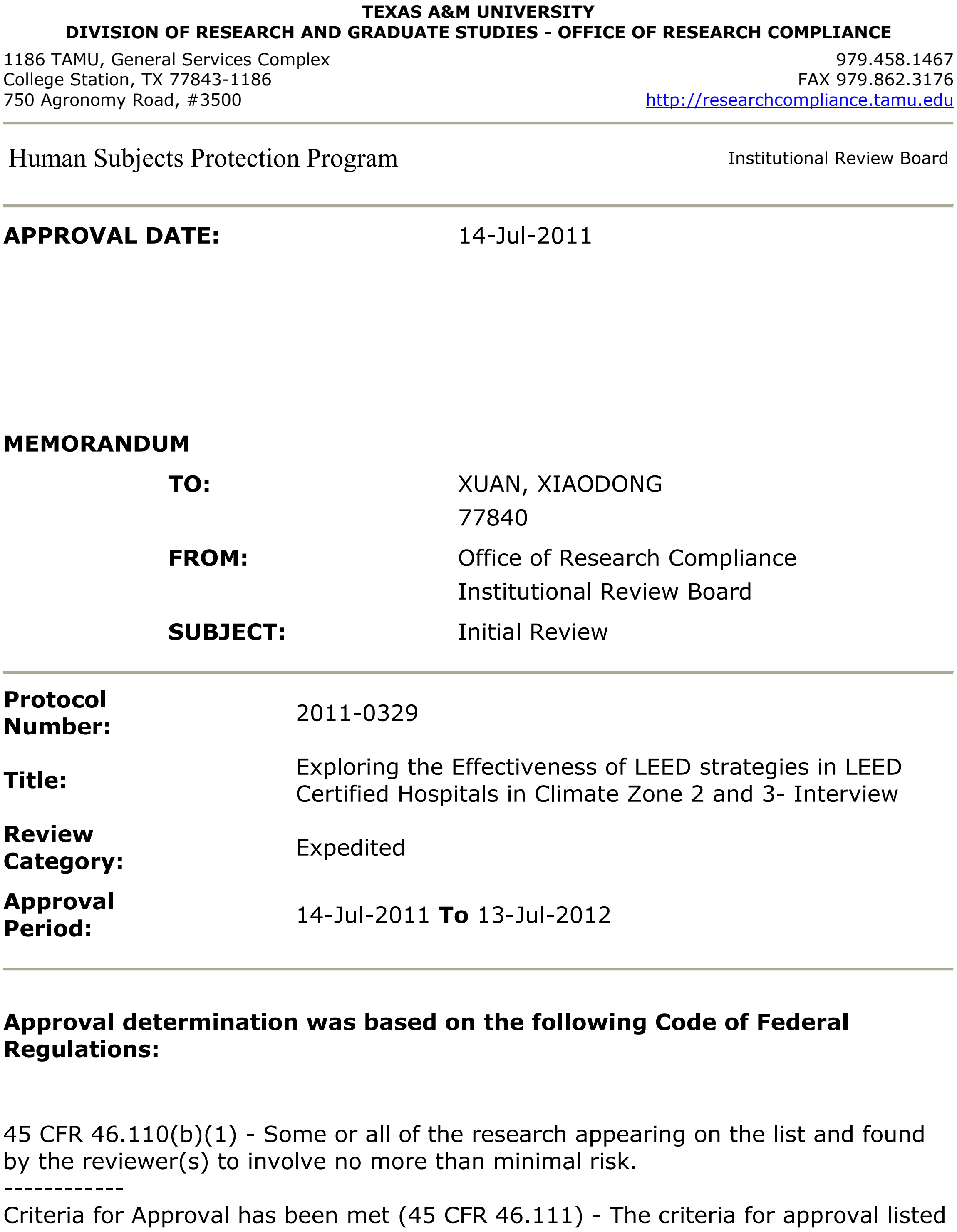
It has been determined that the referenced protocol application meets the criteria for exemption and no further review is required. However, any amendment or modification to the protocol must be reported to the IRB and reviewed before being implemented to ensure the protocol still meets the criteria for exemption.

This determination was based on the following Code of Federal Regulations:
(http://www.hhs.gov/ohrp/humansubjects/guidance/45cfr46.htm)

45 CFR 46.101(b)(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior, unless: (a) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (b) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

Provisions:

IRB Approval for Telephone Interview



TEXAS A&M UNIVERSITY
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http://researchcompliance.tamu.edu

Human Subjects Protection Program

Institutional Review Board

APPROVAL DATE: 14-Jul-2011

MEMORANDUM

TO: XUAN, XIAODONG
77840

FROM: Office of Research Compliance
Institutional Review Board

SUBJECT: Initial Review

Protocol Number:	2011-0329
Title:	Exploring the Effectiveness of LEED strategies in LEED Certified Hospitals in Climate Zone 2 and 3- Interview
Review Category:	Expedited
Approval Period:	14-Jul-2011 **To** 13-Jul-2012

Approval determination was based on the following Code of Federal Regulations:

45 CFR 46.110(b)(1) - Some or all of the research appearing on the list and found by the reviewer(s) to involve no more than minimal risk.

Criteria for Approval has been met (45 CFR 46.111) - The criteria for approval listed

in 45 CFR 46.111 have been met (or if previously met, have not changed).
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(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation or quality assurance methodologies.

(Note: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b) (3). This listing refers only to research that is not exempt.)

Provisions:	
Comments:	Waiver of Documentation of Informed Consent (45 CFR 46.117(c)(2)): the research involves no more than minimal risk of harm to subjects and involves no procedures for which written consent is normally required outside of the research context

This research project has been approved for one (1) year. As principal investigator, you assume the following responsibilities

1. **Continuing Review:** The protocol must be renewed each year in order to continue with the research project. A Continuing Review along with required documents must be submitted 30 days before the end of the approval period. Failure to do so may result in processing delays and/or non-renewal.
2. **Completion Report:** Upon completion of the research project (including data analysis and final written papers), a Completion Report must be submitted to the IRB Office.
3. **Adverse Events:** Adverse events must be reported to the IRB Office immediately.
4. **Amendments:** Changes to the protocol must be requested by submitting an Amendment to the IRB Office for review. The Amendment must be approved by the IRB before being implemented.
5. **Informed Consent:** Information must be presented to enable persons to voluntarily decide whether or not to participate in the research project.

This electronic document provides notification of the review results by the Institutional Review Board.

VITA

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Address:	Department of Architecture, Texas A&M University College Station, TX 77843-3137
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Education:	B.E., Architecture, Anhui University of Architecture, China, 2004 M.Arch., Architecture, Hefei University of Technology, China, 2007 Ph.D., Architecture, Texas A&M University, 2012 Certificate in Health System and Design, Texas A&M University, 2012
Certification:	Leadership in Energy & Environmental Design (LEED) accredited professional
Work Experience:	Teaching Assistant. September 2009 to May 2012 College of Architecture, Texas A&M University, College Station, Texas. Graduate Assistant of Non Teaching. September 2007 to May 2009 College of Architecture, Texas A&M University, College Station, Texas. Intern Architect. March 2004 to September 2004 Institute of Architectural Design, Hefei University of Technology, China.