THE RELATIIONSHIPS AMONG INDOOR ENVIRONMENTAL QUALITY, OCCUPANT SATISFACTION, WORK PERFORMANCE, AND SUSTAINABILITY EHTIC IN SUSTAINABLE BUILDINGS

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Abstract

The purpose of this study was 1) to develop an explanatory model showing simultaneous relationships among occupants' satisfaction with indoor environmental quality (IEQ) criteria at the workstation level, their satisfaction with the overall facility (i.e., site, building, and interior), their overall work performance, and their sustainability ethic in sustainable buildings; 2) to test the developed model and suggest a good-fit model; and 3) to estimate the hypothesized relationships among variables.

Secondary data analysis was used to examine the purpose of this study. The data were obtained from the B3 Sustainable Post-Occupancy Evaluation Survey database hosted by the Center for Sustainable Building Research at the University of Minnesota. Data were collected from three sustainable buildings, all located in Minnesota and a total of 289 respondents were used for data analysis.

Exploratory factor analysis and confirmatory factor analysis provided support for a good-fit five-factor model, including furnishings, thermal conditions, view conditions, lighting conditions, and acoustics and privacy conditions, related to occupants' satisfaction with sustainable IEQ criteria. Path analysis was used to examine simultaneous relationships among independent and dependent variables. Satisfaction with thermal conditions did not significantly influence both satisfaction with overall facility and overall work performance. The only significant relationships were between satisfaction with furnishings and acoustics and privacy conditions and overall work performance. There were significant relationships among satisfaction with overall facility, overall work performance, and sustainability ethic.

The importance of this study is that the findings extended the scope of the research through the development of a hypothesized model, extraction of IEQ factors, and as a test for a good-fit model showing the simultaneous relationships among variables. Most importantly, this

study found that there is a connection between occupants' sustainability ethic and their satisfaction and work performance. Therefore, in the future research, a revised model showing a continuous process among all variables can be suggested and tested with much larger sample size. In addition, five IEQ factors, derived from various IEQ attributes addressed in B3-SPOES questionnaire, can be used for newly development of occupant survey questionnaire that has reliability and validity.

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CHAPTER ONE: INTRODUCTION

Background

Sustainable building design has become an increasingly common practice for the benefit of both occupants and business owners by providing enhanced quality of indoor environments and reduced energy costs compared to conventional building design. In the U.S., buildings consumed 40 percent of total energy used in 2008 and, specifically, commercial buildings used 46.2 percent of building energy consumption and 18.4 percent of U.S. primary energy consumption (US DOE, 2011). Energy consumption is closely associated with natural environmental problems because nature has provided all of the energy and raw materials for buildings (Jones, 2008; Winchip, 2007). As a result of growing demands for energy and raw materials, along with pollution caused by the emission of noxious and poisonous by-products, buildings tended toward a negative impact on the natural environment (Jones, 2008). Sustainable design helps create buildings that minimize this negative impact on the natural environment by reducing energy consumption and pollution as well as maintaining the ecological balance (ASHRAE, 2006).

Sustainable buildings have been designed, constructed, and evaluated according to sustainable design guidelines and rating systems to improve indoor environmental quality in addition to reducing energy consumption and pollution. Examples of these sustainable design guidelines and rating systems are the Buildings, Benchmarks, and Beyond-Minnesota Sustainable Building Guidelines (B3-MSBG) developed by the Center for Sustainable Building Research (CSBR) at the University of Minnesota and the

Leadership in Energy and Environmental Design (LEED) Green Building Rating System^{TM} developed by the U.S. Green Building Council (USGBC). Sustainable design guidelines and rating systems identify the overall categories for human and environmental health as well as for high building performance, such as site, water, energy, materials, indoor environmental quality (IEQ), etc., that must be considered when designing, constructing, operating, and maintaining buildings. Each category is rated on a point scale and buildings must earn a minimum number of points in each category for certification. Thus, sustainable buildings designed and constructed by sustainable design guidelines and evaluated by sustainable rating systems can offer significant cost savings from reduced energy usage as well as lower operation and management costs (Kats, 2005; Seal, Browning, & Frej, 2005).

In addition, various sustainable IEQ criteria included in these guidelines and rating systems, such as thermal comfort, indoor air quality (IAQ), acoustics, vibrations, electric lighting, daylighting, views, controllability of systems, and furnishings can directly affect occupants who use buildings. These criteria also contribute to potential cost savings derived from occupants. Specifically, improved IEQ of sustainable office buildings can increase businesses' profitability by increasing occupant (i.e., employee) satisfaction thereby, reducing turnover rates. Employees are the second highest cost for businesses, and retaining them increases businesses' return on investment (Chilton & Baldry, 1997; Mendler, Odell, & Lazarus, 2006). In other words, sustainable design of office buildings tends to provide employees with improved IEQ, such as increased daylight, access to outside views, healthy IAQ, access to personal temperature and lighting controls, and increased comfort level, so that employees may be more satisfied with their work environments and work more productively, which ultimately leads to improved retention (Bonda & Sosnowchik, 2007; Fisk, 2002; Heerwagen, 2000; Lee, 2007). In contrast, poor indoor environments, such as those with glare problems, overheating problems, and the lack of sound and visual privacy, may contribute to employees' dissatisfaction and poor work performance. As a result, employees may look for other jobs in an effort to seek better work environments.

Many studies have been interested in the impact of IEQ on organizations' economic bottom lines by investigating the linkage between occupants and business profitability (Bonda & Sosnowchik, 2007; Fisk, 2000; Mendler, et al., 2006). According to those studies, building owners and businesses have become interested in the suggested benefits of improved IEQ produced by sustainable design in terms of its contribution to the long-term organizational effectiveness and cost-benefit. In addition, practitioners have also continued to seek evidence that interior environments of sustainable buildings affect occupant satisfaction and lead to improvements in their work performance, which ultimately contributes to business success.

Under these circumstances, sustainable design has become an important part of interior designers' approaches to the design of work environments by reducing negative environmental impact on humans, in particular the buildings' occupants. As those who are in charge of designing indoor environments to improve occupant's quality of life, interior designers have a responsibility to protect the environment and the health, safety, and welfare of building occupants. Designing sustainable interiors to provide improved

IEQ requires an understanding of how buildings influence both the environment and occupants (Winchip, 2007) based on social sustainability, economic sustainability, and environmental sustainability. A holistic approach to these three principles of sustainability contributes to the potential benefits of sustainable interior design in terms of improved IEQ and its effect on occupants, such as enhancing occupant comfort and welfare (social benefit), increasing occupant productivity (economic benefit), and improving occupant health by reducing air pollution (environmental benefit).

Problem Statement

Post-occupancy evaluation (POE) has been used to examine the influence of sustainable IEQ criteria on occupants' satisfaction and their perceived work performance in sustainable office buildings. Among various POE methods, occupant survey findings have indicated that sustainable buildings positively or negatively contribute to occupants' satisfaction and work performance compared to conventional buildings. In addition, the investigation of occupants' satisfaction with specific IEQ criteria and the effect of those criteria on occupants' work performance has been described in studies conducted by research centers, such as the Center for the Built Environment (CBE) at the University of California, Berkeley; the Center for Building Performance and Diagnostics (CBPD) at Carnegie Mellon University; and the Center for Sustainable Building Research at the University of Minnesota. However, little has been done to investigate how occupants' satisfaction with specific IEQ criteria at the workstation level is related to occupants' satisfaction with the overall facility environments (i.e., site, building, and interior) and their perceived overall work performance. Especially, the investigation of workstation environments was important to explore occupants' satisfaction and work performance because occupants spend most time of their working hours at their workstations. In the context of this research, workstation is an area, as in an office, outfitted with equipment and furnishings for one worker and usually including a computer. Further, little is known about occupants' sustainability ethic (i.e., whether sustainability or sustainable design is important to them) and its relationship to their satisfaction and work performance. Considering the increasing importance of occupants' perceptions of the quality of buildings and indoor environments, it is important to examine whether occupants' satisfaction with environments and the effect of that satisfaction on their work performance contribute to the development of their sustainability ethic. Most importantly, little research has been done to investigate the simultaneous relationships between occupant outcomes, such as satisfaction, work performance, and sustainability ethic, and IEQ criteria of sustainable buildings at the workstation level and the overall facility level, which would better reflect real life's complexity wherein all factors simultaneously interact with each other.

Purpose and Research Questions of the Study

The purpose of this study was 1) to develop an explanatory model showing simultaneous relationships among occupants' satisfaction with IEQ criteria at the workstation level, their satisfaction with the overall facility (i.e., site, building, and interior), their overall work performance, and their sustainability ethic; 2) to test the developed model and suggest a good-fit model; and 3) to estimate the hypothesized relationships among variables. To accomplish this purpose, first a hypothesized model, showing overall linkages among all variables, was proposed based on the review of literature. Second, IEQ criteria that would be used as variables in the model were identified through factor analysis, showing the specific loading patterns of various IEQ features on each IEQ criterion. Finally, the proposed model, including identified IEQ criteria and other variables such as occupants' satisfaction, their work performance, and their sustainability ethic, was tested using path analysis to examine the extent to which variables were linked and to evaluate the strength of relationships among variables.

Specific research questions to investigate the purpose of this study are:

1) What are the relationships among occupants' satisfaction with IEQ criteria at the workstation level, their satisfaction with the overall facility, their overall work performance, and their sustainability ethic?
2) What is the best model showing the simultaneous relationships among occupants' satisfaction with IEQ criteria at the workstation level, their satisfaction with the overall facility, their overall work performance, and their sustainability ethic?

Significance of the Study

This study can contribute to better sustainable design research and practice. One significant contribution of this study can be to develop and test a model explaining the overall complex and simultaneous relationships among sustainable IEQ criteria, occupants' perceptions of their environments, and their sustainability ethic. This model can serve as a basic conceptual framework for future interior design researchers who will investigate the extent of influences of IEQ criteria on occupants who use sustainable buildings as well as make comparisons with non-sustainable buildings. The results of this study can be used as a baseline to measure the relationships between sustainable interior design features and occupants' perceptions of their environments as well as their sustainability ethic. Moreover, as a part of a larger database of POEs, the results can inform sustainable building guidelines and rating systems in addition to their implications for building interior design practices in non-sustainable buildings.

CHAPTER TWO: LITERATURE REVIEW

This chapter reviews a range of available literature on the sustainable design movement, IEQ of sustainable interior design, relationships between IEQ of sustainable interiors and occupants' satisfaction and work performance, and occupants' sustainability ethic. The sustainable design movement section includes sustainable building design and sustainable interior design. Portions on IEQ of sustainable interior design deal with the importance of IEQ, IEQ in sustainable design guidelines and rating systems, and POEs of IEQ. The section on relationships between occupants' satisfaction with IEQ criteria at the workstation level and satisfaction with the overall facility and overall work performance reviews related studies about relationships between occupants' satisfaction with each IEQ category at the workstation level and their satisfaction with the overall facility and overall work performance. The sustainability ethic section discusses occupants' perceptions on the importance of sustainability in relation to their satisfaction and work performance. A theoretical framework is also discussed to explain relationships between IEQ of sustainable interior environments, occupant satisfaction, their work performance, and their sustainability ethic. Finally, the hypotheses of this study, along with a proposed model, are identified based on the literature review.

Sustainable Design Movement

Sustainable development, as defined in the 1987 Brundtland report *Our Common Future*, is development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (p. 43). Sustainable development is composed of environmental, social, and economic sustainability. These three aspects need to be integrated and balanced to obtain a comprehensive understanding for designing sustainable buildings and interior environments.

Sustainable Building Design

During the last decade, the design of sustainable buildings has rapidly increased in the U.S. and many other countries around the world. Sustainable building design can improve overall building performance and occupant well-being and minimize a building's life-cycle environmental impact and cost. The term "sustainable" can be defined as "a systematic effort to create, sustain, and accelerate changes in practice, technology, and behavior to reduce building-related environmental impacts while creating places that are healthier and more satisfying for people" (Pyke, McMahon, & Dietsche, 2010, p. 4). "Sustainable" is often used interchangeably with "green," but meanings between sustainable and green are slightly different. Sustainable design is a macro perspective related to protection of the health and welfare of global ecosystems for current and future generations, whereas green design is a micro perspective related to protection of the health and welfare of users in the built environment (Jones, 2008). In the context of the built environment, a green building is a building that is designed and constructed to do less damage to the environment and people than would a conventional building. A sustainable building pursues a more precise goal of designing and constructing a building that has no impact on the environment by co-existing indefinitely with the global ecological balance (Building Science Corporation, 2008).

Generally speaking, sustainable design can make buildings more responsive to environments and occupants by providing various benefits based on the three principles of sustainability: environmental sustainability, social sustainability, and economic sustainability (US EPA, 2010a). As shown in Figure 1, environmental benefits of sustainable buildings are to (1) enhance and protect biodiversity and the ecosystem, (2) improve air and water quality, (3) reduce waste streams, and (4) conserve and restore natural resources. Social benefits of sustainable buildings are to (1) enhance occupant comfort and health, (2) heighten aesthetic qualities, (3) minimize strain on local infrastructure, and (4) improve overall quality of life for occupants. The economic benefits of sustainable buildings are to (1) reduce operating costs; (2) create, expand, and shape markets for green products and services; (3) improve occupant productivity; and (4) optimize life-cycle economic performance (US EPA, 2010a). Therefore, a sustainable building can be considered as "a facility designed, built, operated, renovated, and disposed of using ecological principles for the purpose of promoting occupant health and resource efficiency plus minimizing the impact of the built environment on the natural environment" (Kibert, 2004, p. 491). This relationship is depicted in Figure 1, with the overlapping of circles to indicate the interrelationships of environmental, social, and economic principles.

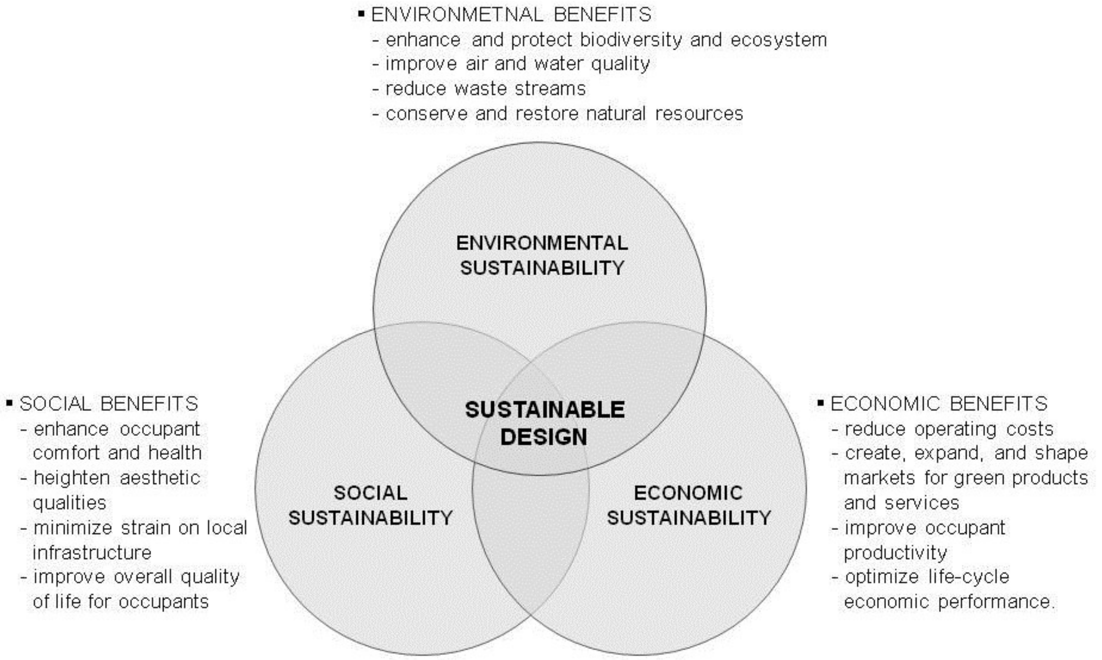

Figure 1. Benefits of three principles of sustainability (US EPA, 2010a).

Most studies related to sustainable building design focus on ways in which the building system saves energy and reduces negative impacts on the natural environment. These are from architectural and engineering perspectives, and less has been done about the role of interior designers in designing indoor environments of sustainable buildings and, further, in improving the quality of indoor environments that may directly affect occupants.

Sustainable Interior Design

Interior design is "a multi-faceted profession in which creative and technical solutions are applied within a structure to achieve a built interior environment" (NCIDQ, 2004). Interior designers have a responsibility to protect the health, safety, and welfare of a building's occupants (Stieg, 2006; Winchip, 2007). With the focus on sustainability, interior designers are expected to plan efficient and effective spaces for occupants by applying the sustainable life cycle approach to the interior environment (Jones, 2010). Interior designers who plan and design sustainable interior environments require an understanding of "how" the indoor environments of buildings affect "people" who use them, and how people use spaces. Based on this perspective, sustainable interior design can be defined as "interior design in which all systems and materials are designed with an emphasis on integration into a whole for the purpose of minimizing negative impacts on the environment and occupants and maximizing positive impacts on environmental, economic, and social systems over the life cycle of a building" (Kang & Guerin, 2009, p.180).

In maintaining the balance of environmental, social, and economic sustainability for sustainable outcomes, interior designers need to consider environmental issues and recognize the need for sustainable interior design that is unlike the traditional interior design approach, which may focus more on functional quality and aesthetics of spaces (Kang & Guerin, 2009). Bonda and Sosnowchik (2007) proposed a model showing the three sustainable principles of environmental sustainability (EnS), social sustainability (SS), and economic sustainability (EcS), as well as three areas of overlap between environmental/social (EnS/SS), social/economic (SS/EcS), and economic/environmental (EcS/EnS), especially in sustainable commercial interiors (see Figure 2). As evidenced by this model, sustainable interior design, balanced by three sustainable principles, can produce a number of benefits to occupants, buildings, nature, and businesses' profitability.

Most especially, this model shows the importance of the interaction or overlap of the principles. This means that all principles must be considered simultaneously for sustainable interior designs.

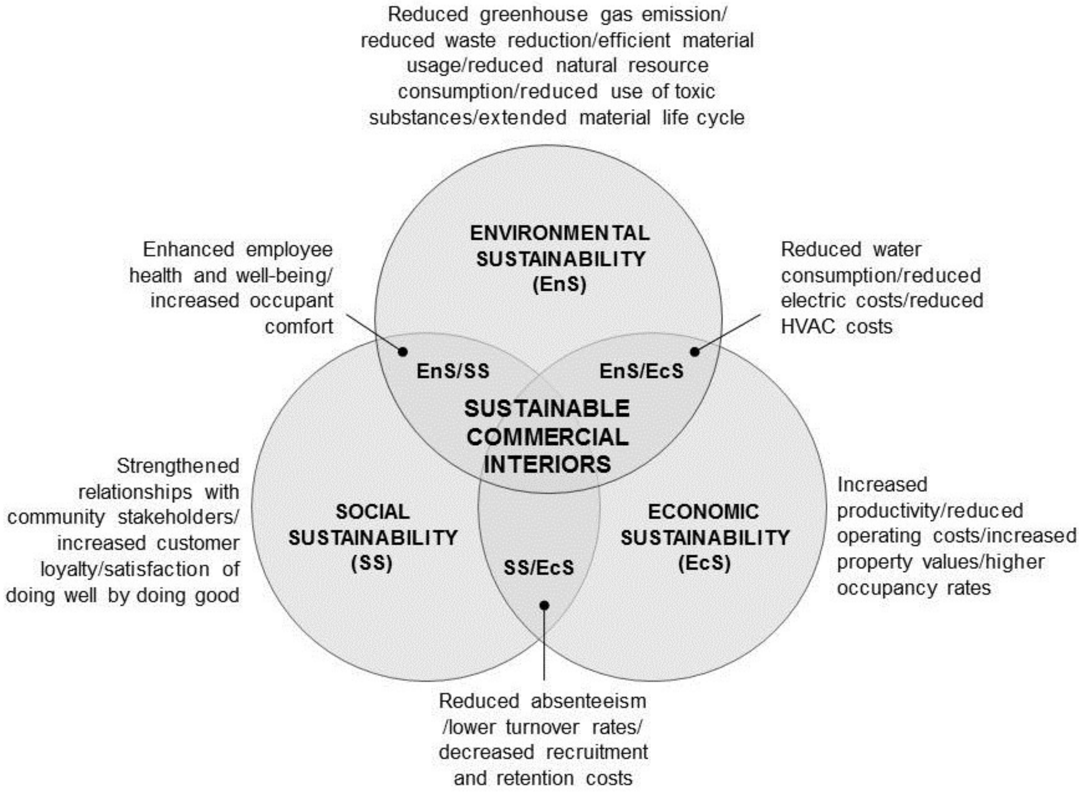

Figure 2. Environmental, social, and economic sustainability of sustainable commercial interiors (Bonda & Sosnowchik, 2007).

To better understand the fundamentals of sustainable design and develop a sustainable interior practice based on sustainability principles, Stieg (2006) provided five aspects of a sustainable interior design practice: connection, knowledge, process, practice, and commitment. She suggested that to understand the meaning and importance of sustainable interior design practice and develop a framework of ecological design from an interiors perspective, interior designers need to develop an intellectual and emotional *connection* to the natural environment by applying adequate *knowledge* regarding environmental impact of practices to environmentally conscious decisions based on verifiable and applicable information. According to Stieg, by incorporating effectiveness, aesthetics, economics, ethics, and environment into the design *process*, interior designers can make appropriate design decisions, create design solutions, and improve the *practice* of sustainable interior design based on their *knowledge* of and *commitment* to sustainability.

Various sustainable design guidelines and rating systems also deal with criteria related to sustainable interior design. Among those criteria, materials and IEQ come under the purview of sustainable interior designers. Materials are one of the main producers of contaminants in interior spaces, which can deteriorate IAQ and worsen the health of occupants and that of the natural environment (CDC, 2010). Thus, interior designers can design healthy interiors by specifying materials that minimize contaminants and reduce impacts on environments and occupants (ASID, 2010). IEQ has highly influential criteria that directly affect occupants who use interior spaces and is composed of various features, such as thermal comfort, IAQ, acoustics, lightings, controllability of systems, privacy, and furnishings. Knowledge of design and specification of IEQ criteria can provide interior designers with the ability to improve the health, safety, and welfare of building occupants. Therefore, IEQ is an important part of the practice knowledge of interior designers.

IEQ of Sustainable Interior Design

Importance of IEQ

Americans spend approximately 90% of their time indoors, therefore the quality of indoor environments can have a significant impact on people's health and their activities performed in buildings (Kats, 2010; US EPA, 2009). IEQ can be defined as "the measurement of the key parameters affecting the comfort and well-being of occupants" (Garnys, 2007, p. 1) and "elements to provide an environment that is physically and psychologically healthy for its occupants" (Bonda & Sosnowchik, 2007, p. 290). Because people (i.e., employees) are the greatest cost in an organization, designing indoor environments that enhance their comfort, health, and well-being can influence business investments through the benefit of occupant outcomes such as increased satisfaction and productivity (Fisk, 2000; 2002; Heerwagen, 2000). In contrast, decreases in occupant performance caused by inadequate IEQ can have a significant cost impact on a business (Garnys, 2007). Thus, building owners have considered IEQ as a way to improve the quality of people's lives in indoor environments, leading to cost benefits for businesses (Kats, 2010). Therefore, providing high quality indoor environments that support occupants' quality of life indoors can be considered a main strategy of sustainable building and interior design. In other words, it is expected that sustainable buildings can provide occupants with environmentally friendly interior spaces that have a better IEQ compared to non-sustainable buildings (Meir, Garb, Jiao, & Cicelsky, 2009). Benefits of positive IEQ on environmental, social, and economic sustainability are shown in Lee's (2007) diagram (see Figure 3). According to the diagram, IEQ provides direct benefits to occupants, particularly when compared to other sustainable design issues, such as site, water, energy, and materials. For example, better IEQ can provide occupants with better air quality and reduced toxic emissions (environmental benefits), improve occupants' well-being and community (social benefits), and enhance occupants' productivity and reduce their turnover (economic benefits).

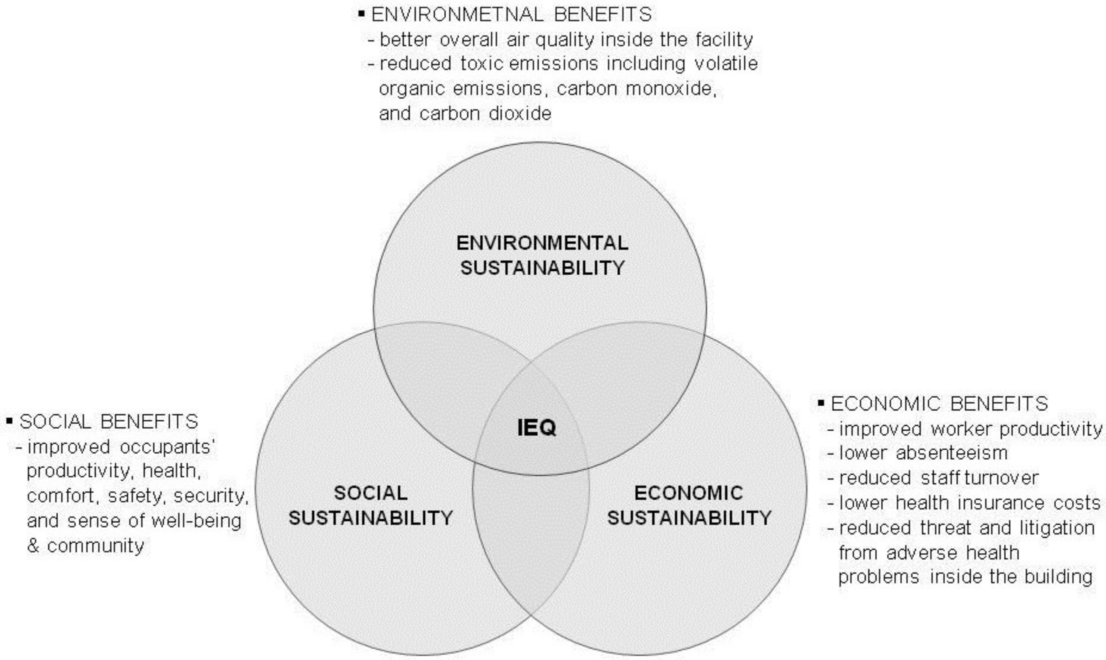

Figure 3. Benefits of IEQ in sustainable interior environments (Lee, 2007).

The importance of IEQ in sustainable interiors is also supported by the fact that the number of credits for IEQ appearing in various sustainable building guidelines and rating systems account for a large percentage of the whole. For example, LEED rating systems have been developed for various building types and processes, such as LEED for new construction (LEED-NC) and LEED for commercial interiors (LEED-CI). In each of these sets of rating systems, the percentage of IEQ credits out of the total credits varies based on their relative importance to the building type and stage in building process. However, in most sets of rating systems, IEQ credits have larger points percentages than those of other criteria, except for sustainable sites and energy and atmosphere. In LEED-CI 2009, for example, IEQ credits are about 15.5 percent (17 points) of the total credits (110 points), which is a larger proportion than credits for water efficiency (11 points), materials and resources (14 points), innovation in design (6 points), and regional priority (4 points).

Therefore, IEQ needs to be considered as a highly important factor in designing sustainable building interiors, and interior designers must understand the environmental, social, and economic benefits of IEQ for occupants' quality of life.

IEQ in Sustainable Design Guidelines and Rating Systems

All over the world, the growing demand for improved IEQ that positively affects occupants' outcomes, such as comfort, health, well-being, satisfaction, and work performance, has been reflected in the incorporation of IEQ criteria in various sustainable design guideline and rating systems, such as Green Star in Australia, the Hong Kong Building Assessment Method (HK-BEAM), the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in Japan, the SBTool used internationally, LEED in North America, and B3-MSBG in Minnesota. Despite differences between the standards and the countries in which they were developed, all include IEQ criteria. Sustainable building rating systems and guidelines transform sustainable building design goals into specific practices and provide a framework to assess the overall building design (Fowler & Rauch, 2006; Gowri, 2004; Kats, 2010). Guidelines and rating systems focus on reducing pollution and building life-cycle impacts on natural environments; conserving energy, water, land, biodiversity, and raw materials; and the health and well-being of people by enhancing IEQ (Winchip, 2007). A review of several of these rating systems shows the role IEQ has in each one.

Green Star is one of the newest environmental assessment tools developed by the Green Building Council of Australia (GBCA) for evaluating the environmental design and performance of buildings. Green Star was developed to establish a common language, set a standard of measurement for sustainable buildings, raise awareness of sustainable building benefits, and identify building life-cycle impacts (GBCA, 2009a). This was developed based on existing systems and tools, including the British Research Establishment Environmental Assessment Method (BREEAM) and the North American LEED, for assessing commercial buildings (GBCA, 2009b). Green Star covers nine categories: management, IEQ, energy, transport, water, materials, land use and ecology, emissions, and innovation. Each category has credits, and scores are awarded in each credit. According to earned points, buildings can receive Stars based on their sustainability rating. A 4-Star rating indicates “Best Practice,” a 5-Star rating is for “Australian Excellence,” and a 6-Star rating is for “World Leadership” (GBCA, 2008). The Green Star IEQ category targets environmental impact and occupant well-being by addressing the following issues: occupant’s thermal comfort, air quality, electric lighting, daylight, views, individual control, and indoor pollutants by materials and tenants (GBCA, 2009c; 2010).

The Hong Kong Building Environmental Assessment Method (HK-BEAM) was developed to assess, certify, and label the performance of all types of new and existing buildings for providing occupants with safe, healthy, and comfortable environments through reducing impacts on the environment (BEAM Society, 2010a). It was established by the BEAM Society in 1996 with assessment methods for new and existing office buildings based on the UK British Research Establishment Environmental Assessment Method (BREEAM) (HKGBC & BEAM Society, 2010a; 2010b). The goal of BEAM is to embrace social and environmental sustainability, provide economic benefits to stakeholders, and improve the quality of indoor environments for health, safety, and well-being of occupants (BEAM Society, 2010b). The BEAM includes the following categories: site aspects, materials aspects, energy use, water use, IEQ, and innovations/additions. Credits are gained under each category, and the overall sustainability grade is determined by the percentage of credits and weighting factors. The grades from highest to lowest are classified as Platinum, Gold, Silver, or Bronze. The BEAM IEQ category is related to the health, comfort, and well-being of occupants and includes security, hygiene, IAQ, ventilation, thermal comfort, lighting quality, acoustics and noise, and building amenities.

The Comprehensive Assessment System for Built Environment Efficiency (CASBEE) system is also a new tool for examining the environmental performance of buildings in the Japanese market. CASBEE was developed by the Japan GreenBuild Council (JaGBC), Japan Sustainable Building Consortium (JSBC), and the Institute for Building Environment and Energy Conservation (IBEC) (JaGBC & JSBC, 2009).

CASBEE has four assessment tools that correspond to the building life cycle: Tool-0 CASBEE-PD is for pre-design applications; Tool-1 CASBEE-NC is used for new construction projects; Tool-2 CASBEE-EB is for existing buildings; and Tool-3 CASBEE-RN is for renovation (JSBC, 2006a). This tool has two categories of assessment: Q (Quality) – building environmental quality and performance, and L (Loading) – building environmental loadings (JSBC, 2006b). Q is divided into three items: indoor environment, quality of services, and outdoor environment on site. L is also divided into three items: energy, resources and materials, and off-site environment. Building Environmental Efficiency (BEE) is measured by dividing Q by L and presents the building's environmental performance assessment results. A building with a high Q value and a low L value demonstrates the most environmental sustainability. The IEQ category includes the following criteria: noise and acoustics, thermal comfort including temperature and humidity, lighting and illumination including daylight, air quality including ventilation, and controllability (Chung, 2005).

As a generic framework to evaluate building performance, the Sustainable Building Tool (SBTool) is an international benchmarking tool developed to allow countries to modify it to their own locally relevant rating systems along with a common structure and terminology (iiSBE, 2007). SBTool is a continuation of Green Building Tool (GBTool) developed through the Green Building Challenge (GBC) process managed by the International Initiative for a Sustainable Built Environment (iiSBE) since 1996 (iiSBE, 2010). More than 20 countries have participated in the development of SBTool, tested it on buildings of their own countries, and presented results in the international Sustainable Building (SB) conferences (Larsson, 2007). Performance levels of the generic building type can be expressed in numeric values (data-oriented benchmarks) and a text form (text-oriented benchmarks) (iiSBE, 2007; Larsson, 2007). Performance values are described in a scale ranging from -1 to +5: -1 for deficient, 0 for minimum acceptable performance, +3 for good practice, and +5 for best practice. More subjective performance aspects are provided with text statements. The SBTool includes three levels of parameters: criteria, categories, and issues (Larsson, 2010). Criteria are scored with a scale ranging from -1 to +5; category scores are the total of weighted criteria scores; and issue scores are the total of weighted category scores. There are seven issues in the SBTool: site selection, project planning and development; energy and resource consumption; environmental loadings; IEQ; service quality; social and economic aspects; and cultural and perceptual aspects. IEQ issues include IAQ, ventilation, air temperature and relative humidity, daylighting and illumination, and noise and acoustics. A controllability category is included under a service quality issue.

Among sustainable building guidelines and rating systems, LEED, developed by the USGBC to accelerate the adoption of sustainable building practices, is currently the dominant system in the U.S. market and is also being adapted to multiple markets worldwide (Fowler & Rauch, 2006; Gowri, 2004; USGBC, 2010a). LEED was created to define green building by establishing a common standard of measurement, promote integrated, whole-building design practices, recognize environmental leadership in the building industry, stimulate green competition, raise consumer awareness of green building benefits, and transform the building market (USGBC, 2010b). In 2005, the

USGBC published LEED for Commercial Interiors (LEED-CI), that suggested IEQ is affected by manufacturing processes, construction practices, and material composition of products (Winchip, 2007). LEED-CI promotes a whole-building approach to sustainability by recognizing the following major categories: sustainable sites, water efficiency, energy and atmosphere, materials and resources, IEQ, innovation and design process, and regional priority (USGBC, 2010c). Each category has a specific number of points and depending on the total points earned, a building can be qualified for one of four levels from highest to lowest: Platinum, Gold, Silver, or Certified (USGBC, 2010d). The LEED-CI IEQ category emphasizes the importance of preventing IEQ problems (rather than improving contaminated interiors) through identifying materials with no harmful chemical compounds. The LEED-CI IEQ category includes outdoor air delivery monitoring, increased ventilation, construction IAQ management, low-emitting materials, indoor chemical and pollutant source control, controllability of systems (thermal comfort and lighting), thermal comfort, and daylight and views.

The B3-MSBG, initiated in 1997 by Hennepin County, Minnesota, and currently maintained by the CSBR at the University of Minnesota, is designed to be compatible with national guidelines such as LEED while maintaining regional values, priorities, and requirements (CSBR, 2010a). As a part of the Building, Benchmarks and Beyond (B3) project, this guideline embodies many regionally specific strategies in an open framework. In addition to design guidelines, it is also a management tool with interconnected sets of information on design process, strategies, and case studies with a flexible scorekeeping system (CSBR, 2010b). The B3-MSBG includes five major criteria: performance management, site and water, energy and atmosphere, IEQ, and materials and waste. The B3-MSBG IEQ criteria are constructed “to help prevent harm coming to occupants, then to optimize environmental quality conditions to correspond with human physiological processes, and finally to fine tune environmental conditions to work activities in a way that further enhances personal and organizational productivity” (CSBR, 2010c). IEQ criteria include restricting environmental tobacco smoke, specifying low-emitting materials, moisture control, ventilation design, thermal comfort, quality lighting, effective acoustics, reducing vibration in buildings, daylight, view space and window access, and personal control of IEQ conditions and impacts. The criteria also encourage healthful physical activity that can promote occupant health, well-being, and productivity as well as environmental and economic goals for sustainable buildings (CSBR, 2010c).

Post-Occupancy Evaluation (POE) of IEQ

Post-occupancy evaluation (POE) for investigating occupants’ satisfaction and performance can be one method of assessing the success of IEQ strategies in sustainable buildings (Kats, 2010). POE has been defined as “a process of systematically evaluating the performance of buildings after they have been built and occupied for some time” (Preiser, 2002, p. 42), and as “examinations of the effectiveness for human users of occupied design environments” (Zimring & Reizenstein, 1980). Comprehensive POE methods can provide valuable information that is essential for continuous improvement of existing building design and practices and contributes to future versions of assessment methods, better ensuring the success of future building development that is truly sustainable (Abbaszadeh, Zagreus, Lehrer, & Huizenga, 2006; Zimmerman & Martin, 2001). Therefore, POE methods need to be standardized across the industry to provide building owners, facilities managers, occupants, and design teams with compatible results about whether there is improvement in building environments at different stages of occupancy (Jaunzens, Grigg, Cohen, Watson, & Picton, 2003; Turpin-Brooks & Viccars, 2006). POE can be conducted using various methods, such as physical environmental measurements, on-site walk-through observations of indoor parameters, and occupant surveys using questionnaires to assess occupied buildings' aspects (Meir, et al., 2009). Among them, POE using occupant surveys is intended to make the built environment design process more research-oriented by providing a systematic evaluation about a building from the perspective of the people who use them (Zimmerman & Martin, 2001). As a result, it provides designers with information regarding the performance of their designs and provides building owners and occupants with guidelines to achieve the best environments from their existing resources (RIBA, 1991).

Various researchers have developed the occupant survey questionnaire to investigate occupants' perceptions of indoor environments. The occupant survey developed by Building Use Studies Ltd. (BUS) was used to determine occupant satisfaction with the building in the Post-occupancy Review Of Buildings and their Engineering (PROBE) projects in the United Kingdom (Bordass & Leaman, 2004). The standard pre-visit questionnaire (PVQ) was also used to get initial information on the building, its operation, occupancy, usage, and management (Cohen, Standeven, Bordass, & Leaman, 2001). The occupant survey included the following items: 1) occupants' background information, 2) overall building (design and how well it meets perceived needs), 3) personal control (heating, cooling, lighting, etc.), 4) speed and effectiveness of management after complaints have been made, 5) temperature, 6) air movement, 7) air quality, 8) lighting, 9) noise, 10) overall occupant comfort, 11) occupant health, and 12) occupant productivity at work (Cohen et al., 2001). A few site-specific questions were adjusted or added for the special interest of the research team or occupiers in some buildings (Cohen et al, 2001). The distinct features of PROBE are: 1) a benchmark of each building instead of a larger data-set; 2) the combination of technical and energy studies; and 3) the exploration of the design, management, and occupants' activities (Leaman & Bordass, 2001).

For the past several years, the Center for the Built Environment (CBE) at the University of California, Berkeley, has been conducting a web-based IEQ survey to assess the performance of workspaces, identify areas in need of improvement, and provide useful feedback to designers and building operators concerning specific aspects of building design features and operation strategies from the occupants' perspective (Meir et al., 2009). The CBE questionnaire is the most popular POE instrument used to evaluate the quality of indoor environments of workplaces in sustainable and non-sustainable buildings. The questionnaire is composed of objective and subjective measures. The objective measures include occupants' gender, age, type of work, office type, proximity to windows and exterior walls, and various types of control over the workspace environment. The subjective measures include occupants' satisfaction and self-reported productivity in seven IEQ criteria: office layout, office furnishings, thermal comfort, air quality, lighting, acoustics, and cleanliness (CBE, 2009). Overall satisfaction with the building and overall satisfaction with the workplace are also included in the questionnaire. The CBE questionnaire has been implemented in over 475 sustainable and non-sustainable buildings with over 51,000 occupant responses (as of October 2009), and additional survey modules have been created to gather data on additional topics such as security, accessibility, transportation, and sustainable building features (CBE, 2009). A 7-point Likert-type scale, ranging from “(-3) very dissatisfied” to “(+3) very satisfied” and “(-3) interferes” to “(+3) enhances” with “(0) neutral midpoint,” is used for satisfaction and productivity questions.

The National Environmental Assessment Toolkit (NEAT) studies, undertaken by Carnegie Mellon University’s Center for Building Performance and Diagnostics (CBPD) with the support of U. S. General Services Administration (US GSA), have been used to illustrate the value of instrumented post-occupancy evaluation to: 1) promote occupants as sensors and controllers, 2) identify technologies and systems that work, 3) prove that the place influences health and productivity, 4) ensure investment where it matters, 5) recognize the importance of behavior on environmental gains, and 6) catalyze innovation (Loftness et al., 2009). The application of NEAT is useful in pre- and post-evaluations of occupants’ satisfaction and performance in the different work environments (Lahlou, 2009). This tool has been used in the pre- and post-evaluations of over 20 federal facilities to link IEQ to facility management costs, health, and productivity (CBPD, 2010). NEAT combines user satisfaction questionnaires and expert walkthrough assessments of the workstations (CBPD, 2010; Lahlou, 2009; Loftness et al., 2009). User satisfaction questionnaires, composed of an on-site questionnaire for immediate satisfaction and an online detailed questionnaire for year-long satisfaction, examine occupants' satisfaction with the physical environment of their personal workstations in terms of thermal comfort, air quality, lighting and views, acoustic quality, and maintenance as well as functionality, community, and well-being of occupants. The expert walkthrough assessments include workstation spot measurements for simultaneous environmental assessment of thermal, visual, acoustic, and air quality; 24-hour continuous measurements to check changeability of environment conditions according to varied system-cycle and occupancy conditions; and records of the technical attributes of building systems. The benefit of NEAT is that this toolkit consists of subjective occupant responses and objective physical measurements.

The Center for Sustainable Building Research (CSBR) at the University of Minnesota has developed a self-administered, on-line POE called the B3-Sustainable Post-Occupancy Evaluation Survey (B3-SPOES). The B3-SPOES has been developed to reflect sustainable IEQ criteria including those of the B3-MSBG along with other existing occupant survey questionnaires. The B3-SPOES IEQ categories include thermal conditions, IAQ, lighting conditions, view conditions, acoustic conditions, privacy conditions, furnishings, personal controls, functionality and features, aesthetics, technology, and cleaning and maintenance (Guerin, Brigham, Kim, Choi, & Scott, 2011). This tool measures the effect of the designed environment on desired human outcomes: occupant satisfaction, work performance, health and well-being, recycling, and alternative commuting behaviors. Modules of the B3-SPOES include (1) demographic information about occupants' locations in the facility and workstation types; (2) behavior and belief questions related to occupants' job satisfaction, work performance, health, well-being, physical activity, recycling, and alternative commuting; (3) environment module questions composed of categories (e.g., thermal conditions) and attributes (e.g., temperature, humidity, and air velocity) of the designed environment, a scale of the designed environment (e.g., workstation level and overall facility level), and a human outcomes to be evaluated (e.g., satisfaction and work performance); and (4) feature influence module questions that track which features contribute to specific desired human behaviors. There are three survey levels in the B3-SPOES: (1) "Scan Level," that is required and useful for quick evaluation of human outcomes related to IEQ criteria; (2) "Core Level," that includes Scan Level and adds detailed questions about each IEQ issue for additional analyses; and (3) "Advanced Level," that includes Scan and Core Levels plus other areas of owner, designer, or researcher interest based on design goals. The B3-SPOES has been written in easily understood language and has been statistically evaluated for reliability and validity. Through testing in several sustainable buildings that were designed and built by the B3 Guidelines and LEED rating systems, this tool has continued to be revised and is ready to provide a database of POE questions for evaluating sustainable buildings.

The ultimate goal of POE occupant surveys of sustainably designed buildings is to collect occupants' responses and develop a benchmarking database comprising the records of buildings investigated, thereby enabling the comparison of responses among different buildings (Meir et al., 2009). Occupants' responses related to satisfaction with their indoor environments and the effect on their work performance can enable designers and business owners to provide better quality environments to occupants and avoid problems that can be obstacles to satisfaction and performance. Occupants of sustainable buildings who work throughout the entire facility can be affected by the IEQ of the entire facility (i.e. site, building, and interiors). However, it is known that most occupants spend the majority of their time at their workstation. Therefore, it is important to investigate occupants' perceptions of IEQ of their work environments at the workstation level as well as the overall facility level to gain improved quality of work environments in the future. However, there are not sufficient data about relationships between occupants' satisfaction with IEQ criteria at the workstation level and satisfaction with the overall facility and its effect on their overall work performance. In the next section, the relationships between occupants' satisfaction with IEQ at the workstation level and the overall facility and the effect on their perceived work performance that have found in prior studies are discussed.

Relationships between Satisfaction with IEQ Criteria at the Workstation Level, Satisfaction with the Overall Facility, and Overall Work Performance

Much of the interest in sustainable design is related to occupants' potential benefits that are associated with improved IEQ. Key environmental factors affecting occupants include the environment's air quality, its temperature conditions, lighting, ventilation, and the degree or type of personal control over environmental conditions an occupant has (Heerwagen, 2003). Studies related to IEQ have evolved from thermal condition in the 1970s-1980s and IAQ in the 1990s to the relationship between IEQ and occupant health, well-being, and performance (Garnys, 2007). During the last decade, researchers have consistently found evidence that there is a linkage between IEQ of work environments and occupants' satisfaction and work performance. For example, Clements-Croome and Baizhan (2000) conducted a study on the relationship between performance and the indoor environment of offices. They found that occupants showed a low level of self-assessed performance when overall dissatisfaction with the indoor environment was high. Crowded workplaces, thermal problems, and sick building symptom factors, such as indoor air quality and pollution, were the main complaints about unsatisfactory environments. Fisk (2000; 2002) estimated the nationwide improvements in health and performance potentially attainable by providing improved IEQ in U.S. buildings. He found that direct improvements in worker performance from changes in the thermal environment and lighting yielded estimated potential performance gains of between $20 billion and $160 billion. Other studies also indicated that the improved IEQ of buildings is linked to occupants' enhanced work performance, including increases in the amount of work accomplished, improved worker retention, reduced absenteeism from work, and reduced sick days (Fisk, 2000; 2002 ; Loftness et al., 2010).

As mentioned before, occupant survey questionnaires developed by research centers, such as the B3-SPOES of the CSBR at the University of Minnesota, included questions about various IEQ criteria. The most commonly used IEQ criteria in those questionnaires are thermal conditions, IAQ, acoustics conditions, lighting conditions, view conditions, personal control, privacy conditions, and furnishings, all of which are included in B3-SPOES questionnaire, which was used for this study. A review of these

IEQ criteria and their relationships with occupants' satisfaction and work performance found in prior studies is presented in the following sections.

Thermal Conditions and Occupants' Satisfaction and Work Performance

The thermal condition of a work environment is a key component of IEQ and is measured by occupant thermal comfort. An internationally accepted definition of thermal comfort is "the state of mind that expresses satisfaction with the thermal environment," as described by the ANSI/ASHRAE Standard 55, *Thermal Environmental Conditions for Human Occupancy* (ASHRAE, 2004). According to the ANSI/ASHRAE Standard 55, if 80% of the occupants are satisfied with a thermal environment of a building at any given time, the thermal condition of that environment is considered reasonably comfortable. This standard specifies indoor environmental factors and personal factors that establish thermal comfort acceptable to a majority of occupants within the space. The indoor environmental factors include air temperature, radiant temperature, air velocity, and relative humidity; personal factors include a person's physical activity level, metabolic rate, and clothing insulation. In office buildings, the materials of furnishings such as chairs with mesh backs and seats can make employees feel comfortable at higher temperatures by reducing the heat build-up, and colors of interior surfaces can affect employees' perceptions of coolness or warmth (BuildingGreen, 2004). Interactions of these factors, as well as others, affect occupants' perceptions of thermal comfort of indoor environments.

Various studies have indicated that thermal conditions are one of the most significant indoor environmental factors influencing occupants' satisfaction, and that improving thermal condition leads to better occupant satisfaction and perceived work performance (Clements-Croome & Baizhan, 2000; Nasrollahi, Knight, & Jones, 2008). It has been found that there is a difference in satisfaction with the thermal condition between sustainable and non-sustainable buildings. The CBE occupant survey database showed that occupants in 21 LEED-rated/sustainable buildings were more positively satisfied with the thermal condition of their buildings compared to non-green buildings (Abbaszadeh et al., 2006). The CBE occupant survey findings collected from 351 office buidlings also indicated that satisfaction with temperature of the workspace, as one attribute of thermal conditions, contributed significantly to workspace satisfaction and is strongly correlated with satisfaction with overall building (Frontczak et al., 2011). Dissatisfaction with temperature can directly affect employees' physical and mental work performance, without influencing health symptoms (Fisk, 2000; Wyon, 1996). For example, changes in temperature of a few degrees Celsius within the 18°C to 30°C range can significantly influence employees' work performance in typewriting, factory work, signal recognition, learning performance, reading speed, and word memory (Wyon, 1996). Seppanen and Fisk (2005) also reported that increasing room air temperature within the 20.0–23.0°C range can improve work performance.

As found in prior studies, occupants' satisfaction with thermal conditions at the workstation level may be related to their satisfaction with the overall facility and work performance.

Indoor Air Quality (IAQ) and Occupants' Satisfaction and Work Performance

The term indoor air quality (IAQ) refers to "the environmental characteristics inside buildings that may affect human health, comfort, or work performance" (IAQ-SFRB, 2010). More specifically, the ANSI/ASHRAE 62.1 Standard (2010) defines the acceptable perceived IAQ as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and which a substantial majority (80% or more) of the people exposed do not express dissatisfaction." IAQ of building environments is related to biological contaminants and chemicals in the interior space, such as indoor pollutant sources from materials and furnishings. In addition, the ventilation rate related to outdoor environmental conditions and human activities such as tobacco smoking also influence IAQ conditions of building environments (IAQ-SFRB, 2010). Indoor air problems caused by interactions of these various factors can affect health, comfort, and performance of building occupants related to whole functions of the organization (Antikainen et al., 2008).

Survey questionnaires that estimate occupants' perceptions of IAQ can be used as subjective evaluations of the quality of indoor air. An IAQ study conducted by the Indoor Environment Department (IED) of Lawrence Berkeley National Laboratory (LBNL) indicated that improved satisfaction with IAQ of overall work environments is associated with improvement of work performance. This study showed that an increase in work performance of approximately 1% can be achieved by a 10% reduction of occupants' dissatisfaction with IAQ (IED, 2010; Wargocki, Wyon, Baik, Clausen, & Fanger, 1999; Wargocki, Wyon, Sundell, Clausen, & Fanger, 2000). A review of studies by Fisk and Seppanen (2007) showed evidence that improved IAQ at workstations can improve work performance. According to their study, indoor pollutant sources such as offgassing of toxins from surface materials, equipment, and furnishings can affect employees' work performance, such as proof reading of text, text typing, speed, and accuracy. In one example, performance in typing and reading was improved by approximately 4% by removing a carpet about which there were complaints related to its negative effect on air quality (Wargocki et al, 2002); typing errors were diminished by 16% by removing computers with CRT monitors producing pollutant sources (Bako-Biro, Wargocki, Weschler, & Fanger, 2004); and text typing was improved in speed and accuracy by removing pollutant sources such as linoleum flooring and shelves (Bako-Biro, 2004). The International Center for Indoor Environment and Energy (ICIEE) at the Technical University of Denmark has conducted a series of studies on the impact of IAQ on human performance. Studies indicated that exposure to a pollutant source, such as a 20-year old carpet, had a significant negative impact on occupants' performance (Fanger, 2008; Wargocki, 2008).

As found in prior studies, occupants' satisfaction with IAQ at the workstation level may be related to their satisfaction with the overall facility and work performance.

Acoustic Conditions and Occupants' Satisfaction and Work Performance

A number of studies have investigated that conversational distraction and uncontrollable noise of office environments affect occupants' productivity (American Society of Interior Designers, 2005). Noise in office workplace is "unwanted sound that disturbs concentration and generally impedes performance" (Steelcase, 2000, p.4). In sustainable buildings, occupants have often shown dissatisfaction with acoustic conditions in their work environments (Abbaszabeh et al., 2006; Field, 2008; Hodgson, 2006). The post-occupancy survey in LEED-certified buildings indicated that speech privacy and disturbance by background noise levels, such as the internal noise from HVAC systems and the external noise from naturally ventilated systems, were employees' main complaints about acoustic conditions (Field, 2008). Another occupant satisfaction survey for six sustainable office buildings using a web-based survey developed by CBE, showed that occupants were generally dissatisfied with the acoustic conditions of their workstations, and speech privacy was a major complaint (Hodgson, 2006). In this study, HVAC noise, office equipment, ringing telephones, external noise from windows open for ventilation, and people moving around were also stated as sources of occupants' dissatisfaction with their acoustic conditions of their workstation. Occupants' satisfaction with acoustic conditions at the workstation level could contribute to satisfaction with overall environments. Case studies conducted by Armstrong indicated that the reduced auditory distraction was the most important feature for occupants' work tasks (American Society of Interior Designers, 2005). In this study, occupants responded that 25% in satisfaction with the overall work environment and 20% in productivity were increased when auditory distractions were reduced or eliminated by using more absorbent materials and added electronic sound masking. Veitch et al. (2003) found that subjectively rated noise and conversation privacy in an open-office were not important predictors of overall environmental satisfaction.

A dissatisfactory acoustical condition of occupants' workstations that produces unacceptable noise from various sources such as use of speakerphones, use of low partitions, and office chatter can distract occupants from concentration on their work (WBDG, 2008a). CBE's survey in one office building determined that 46% of occupants responded that the overall noise level of their workspace made it harder for them to get their work done, therefore, affecting their performance (Salter, Powell, Begault, & Alvarado, 2003).

As found in prior studies, occupants' satisfaction with acoustic conditions at the workstation level may be related to their satisfaction with the overall facility and work performance.

Lighting Conditions and Occupants' Satisfaction and Work Performance

Lighting conditions include electric and daylighting conditions. Interior lighting quality must meets human needs for an individual's well-being such as visibility, activity, communication, mood, comfort, health and safety, and aesthetic judgment (NRCC, 2009a). Poor lighting conditions of occupants' workstations can produce discomfort problems (Boyce, 1998). For example, glare from distant light fixtures that are blocked by high partitions, and inadequate light level on task surfaces can produce visual discomfort that results in dissatisfaction (NRCC, 2009a), reduce accuracy in task performance and increase the time taken to do tasks (NRCC, 2009b). In contrast, high quality lighting conditions can reduce distractions and discomfort by providing employees with appropriate working conditions and aesthetic elements for psychological comfort. Lighting illuminance, amount of glare, and the spectrum of light can also affect work performance because lighting directs attention or influences arousal or motivation (NEMA, 1989).

Daylighting has often been considered a useful source of energy savings and a means to increase occupants' visual comfort in sustainable buildings. Jones (2008) defined daylighting as a "method of introducing natural light into interior spaces to reduce levels of electric lighting" (p. 371). Daylighting can reduce electric lighting energy consumption, and 20 to 60 percent of overall building energy use can be saved through the integration of daylighting strategies (Jones, 2008; WBDG, 2008b). Thus, there has been increasing interest in incorporating daylighting strategies in sustainable office building designs as methods for energy saving by reducing electric lighting levels (Krarti, Erickson, & Hillman, 2005). Further, daylighting can increase employees' satisfaction, which leads to improved work performance by providing more comfortable working environments (Li & Tsang, 2008; NIBC, 2008).

Findings of occupant surveys in 21 sustainable buildings when compared to non-sustainable buildings from the CBE database indicated that occupants had complaints about "not enough daylight," "reflections in computer screens," and "too dark" in lighting conditions of both sustainable and non-sustainable buildings, and that there was no difference in the frequency of lighting condition complaint between both building types (Abbaszabeh et al., 2006). Findings of occupant satisfaction survey as a part of Cost-effective Open-Plan Environments (COPE) project conducted by the National Research Council of Canada (NRCC) showed that total illuminance, uniformity, glare, directionality, and presence of window simultaneously influenced satisfaction with lighting conditions of workstations, and overall environmental satisfaction was greatest for occupants with access to daylight.

As found in prior studies, occupants' satisfaction with lighting conditions at the workstation level may be related to their satisfaction with the overall facility and work performance.

Views and Occupants' Satisfaction and Work Performance

Large windows generally used in sustainable office buildings to admit daylight for indoor environments can allow occupants to keep direct visual contact with the outside view (Tzempelikos, 2008). Being near a window can be psychologically and physiologically beneficial, especially if the view contains natural features (Heerwagen & Orians, 1986). Visual contact with nature through windows reduced employees' stress and promoted their quality of life by providing them with restorative experiences (Kaplan, 1992; Ulrich, 1992). In other words, buildings can be more effective and productive places to work by providing access to attractive outside views and connections to nature (WBDG, n.d.). This feature has played a role in performance improvements through psychological factors and improved quality of work life (Kroner, Stark-Martin, & Willermain, 1992). The workplace performance study, conducted by the U. S. General Services Administration (US GSA) with over 6,000 workers in 22 federal workplaces, indicated that workers who have a seated view through windows were more productive and satisfied with their workstations than those without a seated view (US GSA, 2009). Cost-effective Open-Plan Environments (COPE) projects found that as a significant predictor of overall environmental satisfaction, access to a window that provides a view and a connection to the outdoors satisfied occupants (NRCC, 2009b).

As found in prior studies, occupants' satisfaction with view conditions at the workstation level may be related to their satisfaction with the overall facility and work performance.

Personal Control and Occupants' Satisfaction and Work Performance

Existing studies on the effect of controllability of interior systems have shown a link to increased occupant satisfaction and work performance. Fisher (1990) defined personal control by stating "individuals with control can act to change or reverse situations which are disliked."

Perceived personal control over systems of workstations can be positively associated with satisfaction with overall work environment (Lee & Brand, 2005). Results from the CBE survey data showed that more occupants are dissatisfied (42%) than satisfied (39%) with overall thermal comfort at the workstation level, but occupants who have control over their thermal environment such as a thermostat, operable window, portable heater, or portable fan are satisfied with the temperature in their workplace (Huizenga, Abbaszadeh, Zagreus, & Arens, 2006). Results from a study based on data generated by the PROBE research project reported that occupants' perceived work performance was higher in buildings where occupants had more control over their environments, such as temperature and ventilation (Leaman & Bordass, 2001). The research project on the relationship between controllability and performance of office workers in 11 UK buildings examined by Building Use Studies (BUS) in 1996-97 showed that self-assessed performance was significantly associated with perceptions of control of systems, including heating, cooling, lighting, ventilation, and noise (Leaman & Bordass, 1999). Daylight can provide adequate light levels to indoor environments and decrease dependence on electric lighting, however it can also produce glare problems and heat gain. Therefore, worker satisfaction and visual comfort leading to improved worker performance can be increased by incorporating daylighting controls and other electric lighting controls (WBDG, n.d.). However, occupants in sustainable buildings have often shown low satisfaction with control over lighting conditions such as control over light switches compared to those in conventional buildings (Abbaszabeh et al., 2006).

As found in prior studies, occupants' satisfaction with personal control at the workstation level may be related to their satisfaction with the overall facility and work performance.

Privacy Conditions and Occupants' Satisfaction and Work Performance

Privacy can be defined as "the degree to which one's social interactions are regulated," and this has been measured by such factor as isolation from intrusions, speech privacy, auditory privacy, and visual privacy (Marquardt, Veitch, & Charles, 2002). One of the most consistent findings from occupant surveys is that occupants show dissatisfaction levels when their workstation environments have a lack of privacy and a number of distractions; as a result, occupants can be dissatisfied with their overall indoor environments and their work performance can be affected by this unsatisfactory privacy condition (Vischer, 2008). Lower partitions in open-plan offices and glazed walls in private offices and meeting rooms mean there may be little acoustic or visual privacy

(Field, 2008). Occupant surveys in 21 sustainable buildings indicated that occupants in open-plan type workstations were dissatisfied with a lack of speech privacy and with distractions from hearing other people's understandable speech. Rather than distraction with other noise sources such as mechanical noise, office equipment noise, and outdoor traffic noise, these privacy dissatisfactions included items such as "people talking in neighboring areas," "people overhearing my private conversations," and "people talking on the phone," (Abbaszabeh et al., 2006). The results of occupant IEQ surveys in 142 buildings from the CBE database also showed that occupants were significantly more dissatisfied with speech privacy at their workstations than noise level (Jensen, Arens, & Zagreus, 2005). In three open-plan case studies, occupants complained that they were disturbed by conversations in adjacent workstations, and this lack of privacy condition made it difficult to concentrate on their work (Salter et al., 2003).

As found in prior studies, occupants' satisfaction with privacy conditions at the workstation level may be related to their satisfaction with the overall facility and work performance.

Furnishings and Occupants' Satisfaction and Work Performance

The comfort of individual work spaces can be improved by furnishings, and improved comfort can increase occupants' performance and overall environmental satisfaction (Brill, Margulis, Konar, & BOSTI, 1984). Kruk (1989) found that adjustable and ergonomic office furniture increased occupants' performance by 15.4%. Adequate storage and the ability to adjust chairs also directly influence environmental satisfaction (O'Neil, 1994). Frontczak et al. (2011) found that satisfaction with amount of space was different according to workstation types: satisfaction with amount of space in private offices showed the highest significance compared to satisfaction with it in other workstations, such as offices shared with other people and cubicles with partitions. However, Paul (1995) found that adjustable furniture at workstation did not significantly improve workers' environmental satisfaction. The study on the relationship of IEQ and occupant satisfaction and performance in 15 LEED-certified buildings from the CBE database indicated that occupants showed the highest satisfaction level with office furnishing quality compared to other IEQ criteria. In this study, furnishing quality was the only IEQ criterion significantly affecting both occupants' satisfaction and performance in the overall workplace (Lee & Guerin, 2009). This result suggests that the quality of furnishings needs to be considered an important interior feature for building occupants when designing working environments. However, there are few studies on furnishings as a major factor for assessment of indoor environments in terms of the influence on improved occupant satisfaction and work performance.

As found in prior studies, occupants' satisfaction with furnishings at the workstation level may be related to their satisfaction with the overall facility and work performance.

In summary, previous studies related to occupant satisfaction with IEQ and its effect on their work performance have indicated that occupants' satisfaction with IEQ features at the workstation level, such as thermal conditions, IAQ, acoustic conditions, lighting conditions, view conditions, personal control, privacy conditions, and furnishings, are very closely related to their satisfaction with overall facility environments and their work performance. In addition, based on those studies and various literature, occupants' satisfaction with overall facility environments may be also very closely associated with their work performance.

Sustainability Ethic

The concept of ethics is related to the study of human conduct and moral values and involves standards of conduct for individual persons, groups, and professions (Wasserman, Sullivan, & Palermo, 2000). In the view of environmental ethics, humans' ethical behaviors determine the ways they interact with natural environments and how humans include themselves in nature rather than act as managers of it (Rolston, 2003). A sustainability ethic has a future-oriented point of view compared to an environmental ethic. It assumes that natural resources are limited, and humans must value sustainability for their continued use of the environment in the future (UCCP & UC, 2009).

In the design and construction of sustainable buildings, sustainability is significantly related to the value of these buildings in terms of environmental quality, social equity, and economic prosperity (Myers, Ree, & Robinson, 2007; WBCSD, 2006). The businesses that successfully embed sustainability as an integral part of their work by promoting the importance of sustainability can support and enhance occupants' engagement around sustainability (Sustainability at Work, 2010). In other words, sustainability or sustainable design may be important for occupants who use sustainably designed environments because, as shown in prior studies, those occupants showed higher satisfaction levels with their overall environments and perceived their enhanced work performance outcomes. When occupants are satisfied with overall environments that lead to enhanced work performance, their sustainability ethic (which agrees that environmental, social, and economic sustainability are important to the design of environments) may be influenced by their perceptions of those environments. In the current sustainable building market, there is evidence that occupants are demanding more sustainable spaces (Myers, Ree, & Robinson, 2007). However, little has been done to investigate whether these occupants' demand for sustainable design environments is due to their perceptions of the importance of sustainability in designing their environments, or whether demand and perceptions can be influenced by their satisfaction with those environments and perceived work performance. Therefore, occupants' perceptions of environments (i.e., satisfaction with IEQ and perceived work performance) may influence the development of their sustainability ethic.

Theoretical Frameworks

Human Ecosystem Theory

An appropriate theoretical approach to this study is the human ecosystem theory. Human ecosystem theory can be connected to systems theory. Systems theory has greatly influenced the natural and social science disciplines during the 20th-century. Before the 1940s, the terms "system" and "systems thinking" had been used by several scientists. However, Bertalanffy (1950) established the concepts of systems theory as a major scientific movement, and the term "systems theory" originated from Bertalanffy's general system theory (GST). This theory provides a unifying holistic view emphasizing the inter-relationships and feedback processes among components in a system, not just one individual element. The essential concept of systems theory is the shift from the part to the whole, and the shift from objects to relationships. In systems theory, a system consists of individual elements that are constantly changing and evolving, and a system is defined as a set of interdependent components. In other words, all systems are composed of subsystems, are integral parts of larger systems, and are integrated wholes showing cyclical flows. Thus, the change of each element in the system affects one another and changes the system as a whole.

Clapham (1930) coined the term “ecosystem” to indicate the combined physical and biological components of an environment. Later, Tansley (1935) refined the term, describing it as the whole system, including the organism complex and the whole complex of physical factors forming the environment. An ecosystem can describe any situation where there is a relationship between organisms and their environments. When this ecosystem considers human behavior inside the system, it becomes a human ecosystem. The main function of human ecosystem theory is to understand the complex systems’ relationships in which humans interact (Bubolz, Eicher, & Sontag, 1979). Guerin (1992) proposed a theoretical framework of the human ecosystem, which includes three environments (natural environment, social environment, and designed environment) and human organism (see Figure 4). These four components interact with one another bi-directionally. The natural environment (NE) means physical and biological components; the social environment (SE) means psychological and social behaviors of humans; the designed environment (DE) means anything that is constructed or built by humans; and human organism (HO) means an individual, family, group, team, or household.

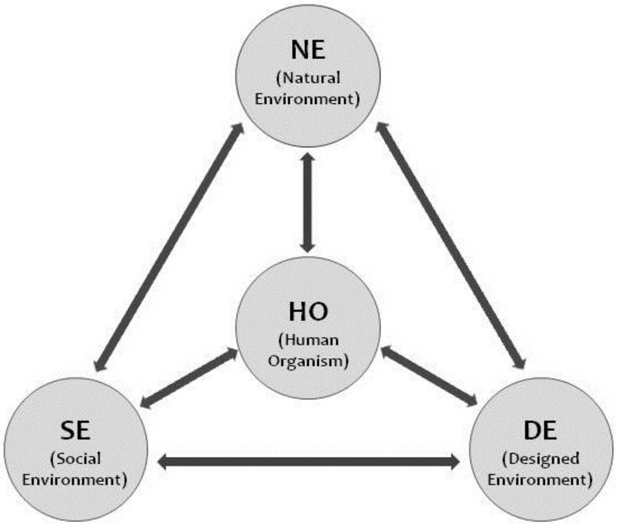

Figure 4. Human Ecosystem Model (Guerin, 1992).

Human ecosystem modeling has been used to research issues that reflect sustainable design and the human behavior. For example, Guerin, Yust, and Coopet (2000) reviewed research on human behavior and energy consumption from 1975 to 1998 to identify occupant predictors of household energy consumption behavior and energy consumption change. They used the human ecosystem model to examine the interrelationships of household occupants and environmental characteristics in the context of energy consumption. Their study showed that all environments interact to influence household energy decisions, and that the human organism is central to the energy consumption issue. Lee (2007) used human ecosystem theory to explain the relationship between the three principles of economic, social, and environmental sustainability with regard to the indoor environment of sustainable office buildings. In the new model she proposed, the indoor environment of sustainable office buildings (Designed Environment) interacts with indoor environmental sustainability (Natural

Environment) and indoor social and economic sustainability (Social Environment) to provide health, satisfaction, and productivity to office workers (Human Organism).

This study used human ecosystem theory to examine the relationships between occupants' satisfaction with IEQ at the workstation level, satisfaction with the overall facility, overall work performance, and sustainability ethic in sustainable interior environments. A proposed theoretical model, shown in Figure 5, explains how the Designed Environment, composed of the IEQ of sustainable buildings, is related to occupants' satisfaction, work performance, and sustainability ethics, based on interactions among sustainability principles, sustainable interior environment, and occupants. Sustainable interior environments consist of thermal conditions, lighting fixtures, personal control, ergonomic furnishings, and various workstation types. Environmental sustainability includes daylighting, outside views, and IAQ such as non-toxic furnishing and finish materials. Social sustainability is acoustic conditions and privacy conditions (i.e., sound and visual privacy) affected by other people. Economic sustainability is related to economic benefits by occupants' improved work performance and increased satisfaction by the change in their perceptions on the importance of sustainability for their indoor environment (sustainability ethic).

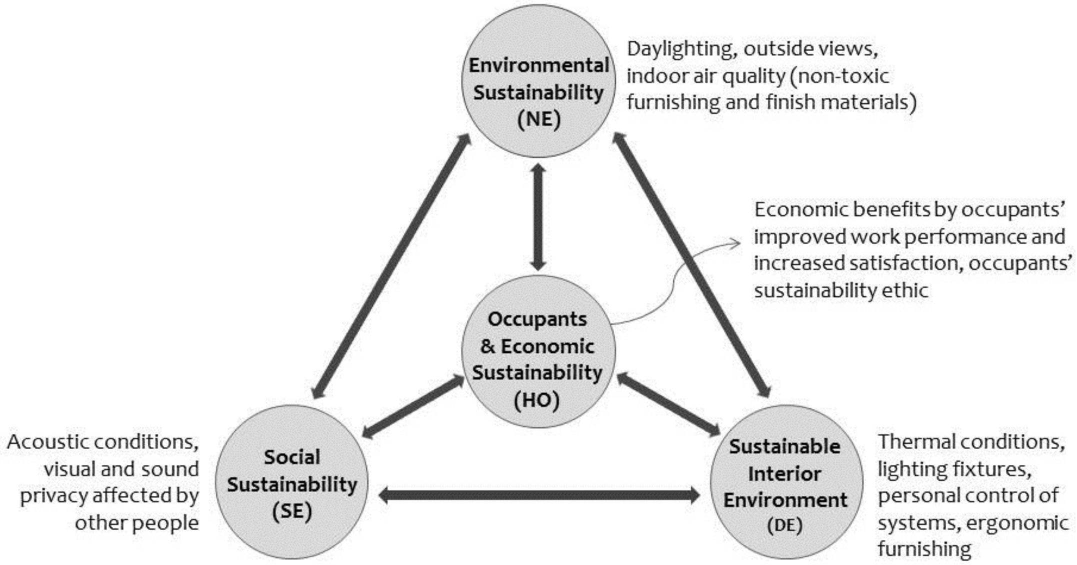

Figure 5. The relationships among IEQ of sustainable interiors, occupant satisfaction and performance, and sustainability ethic in the Human Ecosystem model.

Hypotheses

Based on a review of the existing research findings, occupant survey questionnaires (i.e., B3-SPOES), sustainable design guidelines (i.e., B3-MSBG), and using the theoretical framework of human ecosystem theory, the following hypotheses were developed. As mentioned before, IEQ criteria used in this study primarily came from the B3-SPOES questionnaire developed by the CSBR.

H1: Occupants' satisfaction with sustainable IEQ criteria at the workstation level influences their' satisfaction with the overall facility.

H2: Occupants' satisfaction with sustainable IEQ criteria at the workstation level influences their perceived overall work performance.

H3: Occupants' satisfaction with the overall facility influences their perceived overall work performance.

H4: Occupants' satisfaction with the overall facility influences their sustainability ethic.

H5: Occupants' perceived overall work performance influences their sustainability ethic.

These hypothesized relationships among variables are depicted in the following research model (see Figure 6). This model shows the simultaneous relationships among variables and was used to investigate the purpose of this study through the statistical analyses.

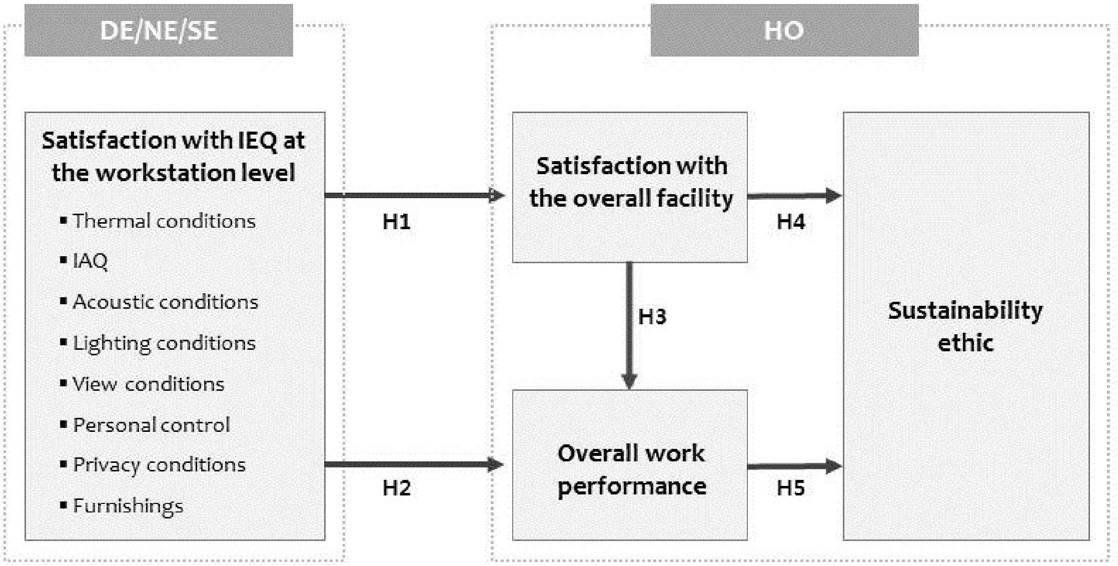

Figure 6. A proposed research model indicating hypothesized relationships among variables.

CHAPTER THREE: METHODS

This chapter describes the methods used to collect occupant data to test the hypotheses. Data collection strategies are described including settings, sample, instrument, and procedure. Data analysis methods used to extract indoor environmental quality (IEQ) factors and test the hypotheses related to relationships among variables of this study are presented.

Data Collection

The purpose of this study was 1) to develop an explanatory model showing simultaneous relationships among occupants' satisfaction with IEQ criteria at the workstation level, their satisfaction with the overall facility (i.e., site, building, and interior), their overall work performance, and their sustainability ethic; 2) to test the developed model and suggest a good-fit model; and 3) to estimate the hypothesized relationships among variables.

Secondary data analysis was used to examine the purpose of this study. The data were obtained from the B3-SPOES (Sustainable Post-Occupancy Evaluation Survey) database hosted by the Center for Sustainable Building Research (CSBR) at the University of Minnesota. The CSBR researchers have developed a self-administered, on-line questionnaire for occupant surveying and submitted it to occupants of several sustainable office buildings located in Minnesota. The B3-SPOES questionnaire was used to investigate occupants' perceptions on how well the buildings achieved the sustainability goals in terms of their satisfaction and perceived work performance as related to IEQ criteria addressed in the B3 State of Minnesota Sustainable Building Guidelines (B3-MSBG).

Settings

Data were collected from three sustainable buildings, two county service centers and one office building, all located in Minnesota.

The two county service centers (labeled as Building 1 and Building 2 for this study) were designed and constructed in two nearly cities in the same county and utilized the B3-MSBG. Both buildings were designed by the same architecture design firm and were occupied in 2007. They have similar size (Building 1 is 40,000 square feet and Building 2 is 50,000 square feet) and functions. The difference between these two buildings is that Building 2 has a library area. Occupants of both buildings worked in enclosed offices (private or shared with other people), cubicles with low or high partitions, or desks with no partitions. Both buildings incorporated various sustainable design features. For example, both buildings allow natural daylight from windows, with coated glass to reduce glare, throughout all office areas and light reflective ceiling finishes are applied to increase energy-efficiency. Occupancy sensors and daylight sensors are installed for lighting control along with high efficiency lamps. Low or no volatile organic compound (VOC) carpet tiles, paints, finishes, and fabrics, as well as air interior ventilation, were used to ensure improved IAQ. Remanufactured office workstations panels and chairs were used that are made of recyclable materials.

The office building (labeled as Building 3 for this study) is a 166,000 square feet, four-story building. This building achieved a high level of LEED certification and was occupied in 2008. Most occupants work in enclosed offices (private or shared with other people) and cubicles with low partitions. Various sustainable features were incorporated in the design of indoor environments of this building: floor air diffusers to individually control temperature in workstation areas; occupancy sensor control of light and controllable desk light; CO_2 threshold sensors for occupied areas; low or no VOC paints, sealants, and carpets; and low cubicle partitions with glass on the top for access to outside view and daylight. Specific daylighting strategies of this building include the corridor between workstations and windows; manually controlled blinds on the windows; two-tiered windows (fritted upper and clear lower part) of high exterior curtain walls; horizontal light shelf on the south; an atrium that allows natural light into the center of the building; light and reflective interior finishes; and automatic daylighting sensor controls.

Population and Sample

The target population of this study was occupants working in sustainable office buildings in Minnesota. The accessible population was occupants who were working in three sustainable buildings located in different cities of Minnesota.

The CSBR conducted POEs for Buildings 1 and 2 in 2008-2009 to understand the process of using the B3-MSBG on projects, to assess achievement of occupant comfort, satisfaction, and work performance with respect to the B3-MSBG criteria, as well as their behaviors and attitudes related to sustainability, and to analyze the buildings' energy and water use. From this POE data, specific IEQ data were selected for this study.

Among a total of 186 occupants of both buildings, 91 occupants participated in the survey. The response rate was 49% (91/186), which is considered a good response rate for an on-line survey. Eight respondents who did not answer most of the questions were removed from the sample to avoid misinterpretation of the data by a large amount of missing values. A total of 83 respondents from both buildings were used for data analysis: 41 for Building 1 and 42 for Building 2. As shown Table 1, in Building 1, 82.9% were female and 17.1% were male. Respondents' ages ranged from 25 to 64 with 43.9% between 45 and 54. The majority of respondents (70.7%) worked at cubicles with low or high partitions. Over two-thirds (68.2%) responded that they spent average 20 to 0 hours per week in the building. In Building 2, 90.5% were female and 7.1% were male. Their ages varied ranging from 25 to 74 with 26.2% between 45 and 54. Most respondents (59.5%) worked at cubicles with low or high partitions and about a quarter of respondents (28.6%) had desks with no partitions in open office space. Over three-quarters of respondents (78.6%) spent an average 20 to 40 hours per week in the building.

The CSBR also conducted a POE for Building 3 in 2010 to investigate occupants' perceptions on how well the facility accomplished its sustainable design goals in terms of occupant satisfaction and performance. The questionnaire was sent to 258 occupants and a total of 221 occupants participated in the survey. The response rate was 85% (221/258), which is considered a very high response rate. As shown Table 1, 56.1% of respondents were male and 42.5% were female. Their ages ranged from 18 to 74, with 65.2% between 35 and 54. Most respondents (77.8%) worked at cubicles with partitions, and 21.3% had enclosed private offices. Most respondents (89.5%) said that they spent over 31 hours per week in the building.

A total of 304 respondents were gained from three buildings. Overall, 54.6% of respondents of three buildings were female and 44.1% were male. Most respondents' ages (63.8%) ranged from 35 to 54. The majority of respondents (74.3%) worked at cubicles with partitions and 19.4% had enclosed private offices. Most of them (77.6%) spent over 31 hours in the buildings. And, most respondents of three buildings moved from prior non-sustainable building to current sustainable building. Table 1 shows the sample descriptions.

Data from three buildings were combined after data screening to achieve a large enough sample size for data analysis. This provided the ability to answer important research questions and reduce sampling errors. The justification for combining data will be discussed in "Chapter Four: Results."

Table 1

Sample descriptions (N=304)

Variables	**Measure**	**Frequency (Percentage)**			
		Building1	**Building2**	**Building3**	**Total**
Gender	Male	7 (17.1)	3 (7.1)	124 (56.1)	134 (44.1)
	Female	34 (82.9)	38 (90.5)	94 (42.5)	166 (54.6)
	(Missing value)	.	1	3	4
	Total	41	42	221	304
Age	18-24	.	.	1 (0.5)	1 (0.3)
	25-34	6 (14.6)	6 (14.3)	27 (21.3)	59 (19.4)
	35-44	12 (29.3)	9 (21.4)	76 (34.4)	97 (31.9)
	45-54	18 (43.9)	11 (26.2)	68 (30.8)	97 (31.9)
	55-64	3 (7.3)	10 (23.8)	24 (10.9)	37 (12.2)
	65-74	.	1 (2.4)	3 (1.4)	4 (1.3)
	(Missing value)	2	5	2	9
	Total	41	42	221	304
Workstation type	Enclosed office, private	8 (19.5)	4 (9.5)	47 (21.3)	59 (19.4)
	Enclosed office, shared with other people	.	1 (2.4)	2 (0.9)	3 (1.0)
	Cubicles	29 (70.7)	25 (59.5)	172 (77.8)	226 (74.3)
	Desk in open office with no partitions	4 (9.8)	12(28.6)	.	16 (5.3)
	(Missing value)	.	.	.	.
	Total	41	42	221	304
Working hours	Less than 20	6 (14.6)	4 (9.5)	2 (0.9)	12 (3.9)
	20-30	14 (34.1)	21 (50.0)	21 (9.5)	56 (18.4)
	31-40	14 (34.1)	12 (28.6)	98 (44.3)	124 (40.8)
	More than 40	7 (17.1)	5 (11.9)	100 (45.2)	112 (36.8)
	(Missing value)	.	.	.	.
	Total	41	42	221	304

Instrument

The B3-SPOES questionnaire was developed and pre-tested by the CSBR to collect occupants' perspectives on their satisfaction and work performance. Researchers discussed whether the instrument appeared to measure the target variables well, and this process made this questionnaire have face validity. Most questions included in this self-administered, on-line POE questionnaire were developed to reflect sustainable IEQ criteria of the B3-MSBG, and some items were selected from other existing POE questionnaires and several sustainable design guidelines reviewed in "Chapter Two: Literature Review."

The total number of items used in B3-SPOES questionnaires was different depending on clients' demands. The questionnaire for Buildings 1 and 2 included a total of 191 items; 95 items were related to occupants' satisfaction with IEQ criteria and the effect of IEQ criteria on their perceived work performance. Among 100 items on a questionnaire for Building 3, a total of 46 questions also measured occupant satisfaction and work performance as related to IEQ criteria. These IEQ questions were composed of both category level questions (i.e., thermal conditions) and attribute level questions (i.e., temperature, humidity, air velocity). Participants were asked to provide their demographic information including characteristics of their personal workplace, and to rate their satisfaction with each IEQ criterion, satisfaction with the overall facility, effect on overall work performance, sustainability ethic, etc. A 7-point Likert-type scale was used for these questions. For satisfaction, 1 was "very dissatisfied" and 7 was "very satisfied." For work performance, 1 was "hinders work performance" and 7 was "enhances work performance." For sustainability ethic, 1 was "not important" and 7 was "very important."

The questionnaire was mostly comprised of closed-ended questions that asked respondents to choose among alternative answers and scales provided by the researcher. This type of question is desirable 1) when there is a large number of respondents, 2) when the answers are to be scored by machine, and 3) when responses from several groups are to be compared (Sommer & Sommer, 2002). Some open-ended questions were included to allow respondents to expand on closed-ended questions.

Procedures

The procedure for the survey received an exemption from the University of Minnesota Institutional Review Board. The instrument was pre-tested with local user groups and sustainable designers for clarity, language, accuracy, and bias. These pre-tests were not related to respondents of target buildings or to people who were engaged in the building design. The questionnaire was revised based on pre-test results. To access the survey, all occupants of target buildings received an email notice requesting their participation. The survey goal, a consent statement, and encouragement from management were also included in this notice. Occupants completed the on-line questionnaire during company time. They received a small gift for their participation in the survey.

Variables

Among questions from the two different questionnaire sets (one for Buildings 1 and 2, and another for Building 3), common items related to satisfaction with IEQ (attributes) at the workstation level were selected for this study. IEQ factors extracted from 20 common items were used as independent variables of the hypothesized model. The dependent variables were occupants' satisfaction with the overall facility, their overall work performance, and their sustainability ethic. The variables for this study are shown in Table 2.

Table 2

Variables of this study

Variables		**Likert-type scale**
Independent Variables	- Satisfaction with IEQ factors extracted from IEQ attributes at the workstation level	- from very satisfied (7) to very dissatisfied (1)
Dependent Variables	- Satisfaction with the overall facility	- from very satisfied (7) to very dissatisfied (1)
	- Overall work performance	- from enhances work performance (7) to hinders work performance (1)
	- Sustainability ethic	- from very important (7) to not important (1)

Data Analysis

Data Screening and Preparation

Data screening was conducted prior to factor analysis and path analysis to find an appropriate sample for the data analyses. A mean substation method was used to handle missing data. Univariate outliers were excluded from the analyses using the standard score greater than ±3.0, and multivariate outliers were identified using Mahalanobis distance at p-value less than .001. Equality of variances on all variables was estimated to provide the rationale for combining multiple surveys from three different buildings. The data set was also examined for multicollinearity and normality, which can affect the results.

Statistics Techniques

Factor analysis and path analysis were used for the data analysis to investigate the purpose of this study. Factor analysis was used to determine if all items are reasonable indicators of the underlying factors, i.e., how strongly each item is related to the factor (Brown, 2006). In other words, factor analysis can be used to analyze the structure of interrelationships among a large number of variables by defining a set of common underlying factors (Hair, Anderson, Tatham, & Black, 1995). In addition, factor analysis was used for construct validity, e.g., obtaining evidence of discriminant validity by demonstrating that items load onto separate factors in the expected manner, and for data reduction, e.g., reducing a larger set of intercorrelated items to a smaller set of composite factors (Brown, 2006).

In this study, exploratory factor analysis (EFA) was used to account for relationships among items related to IEQ attributes and to identify the underlying IEQ factors with a set of items. As shown in Table 3, a total of 20 common items related to occupants' satisfaction with IEQ attributes at the workstation level obtained from B3-SPOES questionnaires for three buildings were used for conducting EFA. Items related to IAQ at the workstation level were not included in these common items.

Table 3

Items (attribute levels of sustainable IEQ criteria) used in EFA

Items
1. Temperature
2. Air velocity
3. Humidity
4. Level of sound privacy
5. Background noises
6. Ability to understand desired sounds
7. Amount of electric lighting
8. Visual comfort of the lighting
9. Amount of daylighting
10. Extent to which you have an external window view when standing
11. Extent to which you have an external window view when seated
12. Extent to which you can control the desk (task) light
13. Ability to control or block the sunlight
14. Automatic controls that change electric lighting in response to daylighting available
15. Extent to which you can control the adjustable floor air vent (diffuser)
16. Comfort of your workstation furnishing
17. Ability to adjust your furniture to meet your needs
18. Amount of space available for your individual storage
19. Amount of space available for your individual work
20. Level of visual privacy

While EFA was used for identifying the underlying factors, confirmatory factor analysis (CFA) was used to confirm EFA findings by examining whether factors identified in the EFA work or not. Therefore, in this study, CFA was used to test how well items represented the number of factors identified by EFA.

Hypotheses of this study were tested using path analysis. As an extension of a regression model, path analysis is used to examine simultaneous relationships among independent and dependent variables. In this study, IEQ factors extracted by factor analysis were used as independent variables, and occupants' satisfaction with the overall facility, their overall work performance, and their sustainability ethic were used as dependent variables for path analysis. The path model, including various causal paths among variables, was tested to indicate the strength and significance of relationships among variables. Goodness-of-model fit was tested by various fit indices, such as the goodness of fit index (GFI), the adjusted goodness of fit index (AGFI), the normed fit index (NFI), the root mean square error of approximation (RMSEA), and so forth. If these fit statistics show satisfactory levels, the collected data are likely to be very closely matched to the hypothesized model.

Limitation

This study combined survey data collected from three different buildings to achieve appropriate and adequate sample size. Although the buildings had similar sustainable design features and functions, the different types of questionnaires, i.e., the length of questionnaire, the number of questions, etc., used for the occupant surveys may lead to different responses on the same questions. Further research is needed using the same questionnaire to combine data from multiple buildings. However, this study is exploratory in investigation of a good-fit model and simultaneous variable influence, so a large sample size had to be used.

The differing occupant demographics of the three buildings, such as gender and working hours, may affect occupants' perceptions of IEQ, their overall facility environments, and their work performance; this, in turn, can influence their sustainability ethic. In the sample of this study, most occupants of Buildings 1 and 2 were female whereas the ratio between male and female was balanced in Building 3. However, there was little difference in the two groups' responses about satisfaction, work performance, and sustainability ethic. Occupants of Buildings 1 and 2 worked between 20 to 40 hours per week while occupants of Building 3 worked over 30 hours per week. However, this is not a substantial difference in affecting the results. Occupants working at different workstation types may affect the results; however, the majority of occupants in the three buildings worked at cubicles with partitions, followed by enclosed private offices. A large sample size was needed in each workstation type and gender group when comparing the different workstation groups' and different gender groups' perceptions on satisfaction, work performance, and sustainability ethic. In order to determine that this small difference in occupants' demographic information did not have an effect on the analysis of data, the equality of variances of populations for the three buildings was checked and discussed in the next chapter.

CHAPTER FOUR: RESULTS

This chapter presents the research findings from factor analysis and path analysis after data screening. Factor analysis results identify factors related to sustainable IEQ criteria. Path analysis results test a hypothesized model indicating relationships among satisfaction with sustainable IEQ criteria, satisfaction with the overall facility, overall work performance, and sustainability ethic, as well as suggest a good-fit model.

Data Screening

Missing Data

Responding participants can fail to provide acceptable response to one or more of the survey items (item non-response). It is important to consider the issues raised by missing data at the data analysis stage because missing data can introduce ambiguity into the inferences as well as misinterpretation of the data drawn from a study. In this study, an imputation method that assigns values for missing responses was used to make sure that all information from respondents was included in the data (Brick & Kalton, 1996). For the imputation method, a mean substitution method was used to replace the missing value with the arithmetic mean value of each variable used in this study.

Univariate and Multivariate Outliers

Outliers were checked because they can have an effect on the results of the data analysis. Outliers are cases that show substantially different scores from others in a set of data (Byrne, 2010). A univariate outlier has an extreme score on a single variable, and a multivariate outlier has an extreme score with respect to multiple variables (Kline, 2011). Univariate outliers can be identified with scores more than three standard deviations from the mean. This converted score is the standard score (z-score), and a sample can be an outlier if the z-score is ±3.00 or greater (Byrne, 2010; Kline, 2011). Multivariate outliers can be detected by computing the squared Mahalanobis distance (D^2) that indicates the distance in standard deviation units between a set of scores for an individual case and the sample means for all variable; a value of D^2 with a low p value (.001 or less) leads a multivariate outlier (Byrne, 2010; Kline, 2011).

When checking all 304 samples on all independent and dependent variables, three univariate outliers ($|z| > 3.00$) were found. If these three outliers came from occupants who worked in an enclosed office shared with other people or at a desk with no partitions in an open office that showed a small sample size, the researcher will need to consider keeping these responses since the difference with other respondents could be due to different working environments, and these respondents could also be valuable for data analyses. However, the three univariate outliers came from respondents who worked at cubicles with partitions or enclosed private offices that had a relatively larger sample size, so these three outliers were excluded from the analyses. When checking multivariate outliers, twelve respndents (D^2 with $p < .001$) were dropped, leaving 289 respondents for data analyses.

Combining Multiple Data

This study combined three sets of survey data using the B3-SPOES tools from three sustainable office buildings to construct an analytical data set. This combined set gave the researcher the ability to answer research questions and to increase the overall sample size to reduce sampling errors. Thus, equality of variances on all variables (20 independent variables and three dependent variables) used in this study was examined to verify whether the variances of populations are equal for the three buildings. Most variables showed that the population variances were equal for the three buildings ($p<.05$). However, five variables, such as satisfaction with the overall facility, extent to which subjects have an external window view when standing, extent to which subjects can control the adjustable floor air vent (diffuser), amount of space available for individual work, and humidity did not show the equal variances of populations for the three buildings. However, marked differences among data were not found when the mean values of these variables were checked. Therefore, the combined data were considered acceptable for data analysis of this study.

Sample Size

There are some rough guidelines about sample size for conducting factor analysis and path analysis. Kline (2011) suggested that less than 100 is considered “small,” 100 to 200 is “medium,” and greater than 200 is “large,” which is acceptable for most models. Lee and Song (2004) suggested that when the ratio of sample size to items is 4:1 or 5:1, an accurate and reliable goodness-of-fit test can be produced. In this study, sample size was 289 and the number of initial items was 20, which showed the ratio of sample size to items, 289:20 (14.5:1). Therefore, sample size of this study could be used for an accurate and reliable data analysis.

Factor Analysis Results

Prior to testing a hypothesized model with path analysis, the factors that represent the 20 items related to sustainable IEQ criteria were extracted using factor analysis.

Data Preparation

Multicollinearity. Multicollinearity refers to a situation in which two or more independent variables are highly correlated. Correlations between variables greater than .90, tolerance less than .10 or .20, and Variance Inflation Factor (VIF) greater than 5 or 10 indicate a multicollinearity problem (Garson, 2011a; Hair, Anderson, Tatham, & Black, 1995). No independent variables (20 items) of this study showed multicollinearity (correlations < .664, tolerance > .347, and VIF < 2.883).

Univariate and Multivariate Normality. Multivariate normal distribution means that all variables are univariate normally distributed; the distribution of any pair of variables is bivariate normal; and all pairs of variables have linear and homoscedastic scatterplots (Byrne, 2010; Harrington, 2009; Kline, 2011). Skewness index (SI) and kurtosis index (KI) examined univariate normality for each item. Skewness is "the degree of symmetry of the distribution" and kurtosis is "the shape of the distribution against the normal distribution, by comparing relative height to width" (Burdenski, 2000). SI that is between -3 to 3 and KI that is between -10 to 10 are needed for univariate normality (Kline, 2011). Values of kurtosis that are greater than 20 indicate a potentially serious problem. As shown in Table 4, all 20 items of this study were univariate normal showing SI ranged between -1.212 and .921 and KI ranged between -1.169 and .807. However, the multivariate distribution could be still non-normal (Byrne, 2010; West, Finch, & Curran, 1995). Thus, multivariate normality was examined using Mardia's (1985) multivariate kurtosis. The critical ratio (C.R.) of multivariate kurtosis represents Mardia's multivariate kurtosis. According to Bentler (2005), values of C.R. > 5.0 indicate that data are non-normally distributed. The evidence revealed that data of this study were multivariate non-normally distributed (C.R. = 29.96). When selecting appropriate estimation methods in conducting factor analysis and path analysis, this multivariate non-normality issue should be considered with caution.

Table 4

Univariate normality of 20 items (N=289)

Observed variables (Items)	**Multicollinearity**		**Univariate normality**	
	Tolerance	VIF	Skewness	Kurtosis
1. Temperature	.409	2.443	.067	-1.169
2. Air velocity	.396	2.528	-.423	-.723
3. Humidity	.511	1.958	-.630	-.130
4. Level of sound privacy	.373	2.679	.921	-.511
5. Background noises	.358	2.795	.051	-1.046
6. Ability to understand desired sounds	.476	2.103	-.359	-.386
7. Amount of electric lighting	.414	2.418	-.774	.037
8. Visual comfort of the lighting	.429	2.329	-.403	-.820
9. Amount of daylighting	.347	2.883	-.799	-.100
10. Extent to which you have an external window view when standing	.390	2.567	-1.212	.807
11. Extent to which you have an external window view when seated	.382	2.619	-.450	-1.004
12. Extent to which you can control the desk (task) light	.570	1.755	-.579	-.190
13. Ability to control or block the sunlight	.547	1.829	-.310	-.934
14. Automatic controls that change electric lighting in response to daylighting available	.611	1.637	-.407	-.853
15. Extent to which you can control the adjustable floor air vent (diffuser)	.543	1.842	-.025	-.605
16. Comfort of your workstation furnishings	.381	2.623	-.911	.541
17. Ability to adjust your furniture to meet your needs	.354	2.825	-.643	-.300
18. Amount of space available for your individual storage	.443	2.260	-.749	-.393
19. Amount of space available for your individual work	.350	2.859	-.583	-.720
20. Level of visual privacy	.452	2.210	.326	-1.009

Exploratory Factor Analysis (EFA)

Exploratory factor analysis (EFA) was conducted with the 20 items using SPSS 17.0 to determine how IEQ attribute level items can be tied together to represent new factors. First, it was important to determine whether the data are suitable for factor analysis (Pett, Lackey, & Sullivan, 2003). To do this, the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity that tests the strength of the relationship among items were checked. The KMO values closer to 1.0 mean that factor analysis becomes more acceptable for the data (Kaiser, 1973). The KMO values greater than 0.8 are generally accepted for the appropriateness of factor analysis (Gorsuch, 1983). In this study, the KMO value was 0.91, and Bartlett's test of sphericity showed a significance of the relationships among items ($\chi 2 = 3239.30$, p=.000). Therefore, factor analysis could be conducted for this study.

For high-quality EFA decisions, the following three issues were considered: 1) the factor extraction method, 2) the factor rotation method, and 3) the number of factors retained (Conway & Huffcutt, 2003; Costello & Osborne, 2005).

Factor Extraction Method. The purpose of conducting EFA for this study was to identify the latent factor structure of a set of items. Therefore, a common factor model was selected for this study instead of principal component analysis (PCA), which has the goal of data reduction (Conway & Huffcutt, 2003; Fabrigar, Wegener, MacCallum, & Strahan, 1999; Hair et al., 1995). Among common factor models, maximum likelihood (ML) and principal axis factoring (PAF) are the most frequently used as factor extraction methods, and either of them can be selected depending on whether data meet the assumption of a multivariate normal distribution (Brown, 2006; Fabrigar et al., 1999). ML estimation requires the assumption of multivariate normal distribution of data, and PAF is used when this assumption is severely violated. The data of this study indicated multivariate non-normality, so that ML may result in problematic estimation. Therefore, PAF was more appropriate as an extraction method in conducting EFA.

Factor Rotation Method. The goal of rotation is to produce and clarify the best simple data structure solution (Brown, 2006; Costello & Osborne, 2005). For this study, oblique rotation with a direct oblimin (=0) was selected as a factor rotation method because this represents reality and provides a better simple structure based on the assumption that factors are interrelated. Further, this is more likely to be able to be generalized to confirmatory factor analysis (CFA) compared to orthogonal solutions (Brown, 2006; Conway & Huffcutt, 2003; Costello & Osborne, 2005; Fabrigar et al., 1999; Gorsuch, 1997).

The Number of Factors Retained. The Kaiser-Guttman rule (Guttman, 1954; Kaiser, 1960; 1974) and the scree plot test were used for determining the appropriate number of factors retained. According to Guttman and Kaiser (1960; 1974), factors with eigenvalues greater than 1.0 are retained. The eigenvalue for a given factor indicates the variance in all the variables (items) which is accounted for by that factor, and the ratio of eigenvalues means the ratio of the importance of the factors regarding the variables (Garson, 2011b). This rule can result in either overfactoring or underfactoring (Brown, 2006; Gorsuch, 1983). However, using the eigenvalues for establishing a cutoff is most reliable when the number of variables (items) is between 20 and 50 (Hair et al., 1995). In this study, five eigenvalues were greater than 1.0, accounting for a total of 69.27% of the common variance in the 20 items explained by five factors (see Table 5). The scree plot was also tested to determine the number of factors. The general rule is that the number of factors appears in the last substantial decline in the magnitude of the eigenvalues (Brown, 2006) and prior to the beginning of the straight line (Cattell & Jaspars, 1967). As shown in Figure 7, the fifth point in the scree plot was the last one that dropped substantially in eigenvalues and appeared prior to the straight line. Therefore, a five-factor solution was selected for this study based on the eigenvalues > 1.0 rule and the scree plot.

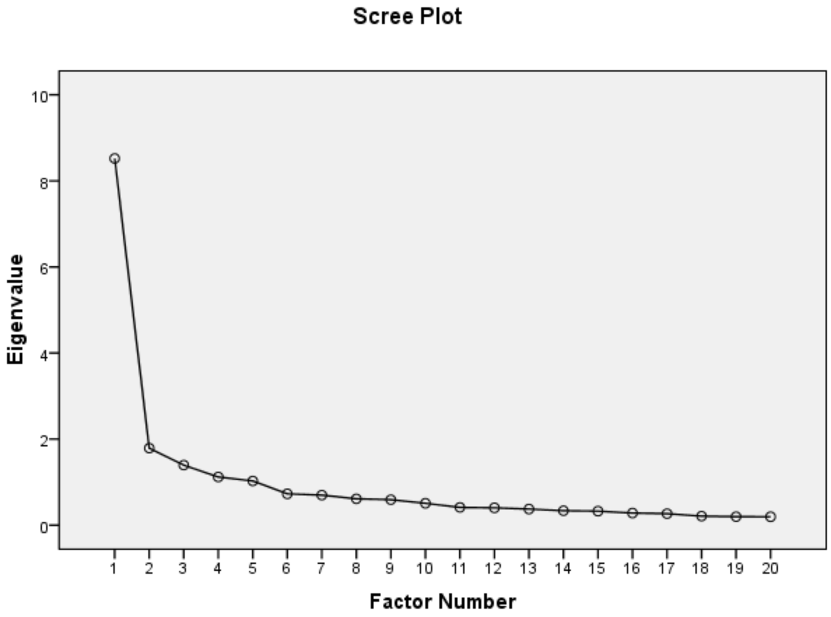

Figure 7. Scree plot.

Factor loadings indicate the degree of correspondence between the item and factor, and higher loadings make the item representative of the factor (Hair et al., 1995). Factor loadings greater than or equal to ±.30 or ±.40 can be interpreted as salient (Brown, 2006). In addition, based on sample size, a factor loading of ±.35 can be considered significant in a sample of over 250 (Hair et al., 1995). Tabachnick and Fidell (2001) recommended that a cut-off value ±.32 is the minimum loading for determining cross-loading items that load on multiple factors. In this study, factor loadings of all items significantly loaded over ±.48 on at least one factor (see Table 5). In addition, there were no cross-loading items at a cut-off value of ±.32. All 20 items were retained under five factors labeled as "Furnishings," "Thermal Conditions," "View Conditions," "Lighting Conditions," and "Acoustics and Privacy Conditions," based on the items that had loaded on each factor. As shown in Table 5, each item loaded on only one factor, and there were no cross-loading items that loaded on two or more factors at a cut-off value of .32.

The extraction process provides communality, which refers to the percent of variance in a given measured variable (i.e., item) explained by all extracted factors (Brown, 2006; Pett, Lackey, & Sullivan, 2003). Communality generally shows for which measured variables the factor analysis is working best or least well (Garson, 2011b). The communality ranges from 0 to 1.0, and higher values mean that more of the variance of an individual item is explained by the extracted factors. In this study, communalities of all items ranged from .36 to .79. The item VC1 (extent to which you have an external window view when standing) had the largest communality (.79), indicating that 79% of the common variance in this item could be explained by all factors jointly. However, the extracted factors explained only 36% for the item LC6 (Automatic controls that change electric lighting in response to daylighting available). A communality of .36 seems low. In general, items showing low communalities are little related to each other, so the factor model may not be working well by those items. However, it is more important to consider whether those items are meaningful in defining factors, rather than their communalities show high or low values (Garson, 2011b). The item LC6 is meaningful to explain the “Lighting conditions” factor, so should be remained, although it has a little low communality.

Reliability. Internal consistency reliability was assessed by generating Cronbach’s coefficient alphas for each of five factors independently (Gefen, Straub, & Boudreau, 2000). Internal consistency refers to how well the items consist of an instrument or fit to one of the factors (Pett, Lackey, & Sullivan, 2003). Cronbach’s alpha estimates are generally accepted at a .70 or .80 cutoff value for general research purposes (Henson, 2001; Nunnally & Bernstein, 1994). As shown in Table 5, all factors had Cronbach’s alphas of over .81 and appeared adequate for reliability as follows: Furnishings (four items; $\alpha = .85$), Thermal Conditions (four items; $\alpha = .84$), View Conditions (two items; $\alpha = .81$), Lighting Conditions (six items; $\alpha = .85$), and Acoustics and Privacy Conditions (four items; $\alpha = .86$).

Table 5

Factor loadings, Communality, Eigenvalue, and Reliability (N=289)

Items (IEQ attributes)	**Extracted Factor Loadings**					**Communality**
	1 Furnishings	2 Thermal Conditions	3 View Conditions	4 Lighting Conditions	5 Acoustics & Privacy Conditions	
FU1. Comfort of your workstation furnishings	.78					.64
FU2. Ability to adjust your furniture to meet your needs	.73					.64
FU3. Amount of space available for your individual storage	.70					.54
FU4. Amount of space available for your individual work	.67					.65
TC1. Temperature		.82				.71
TC2. Air velocity		.79				.70
TC3. Extent to which you can control the adjustable floor air vent (diffuser)		.63				.48
TC4. Humidity		.48				.50
VC1. Extent to which you have an external window view when standing			-.80			.79
VC2. Extent to which you have an external window view when seated			-.70			.70
LC1. Amount of electric lighting				-.84		.68
LC2. Visual comfort of the lighting				-.67		.57
LC3. Extent to which you can control the desk (task) light				-.65		.45
LC4. Ability to control or block the sunlight				-.58		.44
LC5. Amount of daylighting				-.56		.67
LC6. Automatic controls that change electric lighting in response to daylighting available				-.49		.36
AP1. Level of sound privacy					.77	.72
AP2. Background noises					.76	.72
AP3. Level of visual privacy					.57	.55
AP4. Ability to understand desired sounds					.49	.52
Eigenvalues	8.52	1.79	1.40	1.12	1.03	
% of variance of Eigenvalues	42.61	8.95	6.98	5.60	5.14	
Reliability (Cronbach's alpha)	.85	.84	.81	.85	.86	

As mentioned before, IAQ factor, that was one of IEQ category included in B3-SPOES, other IEQ survey questionnaires, and sustainable design guidelines, was not extracted through EFA because there were not common items related to IAQ at the workstation level.

Confirmatory Factor Analysis (CFA)

Confirmatory factor analysis (CFA) was conducted using AMOS 18 to validate the five-factor solution derived from EFA. ML estimation is generally recommended for multivariate normal data and is robust to minor non-normality. If there is extreme non-normality (absolute values of kurtosis indices greater than 20.0), the robust ML (MLM) and asymptotically distribution free (ADF) can be used for handling extreme non-normality (Brown, 2006; Harrington, 2009). As mentioned in prior analysis, data of this study did not show the multivariate normality (C.R. = 29.96). ADF is usually used with categorical data and works well with extremely large sample sizes (1,000 to 5,000), while MLM works well with continuous data and smaller size sample (Brown, 2006; Byrne, 2010). Thus, MLM is preferred for non-normality data. Because AMOS does not provide MLM, the direct ML with robust estimators was used as the best option to test whether the five-factor model fit the data (Byrne, 2010; Yuan, Bentler, & Zhang, 2005).

The factor loadings are the regression coefficient for predicting the observed variables (items) from unobserved factors (Harrington, 2009). The general rules of thumb are that loadings above .71 are excellent, between .40 and to .70 are fairly good, and below .30 are not interpreted (Tabachnick & Fidell, 2007). As shown in Figure 8, factor loadings for all variables on each factor were .59 or greater at the significance level (*p*<.05): factor loadings for four variables on Furnishings ranged from .70 to .82; the loadings for four variables on Thermal Conditions ranged from .70 to .81; the loadings for two variables on View Conditions ranged from .82 to .86; the loadings for six variables on Lighting Condition ranged from .59 to .81; and the loadings for four variables on Acoustics and Privacy Conditions ranged from .72 to .84. The correlation among the factors was also significant and they were somewhat related (.40 or greater).

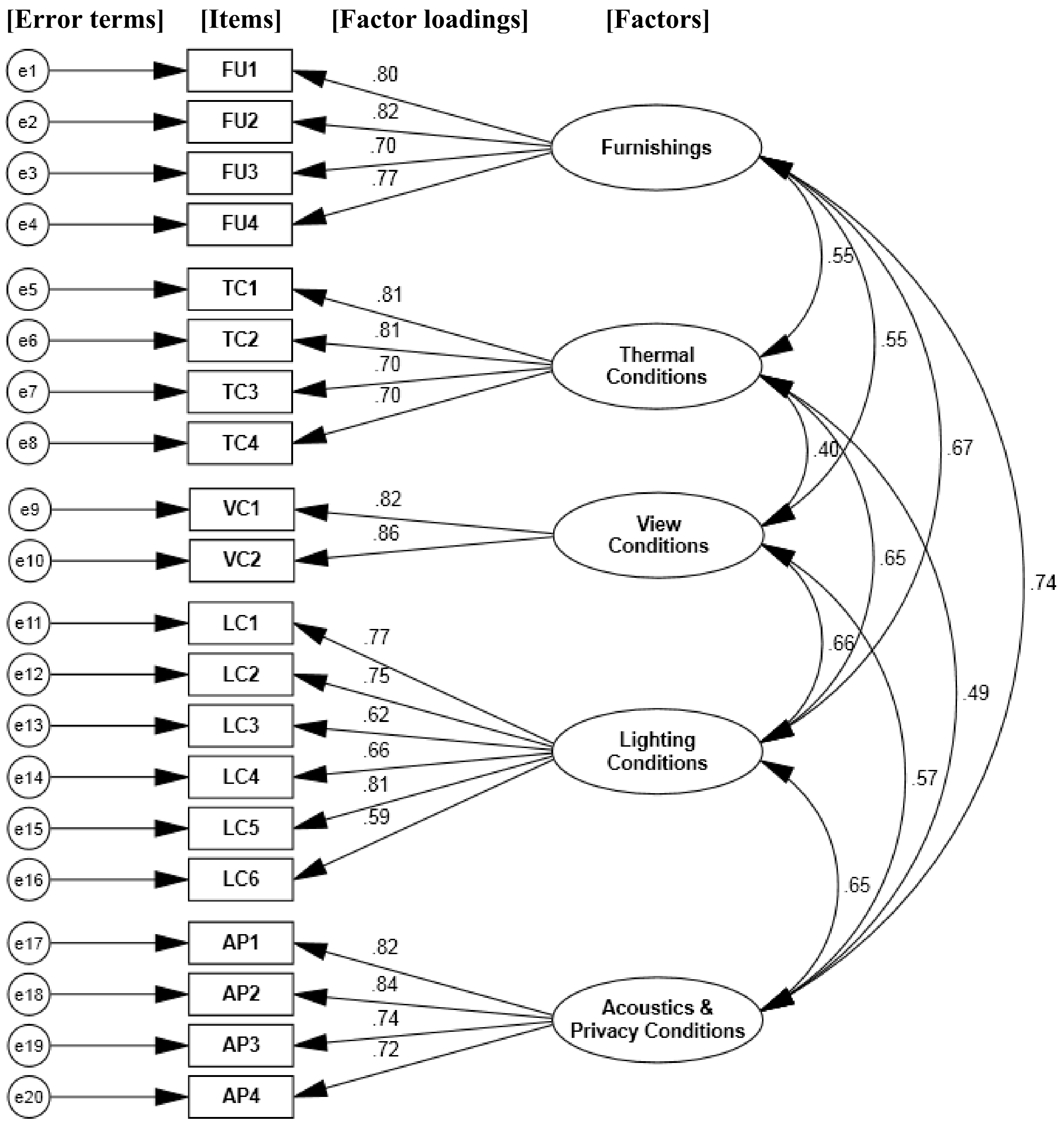

Figure 8. The initial CFA model based on the EFA result.

Model Fit. The traditional chi-square fit index (χ^2/df) was examined to evaluate the model fit. However, this test can be dependent on sample size and is overly stringent in evaluating fit (Bentler, 1990; Harrington, 2009). Therefore, several different goodness-of-fit indices, such as the goodness-of-fit index (GFI), the adjusted goodness-of-fit index (AGFI), comparative fit index (CFI), Bentler-Bonett normed fit index (NFI), the incremental fit index (IFI), Tucker-Lewis index (TLI), and the root mean error square of approximation (RMSEA), were also used to provide a comprehensive evaluation of model fit (Byrne, 2010; Harrington, 2009; Hu & Bentler, 1999). The values of chi-square that are less than 2.0 or 3.0 indicate a good model fit (Chin & Todd, 1995). GFI, AGFI, CFI, NFI, IFI and TLI values that are greater than .90 or .95 indicate reasonably good fit of the model (Brown, 2006; Byrne, 2010; Kline, 2010). The AGFI that is above .80 is also an acceptable value for a good fit (Gefen et al, 2000). The RMSEA that is less than .05 indicates good fit, and values between .05 and .08 suggest reasonable errors of approximation and acceptable fit (Hu & Bentler, 1999; Kline, 2010; Schermelleh-Engel, Moosbrugger, & Müller, 2003; Schumacker & Lomax, 2004). The RMSEA ranging from .08 to .10 indicates mediocre fit, and values that are equal or greater than .10 suggest poor model fit (Byrne, 2010; Kline, 2010). The initial five-factor model was a statistically significant: χ^2 ($df = 160$) = 460.0, $p<.001$. Although some indices indicated an acceptable model fit, the initial CFA model of this study did not fit well: $\chi^2/df = 2.875$, GFI = .860, AGFI = .816, CFI = .904, NFI = .862, IFI = .905, TLI = .886, and RMSEA = .081 (see Table 6).

Model Modification. When testing the initial model with various model fit indices, it was evident that the initial model needed to be a modified good-fit model. The model was modified by examining modification indices (MI) and standardized residuals (Brown, 2006; Harrington, 2009). A MI greater than 4 is considered a significant improvement in model fit (Brown, 2006; Harrington, 2009). Standardized residuals that are equal to or greater than 2.00 or 2.58 should be considered (Brown, 2006; Byrne, 2010).

When examining the MI, the MI for a covariance between FU1 (comfort of your workstation furnishings) and FU2 (ability to adjust your furniture to meet your needs) was 30.54. The covariance between FU3 (amount of space available for your individual storage) and FU4 (amount of space available for your individual work) was 29.79. It made sense that the comfort of workstation furnishings would be related to ability to adjust the furniture to meet subject needs, and that the amount of space available for the individual storage would be related to the amount of space available for the individual work. Therefore, it was reasonable that the paths of covariance were added between error terms for items FU1 and FU2 and for items FU3 and FU4 that loaded on the same factors, "Furnishings." This first modification resulted in some improvement in model fit: χ^2 (df = 158) = 397.9, $p<.001$, χ^2/df = 2.518, GFI = .874, AGFI = .833, CFI = .923, NFI = .880, IFI = .924, TLI = .908, and RMSEA = .073 (see Table 6). However, the model still did not fit well (see Table 6).

Next, the standardized residual covariance was checked. Item TC4 (humidity) had the standardized residuals covariance values of greater than 1.0 or 2.0 with several items, such as AP4 (ability to understand desired sounds, 2.515), FU1 (comfort of your workstation furnishings, 2.477), FU3 (amount of space available for your individual storage, 2.644), and VC1 (extent to which you have an external window view when standing, 2.216). Item AP4 also had high values of the standardized residual covariance with other items, such as TC4 (humidity, 2.515), LC3 (extent to which you can control the desk light, 1.900), and TC3 (extent to which you can control the adjustable floor air vent (diffuser), 1.821). As a result, these two items (TC4: humidity and AP4: ability to understand desired sounds) were deleted from the model to obtain a better model fit. This modification also provided some improvement in model fit: χ^2 ($df = 123$) = 307.8, $p<.001$, $\chi^2/df = 2.503$, GFI = .891 (about .90), AGFI = .849, CFI = .933, NFI = .895 (about .90), IFI = .934, TLI = .917, and RMSEA = .072 (see Table 6). These fit indices suggested the acceptable good model fit, and the final model is shown in Figure 9. The factor loadings for the revised model ranged from .59 to .85, and these showed similar values with the factor loadings for the initial model.

The final CFA model with the remaining 18 items was used to develop and test the path model to investigate simultaneous relationships with other variables (Sustainability Ethic, Overall Satisfaction with the Facility, Overall Work Performance). Table 7 provides means and standard deviations of factors and remaining items of the final CFA model.

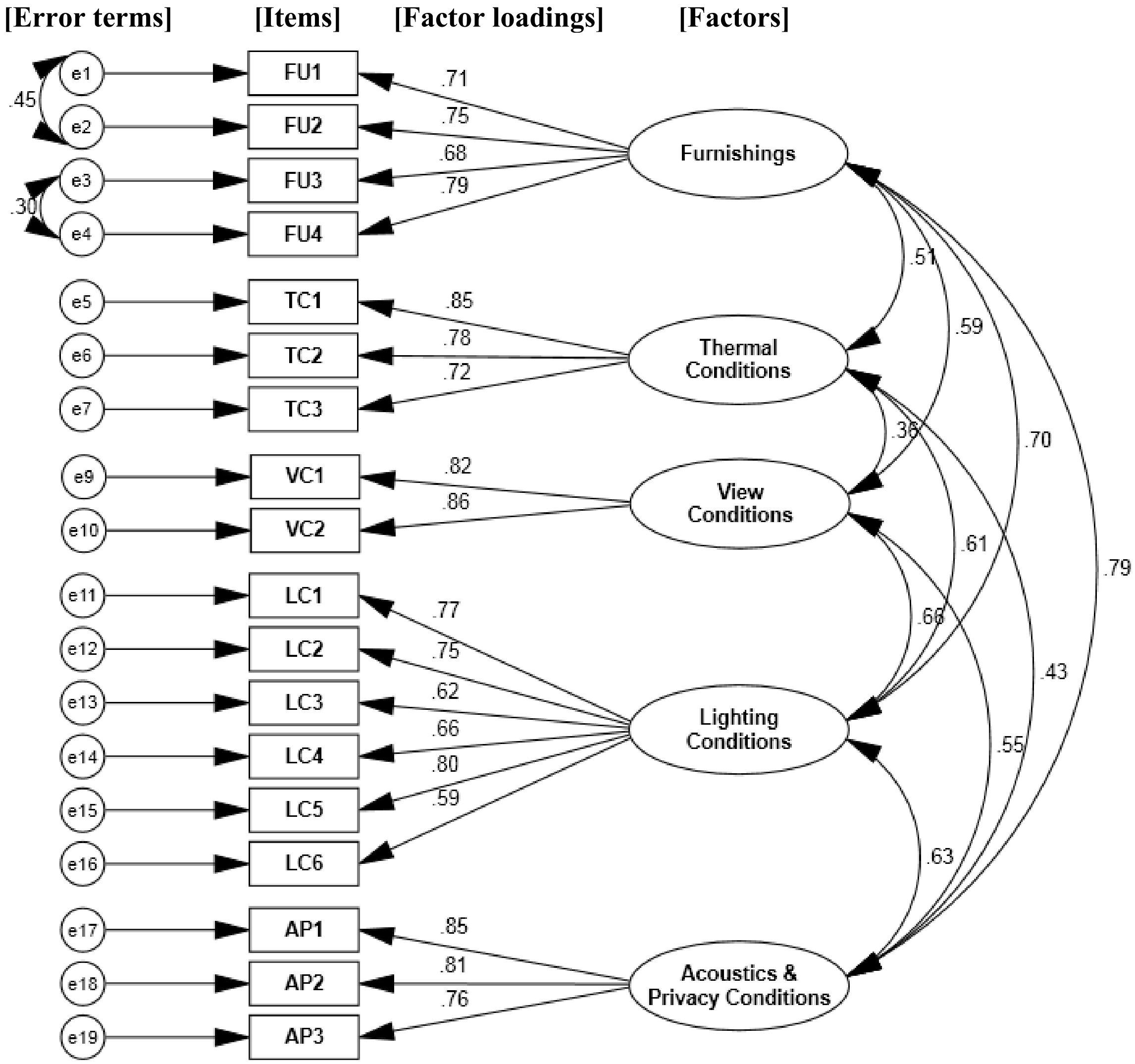

Figure 9. The modified CFA model with two items removed.

Table 6

Fit indices for each CFA model modification (N=289)

Model Modification Step	χ^2	*df*	χ^2/df	**GFI**	**AGFI**	**CFI**	**NFI**	**IFI**	**TLI**	**RMSEA**
1. Initial model	460.0	160	2.875	.860	.816	.904	.862	.905	.886	.081
2. Modification by examination of modification indices : Covariance paths were added between error terms for items FU1 and FU2 and for items FU3 and FU4	397.9	158	2.518	.874	.833	.923	.880	.924	.908	.073
3. Modification by examination of the standardized residual covariance : Items TC4 and AP4 removed	307.8	123	2.503	.891	.849	.933	.895	.934	.917	.072
Cut-off values			≤3.0	≥.90	≥.80	≥.90	≥.90	≥.90	≥.90	≤.08

Table 7

Mean and Standard Deviations of remaining 18 items and extracted factors related to IEQ criteria (N=289)

Factors	Items		Mean	SD
Furnishings	**FU1**.	Comfort of your workstation furnishing	5.29	1.45
	FU2.	Ability to adjust your furniture to meet your needs	4.95	1.61
	FU3.	Amount of space available for your individual storage	5.03	1.75
	FU4.	Amount of space available for your individual work	4.96	1.77
	Total		5.06	1.37
Thermal Conditions	**TC1**.	Temperature	3.89	1.84
	TC2.	Air velocity	4.54	1.74
	TC3.	Extent to which you can control the adjustable floor air vent (diffuser)	3.90	1.72
	Total		4.11	1.52
View Conditions	**VC1**.	Extent to which you have an external window view when standing	5.61	1.61
	VC2.	Extent to which you have an external window view when seated	4.67	2.02
	Total		5.14	1.68
Lighting Conditions	**LC1**.	Amount of electric lighting	5.21	1.56
	LC2.	Visual comfort of the lighting	4.67	1.72
	LC3.	Extent to which you can control the desk (task) light	5.26	1.46
	LC4.	Ability to control or block the sunlight	4.50	1.85
	LC5.	Amount of daylighting	5.23	1.64
	LC6.	Automatic controls that change electric lighting in response to daylighting available	4.54	1.82
	Total		4.90	1.27
Acoustics & Privacy Conditions	**AP1.**	Level of sound privacy	2.83	1.99
	AP2.	Background noises	3.98	1.86
	AP3.	Level of visual privacy	3.60	1.90
	Total		3.47	1.68

Discriminant validity. The size of the factor correlations in CFA solutions should be also interpreted with regard to the discriminant validity of factors. Discriminant validity is demonstrated when measures of different concepts or constructs are distinct (i.e., there are low correlations among the concepts) (Bagozzi, Yi, & Phillips, 1991). Thus, factor correlations that exceed .80 or .85 indicate poor discriminant validity (Brown, 2006). As shown in Table 8, all factor correlations were less than .80, which proved the discriminant validity of factors.

Table 8

Corrrelations of factors

Factors	Furnishings	Thermal Conditions	View Conditions	Lighting Conditions	Acoustics and Privacy Conditions
Furnishings	1.00	.44	-.39	-.59	.58
Thermal Conditions	.44	1.00	-.25	-.52	.28
View Conditions	-.39	-.25	1.00	.45	-.26
Lighting Conditions	-.59	-.52	.45	1.00	-.50
Acoustics and Privacy Conditions	.58	.28	-.26	-.50	1.00

Path Analysis of the Hypothesized Model

The proposed hypothesized model based on literature reviews was analyzed using path analysis (see Figure 6). The findings of factor analysis, as shown in Table 5, produced different factor loadings about satisfaction with sustainable IEQ criteria compared to the hypothesized model. For example, acoustic conditions and privacy conditions were integrated into “acoustics and privacy conditions.” Personal control criterion were separated and merged into other criteria, such as thermal conditions and lighting conditions. As mentioned before, IAQ was not included in the final model because this factor was not extracted throughout factor analyses, and items related to IAQ attributes at the workstation level were not included in common items used in this study.

Sustainable IEQ factors that were combined with attribute level items according to results of factor analysis were used in the path model to show relationships with occupants’ satisfaction with the overall facility, overall work performance, and sustainability ethic. For example, as shown in Table 5, Lighting Conditions were substituted for the average of six items: LC1 (amount of electric lighting), LC2 (visual comfort of the lighting), LC3 (extent to which you can control the desk/task light), LC4 (ability to control or block the sunlight), LC5 (amount of daylighting), and LC6 (automatic controls that change electric lighting in response to daylighting available).

The modified hypothesized model was shown in Figure 10.

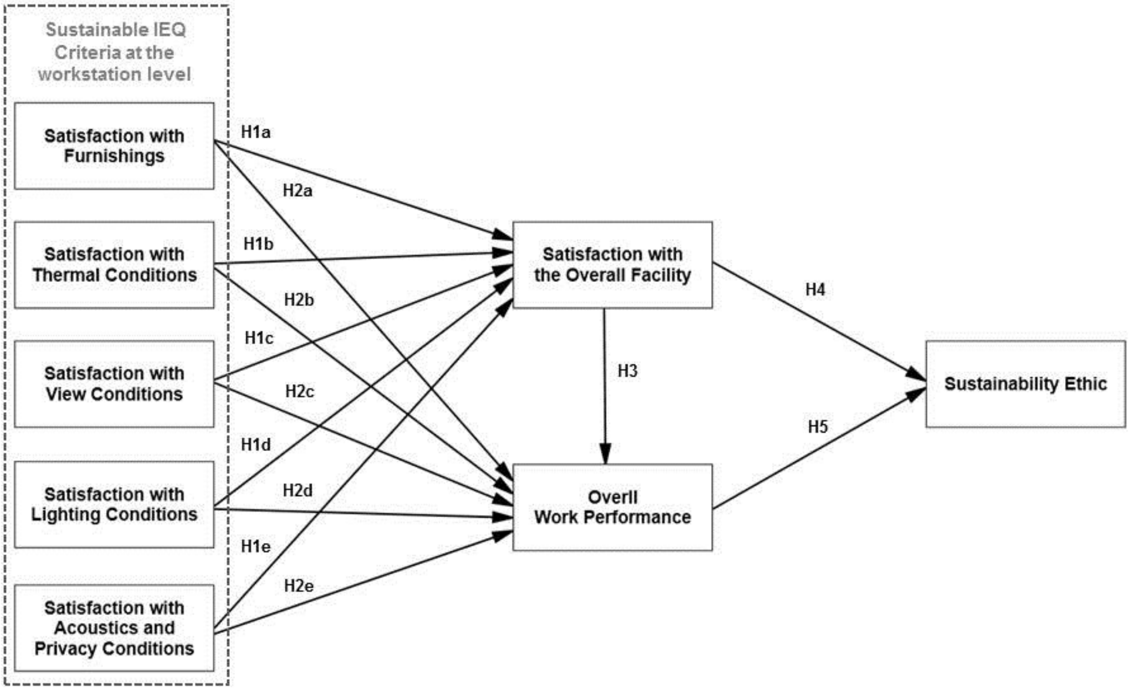

Figure 10. The modified hypothesized path model.

First, the overall fit of the model was examined. The path model was statistically significant: χ^2 (df = 5) = 12.8, p=.026. Various fit indices indicated that the hypothesized path model had a good model-fit: χ^2/df = 2.551, GFI = .989, AGFI = .923, CFI = .993, NFI = .988, IFI = .993, TLI = .959, and RMSEA = .073.

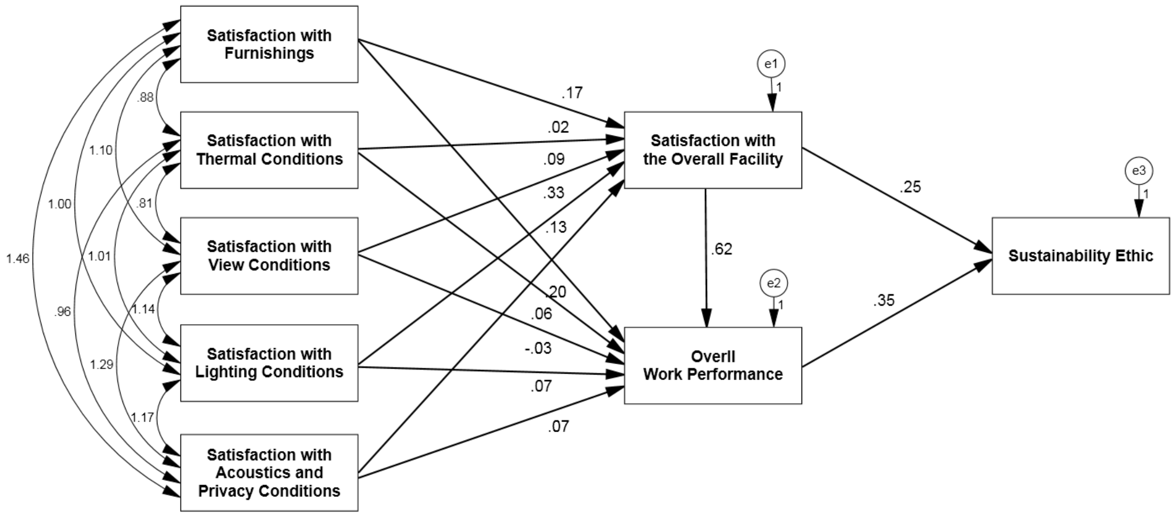

Figure 11. The path coefficient among variables .

Next, the statistical significance of each of hypothesized path between variables was examined (see Figure 11 and Table 9). Hypothesis 1 was that satisfaction with the overall facility is influenced by satisfaction with sustainable IEQ criteria at the workstation level: furnishings (H1a), thermal conditions (H1b), view conditions (H1c), lighting conditions (H1d), acoustics and privacy conditions (H1e). Satisfaction with furnishings ($\beta = .17$, $p<.01$), view conditions ($\beta = .09$, $p<.05$), lighting conditions ($\beta = .33$, $p<.001$), and acoustics and privacy conditions ($\beta = .13$, $p<.01$) were significantly related to satisfaction with the overall facility, indicating that occupants who were satisfied with furnishings, view conditions, lighting conditions, acoustics and privacy conditions of their work environments were also satisfied with the overall facility (site, building, and interior environment). Among them, satisfaction with Lighting Conditions was the highest contributor to predict satisfaction with the overall facility. However, the relationship between satisfaction with the overall facility and thermal conditions were not significant. Therefore, hypothesis 1 was partially supported.

Table 9

Path coefficients for the hypothesized path model (N=289)

Path	***β***	**S.E.**	**C.R.**	***p* value**
H1a: Overall satisfaction with facility ← Satisfaction with Furnishings	.17	.058	2.85	$.004^{**}$
H1b: Overall satisfaction with facility ← Satisfaction with Thermal conditions	.02	.044	.46	.649
H1c: Overall satisfaction with facility ← Satisfaction with View conditions	.09	.041	2.23	$.026^{*}$
H1d: Overall satisfaction with facility ← Satisfaction with Lighting conditions	.33	.064	5.09	$<.001^{***}$
H1e: Overall satisfaction with facility ← Satisfaction with Acoustics and Privacy conditions	.13	.046	2.83	$.005^{**}$
H2a: Overall work performance ← Satisfaction with Furnishings	.20	.049	3.98	$<.001^{***}$
H2b: Overall work performance ← Satisfaction with Thermal conditions	.06	.037	1.61	.108
H2c: Overall work performance ← Satisfaction with View conditions	-.03	.035	-.79	.427
H2d: Overall work performance ← Satisfaction with Lighting conditions	.07	.056	1.19	.234
H2e: Overall work performance ← Satisfaction with Acoustics and Privacy conditions	.07	.039	1.90	$.047^{*}$
H3: Overall work performance ← Overall satisfaction with facility	.62	.049	12.53	$<.001^{***}$
H4: Sustainability ethic ← Overall satisfaction with facility	.25	.095	2.64	$.008^{**}$
H5: Sustainability ethic ← Overall work performance	.35	.088	3.96	$<.001^{***}$

Significant: $p< .05^{*}$, $p< .01^{**}$, $p< .001^{***}$

Hypothesis 2 was that occupants' overall work performance is influenced by satisfaction with sustainable IEQ criteria at the workstation level: furnishings (H2a), thermal conditions (H2b), view conditions (H2c), lighting conditions (H2d), and acoustics and privacy conditions (H2e). Satisfaction with furnishings ($\beta = .20$, $p<.001$) and acoustics and privacy conditions ($\beta = .07$, $p<.05$) were significantly related to occupants' overall work performance. This implies that occupants who were satisfied with furnishings, and acoustics and privacy conditions of their work environment perceived that their overall work performance was enhanced. However, there were no significant relationships between overall work performance and thermal conditions, view conditions, and/or lighting conditions. Therefore, hypothesis 2 was partially supported.

Hypothesis 3 was that occupants' overall work performance is influenced by their satisfaction with the overall facility. There was a significant relationship between occupants' perceived overall work performance and their satisfaction with the overall facility ($\beta = .62$, $p<.001$), indicating that occupants who were satisfied with their overall facility environments perceived their overall work performance was enhanced. Therefore, hypothesis 3 was supported.

Hypothesis 4 was that occupants' sustainability ethic is influenced by their satisfaction with the overall facility. The relationship between occupants' sustainability ethic and their satisfaction with the overall facility was significant ($\beta = .25$, $p<.01$), implying that occupants who were satisfied with their overall facility environments agreed that sustainable design is important to them. Therefore, hypothesis 4 was supported.

Hypothesis 5 was that occupants' sustainability ethic is influenced by overall work performance. There was a significant relationship between occupants' sustainability ethic and their overall work performance ($\beta = .35$, $p<.001$), indicating that occupants who perceived that their overall work performance was enhanced agreed that sustainable design is important to them. Therefore, hypothesis 5 was supported.

As a result of testing the hypothesized model with data from three sustainable office buildings using path analysis, the final path model (see Figure 12) was suggested to explain simultaneous relationships among occupants' satisfaction with IEQ, overall satisfaction with facility, overall work performance, and sustainability ethic.

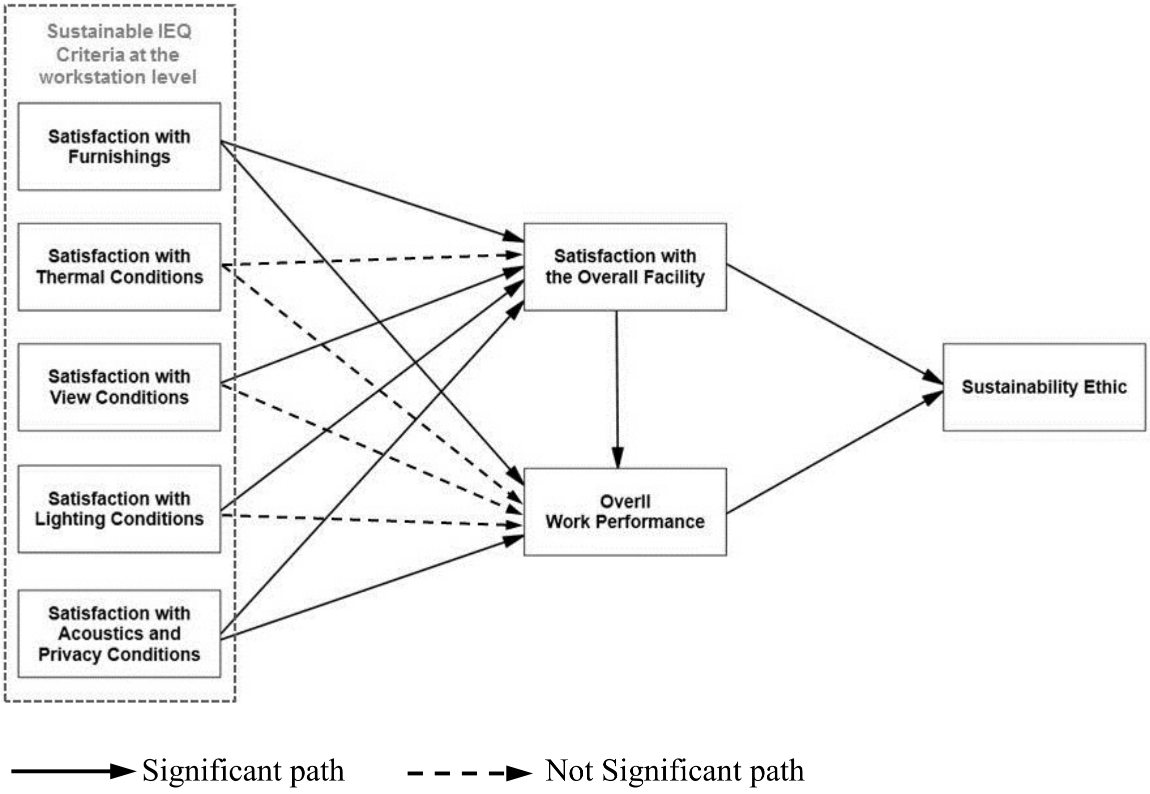

Figure 12. The final path model.

In summary, EFA found five IEQ factors - “Furnishings,” “Thermal Conditions,” “View Conditions,” “Lighting Conditions,” and “Acoustics and Privacy Conditions” – were extracted from 20 items related to satisfaction with IEQ criteria attributes at the workstation level. All factors had internal consistency reliability with Cronbach’s alphas of over .80. CFA confirmed the five-factor solution derived from EFA. However, two items (TC4: humidity and AP4: ability to understand desired sounds) were deleted in the process of model-fit modification to obtain an appropriate model fit. The hypotheses, related to simultaneous relationships among occupants’ satisfaction with IEQ criteria at the workstation level, their satisfaction with the overall facility, their overall work performance, and their sustainability ethic, were estimated using path analysis. As a result, the proposed hypothesized model showed a good model-fit. Hypotheses 1 was partially supported: satisfaction with thermal conditions, view conditions, lighting conditions, and acoustics and privacy conditions significantly influenced satisfaction with the overall facility. Hypothesis 2 was partially supported: furnishings and acoustics and privacy conditions significantly influenced overall work performance. Hypothesis 3 was supported: satisfaction with the overall facility significantly influenced overall work performance. Hypothesis 4 was supported: satisfaction with the overall facility significantly influenced sustainability ethic. Hypothesis 5 was supported: overall work performance significantly influenced sustainability ethic.

CHAPTER FIVE: CONCLUSIONS

This chapter discusses the main findings of factor and path analyses and the implications. It also presents recommendations for future research.

Discussion of Findings

This study estimated the simultaneous relationships among occupants' satisfaction with sustainable IEQ criteria, satisfaction with the overall facility, overall work performance, and sustainability ethic in sustainable office buildings by developing and testing a model. This model had two primary assumptions. The first was that when occupants were satisfied with the sustainable IEQ of their work environments, such as thermal conditions, IAQ, lighting conditions, view conditions, acoustic conditions, privacy conditions, personal control, and furnishings, they were also satisfied with overall facility environments (site, building, and interior) and perceived that their overall work performance was enhanced. The second was that occupants' recognition of the importance of sustainable design could be affected by their increased satisfaction level with overall work environments and enhanced work performance.

Exploratory and confirmatory factor analysis provided support for a good-fit five-factor model related to occupants' satisfaction with sustainable IEQ criteria. These analyses identified five factors that represented 18 items related to IEQ attributes addressed in the B3-SPOES questionnaire: four-item Furnishings, three-item Thermal Conditions, two-item View Conditions, six-item Lighting Conditions, and three-item Acoustics and Privacy Conditions. These factors were found to be internally consistent with Cronbach's alphas ranging from .81 to .86. The low to moderate correlations among the five factors suggested that these factors were somewhat related to each other, but differentiated from others by having unique features, as components of sustainable IEQ that could influence occupants' satisfaction with the overall facility and their overall work performance, which in turn, could be related to their sustainability ethic.

This result somewhat contradicted the current IEQ criteria used in B3-SPOES and other occupant survey tools, such as CBE's IEQ survey. In this study, occupants did not perceive separate personal control criterion from other IEQ criteria. For example, occupants perceived personal control as a contributor to the specific condition being controlled, e.g., lighting conditions included control of sunlight, electric lighting, and desk lighting, but were not perceived as a separate personal control factor. In addition, they perceived acoustic conditions and privacy conditions of their work environments together, indicating that there was a close relationship between these two conditions in estimating their satisfaction level.

Factor analyses also suggested that humidity was not a valuable component to measure occupants' responses to thermal conditions. Further, it was found that the ability to understand desired sound also needed to be deleted from acoustics and privacy conditions because of its complex linkage with other items and factors, resulting in a bad model-fit. This newly identified five-factor model is meaningful itself to investigate how occupants perceive IEQ of their working environments with relation to their satisfaction and work performance.

Path analysis indicated that there were significant and non-significant relationships among satisfaction with sustainable IEQ criteria, satisfaction with the overall facility (i.e., site, building, interior), overall work performance, and sustainability ethic. For example, the findings supported the hypothesis related to the existence of the significant relationships between satisfaction with furnishings and occupants' satisfaction with the overall facility and their work performance. Previous research (Lee & Guerin, 2009) indicated that furnishing quality significantly affected occupants' satisfaction and work performance; the findings of this study also showed that furnishings criteria was an important predictor of occupants' satisfaction with the overall facility and their perceived work performance.

Occupants' satisfaction with thermal conditions did not predict their satisfaction level with overall facility environments and perceived work performance. This result was not consistent with other researchers who found that thermal condition is a significant factor influencing occupants' satisfaction and performance (Clements-Croome & Baizhan, 2000; Fisk, 2000; Nasrollahi, Knight, & Jones, 2008; Seppanen & Fisk, 2005; Wyon, 1996). While these studies showed increased dissatisfaction levels with uneven temperature and the difficulty of control over thermal conditions by different workstation types, the settings of this study have adjustable floor air vents in each workstation regardless of whether they are in private offices or cubicles, thus occupants had control over some of the thermal conditions. Therefore, it seems that there is minimal difference in occupants' satisfaction level with thermal conditions and their effects on occupants' work performance throughout all workplaces. This result seems to be supported by the fact that the mean value of the satisfaction with thermal conditions was close to 4 (neutral) rather than satisfaction or dissatisfaction. From this, it may be surmised that thermal conditions of these setting might not be a significant factor influencing occupants' satisfaction and work performance.

View conditions showed a significant effect on predicting occupants' satisfaction with the overall facility. This finding is consistent with the previous assumptions that visual contact with an outside view psychologically and physiologically affected occupants' satisfaction with their workplaces (Heerwagen & Orians, 1986; NRCC, 2009b; US GSA, 2009). However, occupants' satisfaction with view conditions did not significantly influence their work performance.

Occupants' satisfaction with lighting conditions was also significantly related to their satisfaction with the overall facility as the strongest sustainable IEQ component influencing their satisfaction with the overall facility, in turn, influencing their sustainability ethic. However, satisfaction with lighting conditions was not a significant contributor to predict occupants' overall work performance, contradicting other studies that have indicated positive relationships between lighting conditions (i.e., adequate light level, visual comfort, amount of glare, lighting illuminance, the spectrum of light, etc.) and occupants' work performance (Li & Tsang, 2008; NEMA, 1989; NIBC; 2008; NRCC, 2009b). Because occupants in this study were satisfied with lighting conditions of their workstations, such as the amount of electric lighting and daylighting, visual comfort of lighting, control over the desk light, control over the sunlight, and automatic controls of electric lighting depending on daylighting available, they might not have been affected by lighting conditions when they were working.

Occupants' satisfaction with acoustics and privacy conditions also significantly influenced occupants' satisfaction with the overall facility and their overall work performance. This finding was consistent with previous studies that indicated acoustics and privacy conditions were a significant factor to predict occupants' overall satisfaction and work performance. These studies found that although buildings were constructed by sustainable design guidelines, unsatisfactory acoustics and privacy conditions, due to lack of speech and visual privacy, disturbance by background noise, and equipment noise, have made it difficult for them to concentrate on their work and led to occupants' complaints (Abbaszabeh et al., 2006; Field, 2008; Hodgson, 2006; Salter et al., 2003).

The findings indicated that occupants' satisfaction with the overall facility influenced by their satisfaction with sustainable IEQ significantly influenced their overall work performance, and that these two variables jointly influenced occupants' sustainability ethic. All significant relations among variables showed positive coefficient values that meant when occupants were satisfied with furnishings, views conditions, lighting conditions, and acoustics and privacy conditions of their workstations, their satisfaction level with the overall facility increased; when they were satisfied with furnishings and acoustics and privacy conditions, their perceived work performance was enhanced; and under such circumstances they agreed that sustainability or sustainable design was important to them. In fact, most occupants from three buildings of this study moved from prior non-sustainable buildings to current sustainable buildings. Thus, most of them had working experiences in differing types of buildings – sustainable and non-sustainable. Therefore, their experiences of increased satisfaction levels and enhanced work performance in sustainably designed buildings, compared to experiences in non-sustainable buildings, might influence their sustainability ethic.

As mentioned above, the effect of occupants' satisfaction with IEQ criteria on the satisfaction level with the overall facility and their enhanced or hindered work performance has been separately investigated by prior researchers. However, most studies have not demonstrated the "simultaneous" relationships among these variables. Further, sustainability ethic has not been fully investigated itself, and not as it related to other variables in prior studies. In fact, comparison with other studies may not be appropriate because this study was conducted in different settings with different survey items than other studies.

The importance of this study is that the findings extended the scope of the research through the development of a hypothesized model, extraction of IEQ factors, and as a test for a good-fit model showing the simultaneous relationships among various sustainable IEQ criteria, overall facility satisfaction, perceived work performance, and importance of sustainable design to occupants. Another important finding was that as a significant component of sustainable IEQ, furnishings criterion that has been relatively uninvestigated in other research could play an important role in occupants' increased satisfaction level with their work environments and their enhanced work performance. This could in turn influence their recognition of the importance of the sustainable design. Most importantly, this study found that there is a connection between occupants' sustainability ethic and their satisfaction with the overall facility and their perceived work performance. If occupants are working in sustainable environments, that may influence their belief in sustainability, and in turn, occupants may expect better working environments from facility owners in terms of sustainable interiors. Therefore, the developed and tested model of this study presents a valuable original tool with which to look at the continuous or evolutionary process among occupants' satisfaction with the sustainable design, its effect on their work performance, and their sustainability ethic. Based on the findings of this study, a revision model including these feedback loops can be suggested to help identify additional hypotheses (see Figure 13). This revised model effectively fits with the human ecosystem model that shows bi-directional interactions between humans and environments, as shown in Figure 5.

Figure 13. The revised model to identify additional hypotheses and to fit with the human ecosystem model, based on findings of this study.

Implications

Sustainable IEQ criteria are the most important components in designing and constructing office buildings focused on improving occupants' quality of life in work environments. A number of studies have found that sustainably designed buildings directly influenced occupants' satisfaction level with their workplace and overall facility environment as well as their work performance. Under these circumstances, this study makes both academic and practical contributions. First, while previous studies related to sustainable IEQ criteria and occupants' satisfaction and work performance have only suggested the one-path relationship between variables, this study could provide a comprehensive model showing more complex relationships between occupants and physical work environments. Simultaneous relationships among variables may reflect the real world's complexity. The relationships between two situations could be affected by other situations, and as such, investigating simultaneous relationships among all possible situations can produce more robust evidence. Therefore, this study can contribute future research to investigate the simultaneous relationships with respect to the positive or negative effect of sustainable IEQ features on occupants of these environments. Further, the developed and tested model can be used in future studies as a basic conceptual model for comparison to the newly developed models using different data sets. Moreover, this model itself can be used to evaluate various sustainable buildings and to compare which specific IEQ factors influence occupants' satisfaction, work performance, and sustainability ethic in those buildings. Finally, as shown in Figure 13, the developed and tested model composed of simultaneous relationships could provide an improved application of the human ecosystem model including environments, human organism, and their interactions.

In addition, five IEQ factors, derived from various IEQ attributes addressed in B3-SPOES questionnaire, can be used for development of occupant survey questionnaire by newly identifying the combination of IEQ attributes with reasonable level of internal consistency reliability and discriminant validity. For example, while most occupant survey questionnaires separated personal control criterion from other IEQ criteria, the findings of this study revealed the evidence that when occupants perceived their indoor environment features, such as lighting conditions and thermal conditions, they also considered personal control over these conditions. These findings will contribute to a future, large research database and to assist in the revision of current occupant survey questionnaires related to IEQ of sustainable buildings. Other items related to IEQ that represent the exact B3-MSBG can be added to the new version of the questionnaire. This new version of the questionnaire can be used to test the model of this study by collecting a much larger sample.

Therefore, current and future interior designers should consider that IEQ criteria together contribute to occupants' satisfaction and work performance, when designing sustainable interior environments. Further, the findings and developed model of this study can help interior designers who will plan and design new settings to understand which design features of interior environments positively affect the occupants' satisfaction level and their work performance and how those features are interrelated and influence occupants simultaneously. When an occupant IEQ survey is conducted in a single building, this tested conceptual model can act as a decision-making and diagnostic tool. The upgraded SPOES questionnaire can also be used for interior designers and business owners to recognize which environmental features need to be improved for occupants' quality of life. Finally, as found in this study, occupants who were satisfied with the site, building, and interior environments and perceived their enhanced work performance agreed that sustainability or sustainable design was important to them (sustainability ethic). This finding supports the importance of interior designers' understanding and use of sustainable design for interior environments.

Future Research

This study developed a model showing significant, simultaneous relationships among occupants' satisfaction with IEQ, satisfaction with the overall facility, overall work performance, and sustainability ethic. The model can be modified based on the findings of this study in the future research. First, this study found that occupants' satisfaction with the overall facility and their work performance influence their sustainability ethic. Therefore, future research can hypothesize that occupants' sustainability ethic also influences their satisfaction and work performance. In other words, if occupants agree that sustainability or sustainable design is important to them, their satisfaction level with IEQ features and overall environments would be higher and as a result, their work performance would be more enhanced, compared to occupants who do not agree on the importance of sustainable design. Second, future research can develop a model including direct paths from occupants' satisfaction with IEQ criteria to their sustainability ethic because occupants who are satisfied or dissatisfied with specific IEQ criterion may agree or disagree that sustainability or sustainable design is important to them.

This study also contributed in developing and validating IEQ factors extracted from various IEQ attributes, using factor analysis. According to the findings of this study, personal control criterion should be incorporated into other IEQ criteria, and acoustics and privacy conditions were closely related to each other. Therefore, future research can verify these factors or find other factor loading patterns using different datasets from various settings.

Occupants of this study had different backgrounds – age, working hours, workstation types, etc. Therefore, these variables can influence the relationships addressed in the developed model. Among them, different workstation type can result in a different good-fit model including different significant paths among variables. Prior studies have explored whether there is a significant difference in occupants' satisfaction with IEQ and overall environments and their work performance by workstation type, such as private offices and cubicles with partitions (Field, 2008; Lee, 2010; Newsham, 2005; Veitch et al., 2003; 2007). According to these studies, occupants showed different satisfaction levels with some IEQ criteria. For example, occupants who are in cubicles can be dissatisfied with their workstation environments due to distractions from other people, lack of privacy, noise from equipment, poor air quality, uncomfortable temperatures, and poor ambient lighting. Of special note, a number of studies indicated that there were statistically significant differences in acoustic and privacy conditions between private offices and cubicles. Therefore, the influence of the workstation type on simultaneous relationships between sustainable IEQ features and occupants' satisfaction and work performance can be investigated in future research. Working as a moderator, different workstation types would lead to the development of a different model based on different work environments. Thus, interior designers would apply different design strategies to each workstation type to provide occupants with better quality of life by decreasing their dissatisfaction with their working environments as well as helping them to concentrate on their work.

Finally, future research can use multiple items to test sustainability ethic, work performance, and overall satisfaction, while acknowledging that this study used a single item for these variables. The current version of the SPOES questionnaire includes multiple items for these variables. A new model including more specific relationships between items and factors can be estimated using a structural equation modeling (SEM) statistical technique.

Conclusion

This study developed and tested a model showing simultaneous relationships among occupants' satisfaction with sustainable IEQ criteria, their satisfaction with the overall facility, their overall work performance, and their sustainability ethic. By providing a conceptual framework among variables, this study helped determine which specific IEQ criteria are significantly related to occupants' overall satisfaction and work performance that can influence their sustainability ethic. As a result, this study contributed to both academic and practice fields by providing various potential for the sustainable interior design field.

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APPENDIX A: ABBREVIATION LIST

AIA : The American Institute of Architects
ASHRAE : American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASID : American Society of Interior Designers
B3-MSBG : Buildings, Benchmarks, and Beyond
Minnesota Sustainable Building Guidelines
B3-SPOES : B3-Sustainable Post Occupancy Evaluation Survey
BREEAM : BRE Environmental Assessment Method
BSC : Building Science Corporation
CASBEE : Comprehensive Assessment System for Built Environment Efficiency
CBPD : Center for Building Performance and Diagnostics
CDC : Centers for Disease Control and Prevention
CSBR : Center for Sustainable Building Research
GBCA : Green Building Council of Australia
HKGBC : Hong Kong Green Building Council
IAQ-SFRB : Indoor Air Quality Scientific Findings Resource Bank
ICIEE : The International Center for Indoor Environment and Energy
IED : Indoor Environment Department
iiSBE : International Initiative for a Sustainable Built Environment
JaGBC : Japan GreenBuild Council
JSBC : Japan Sustainable Building Consortium
LEED : Leadership in Energy and Environmental Design
NCIDQ : National Council for Interior Design Qualification
NEAT : National Environmental Assessment Toolkit
NRCC : National Research Council Canada
POE : Post-occupancy evaluation
PRRES : Pacific Rim Real Estate Society
US EPA : United States Environmental Protection Agency
UCCP : University of California College Prep

UC : University of California
US DOE : United States Department of Energy
US EPA : United State Environment Protection Agency
US GSA : United States General Services Administration
USGBC : United States Green Building Council
WBCSD : World Business Council for Sustainable Development
WBDG : Whole Building Design Guide

APPENDIX B: COMMON QUESTIONS FOR THE STUDY

For each statement below (1-20), identify your level of satisfaction where 1 is Very Dissatisfied and 7 is Very Satisfied.

1. Temperature

Very Dissatisfied 2 3 4 5 6 Very Satisfied

2. Air velocity

Very Dissatisfied 2 3 4 5 6 Very Satisfied

3. Humidity

Very Dissatisfied 2 3 4 5 6 Very Satisfied

4. Level of sound privacy

Very Dissatisfied 2 3 4 5 6 Very Satisfied

5. Background noises

Very Dissatisfied 2 3 4 5 6 Very Satisfied

6. Ability to understand desired sounds

Very Dissatisfied 2 3 4 5 6 Very Satisfied

7. Amount of electric lighting

Very Dissatisfied 2 3 4 5 6 Very Satisfied

8. Visual comfort of the lighting

Very Dissatisfied 2 3 4 5 6 Very Satisfied

9. Amount of daylighting

Very Dissatisfied 2 3 4 5 6 Very Satisfied

10. Extent to which you have an external window view when standing

Very Dissatisfied 2 3 4 5 6 Very Satisfied

11. Extent to which you have an external window view when seated

Very Dissatisfied 2 3 4 5 6 Very Satisfied

12. Extent to which you can control the desk (task) light

Very Dissatisfied 2 3 4 5 6 Very Satisfied

13. Ability to control or block the sunlight

Very Dissatisfied 2 3 4 5 6 Very Satisfied

14. Automatic controls that change electric lighting in response to daylighting available

Very Dissatisfied 2 3 4 5 6 Very Satisfied

15. Extent to which you can control the adjustable floor air vent (diffuser)

Very Dissatisfied 2 3 4 5 6 Very Satisfied

16. Comfort of your workstation furnishing

Very Dissatisfied 2 3 4 5 6 Very Satisfied

17. Ability to adjust your furniture to meet your needs

Very Dissatisfied 2 3 4 5 6 Very Satisfied

18. Amount of space available for your individual storage

Very Dissatisfied 2 3 4 5 6 Very Satisfied

19. Amount of space available for your individual work

Very Dissatisfied 2 3 4 5 6 Very Satisfied

20. Level of visual privacy
Very Dissatisfied 2 3 4 5 6 Very Satisfied

21. The overall satisfaction with the facility (site, building, and interiors):

Very Dissatisfied 2 3 4 5 6 Very Satisfied

22. The overall effect of the facility on your work performance:

Hinders Work Performance 2 3 4 5 6 Enhances Work Performance

23. Overall, the importance of sustainable design to you:

Not Important 2 3 4 5 6 Very Important