The impact of indoor environmental quality (IEQ) on patients' health and comfort in Nigeria

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Abstract

Purpose – The most challenging aspect of hospital design is the creation of an environment that heals rather than the one acting as a barrier to healing. Much has not been done in the aspect of ascertaining the level of impact "indoor environmental quality (IEQ)" has on building occupants in healthcare facilities. Therefore, this study aims to investigate the impact of IEQ on patients' health and well-being.

Design/methodology/approach – The study investigates the hypothesis that four IEQ parameters (thermal quality, acoustic quality, lighting quality and indoor air quality [IAQ]) influence patients' overall satisfaction with the performance of hospital wards. Questionnaire responses were sought from the patients as the main occupants of hospital ward buildings. A proposed weighted structural model for IEQ establishing the relationship between IEQ parameters, patients' overall satisfaction and patients' health outcome was analyzed using structural equation modeling (SEM).

Findings – The most influential IEQ parameters on patients' overall satisfaction with IEQ in hospital wards are thermal quality, IAQ and lighting quality. The findings from this study revealed that the parameters of influence on patients' overall satisfaction and health outcomes vary with hospital ward orientation and design configuration.

Originality/value – This study has explored the need for the integration of all factors of IEQ at the building design stage towards providing a hospital environmental setting that reflects occupants' requirements and expectations and also promotes patient healing processes. This should be the focus of architects and healthcare managers and providers.

Keywords Structural equation modeling, Indoor environmental quality, IEQ parameters, Patients' health, Patients' overall satisfaction

Paper type Research paper

1. Introduction

The purpose of a building as a shelter is to protect humans from the effects of environmental factors in the ecosystem. The provision of this protection from external aggressors by building components, on the other hand, has resulted in an indoor environment that is detrimental to human activities, comfort and welfare. The unfavorable impact of this indoor environment on a patient in a hospital setting could be severe, leading to further health difficulties. As a result, the indoor environment of a hospital facility should be constructed to provide a therapeutic environment that promotes healing, well-being and productivity among the occupants.

Human beings are surrounded by an environment at all times; thus, maintaining their well-being and comfort is a major task (Parsons, 2013). In order to achieve the need for certification as "green" for a sustainable environment, indoor environmental quality (IEQ) performance in buildings must be measured consistently. This evaluation, which defines a building's success or performance, is heavily influenced by the tenants' opinions, especially when the building's indoor atmosphere provides them with comfort and improves their productivity (Frontczak *et al.*, 2012a, b). As a result, providing an indoor environment that improves occupant health and well-being, contentment and performance should be prioritized in building design and environmental sustainability (Fisk, 2000). Today, the assertion of Fisk may be seen in a variety of research on building IEQ, which are concerned

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with the welfare, contentment and task performance of building occupants (Bailey *et al.*, 2013; Cao *et al.*, 2012; Frontczak *et al.*, 2012a, b).

The protection of individuals from the negative effects of the environment was given a lot of emphasis in the early days of nursing practice (Guenther and Vittori, 2007). The presence of a healthy building environment has a substantial impact on patient health and well-being. In the same way, a setting that encourages restorative processes benefits both patients and hospital workers. For example, according to a study by Zborowsky and Kreitzer (2008), a hospital building with a high IEQ rating attracts, maintains and enhances patient healing processes and staff job efficiency. Some scholarly works (Chau *et al.*, 2007; Roulet *et al.*, 2006) have also demonstrated that current hypothetical thoughts and practical data about present building technologies and processes can impact IEQ in a way that can improve building occupants' well-being and efficiency. Furthermore, Apte *et al.* (2000) found that building design indicators and the quality of the interior air environment had a substantial impact on the rates of allergy, asthma symptoms, sick building syndrome (SBS) and worker performance. As a result, the provision of a friendly and acceptable environment for all building inhabitants is critical for a hospital facility to fulfill its duty as a healing environment (Guenther and Gillmore Hall, 2007). The design and construction of hospital buildings' indoor environments should be such that the requirements for comfort are well articulated and improved. This indoor requirement such as noise level, temperature, cleanliness, sound privacy, air quality and humidity have been ascertained to have received the highest priority for improvement in a study carried out by Agyekum *et al.* (2021). However, the habitability of such structures is determined by how they are evaluated. Furthermore, the extent to which environmental friendliness is achieved in hospital buildings can only be measured through performance assessment of the environmental variables and occupants' satisfaction with the building environment. As a result, the goal of this study is to find out how IEQ affects patients' health and well-being. The major goal is to create healthy hospital wards with increased indoor environmental comfort and less negative environmental effects on patients.

2. IEQ and patients' well-being

Evidence – As a result of studies proving linkages between the environment and people's health and wellbeing, evidence-based and patient-centered design of hospital buildings has been progressed (Mourshed and Zhao, 2012). The most difficult component of hospital design is creating an environment that promotes healing rather than hindering it. Much has not been done in terms of determining the influence of "environmental stresses" on healthcare facility inhabitants. This is because other areas of green building design, such as the impact of the environment on building occupants' health and comfort, have garnered more attention as a concern for sustainable development (Smith and Pitt, 2011). Stress has been linked to a poor interior environment in hospitals (Zborowsky and Kreitzer, 2008), which has an impact on patient recovery as well as staff productivity (Andrade *et al.*, 2012). As a result, a lousy indoor environment has a negative impact on a building's occupants' physical and mental health (Mahbob *et al.*, 2011; Sadek and Nofal, 2013). However, research from Andrade *et al.* (2012), Chaudhury *et al.* (2009) and Dijkstra *et al.* (2006) suggests that effective hospital environment design can improve patient care and treatment outcomes while minimizing medical errors and waste.

The nature of the indoor environment in hospital buildings has been found to affect patient healing processes (Chaudhury *et al.*, 2009; Choi *et al.*, 2012; Dijkstra *et al.*, 2006; Ghazali and Abbas, 2012; Huisman *et al.*, 2012), as well as staff well-being and task performance (Chaudhury *et al.*, 2009; Choi *et al.*, 2012; Al-Ahmadi, 2009; Andrade *et al.*, 2012; Janakiraman *et al.*, 2011). In a hospital setting, it has also been discovered that the temperature and air quality of the facility have a major impact on the residents (Hwang *et al.*, 2007). Infections with a high risk factor could be contracted as a result of the presence of indoor air pollutants in a hospital environment. As a result, Salonen *et al.* (2013) said that the resulting risk factor owing to the presence of an air contaminant could result in the death of a patient whose body immunity has been much decreased. Ramaswamy *et al.* (2010) did a study that revealed the impact of air pollutants in hospital facilities where patients were infected with diseases other than those for which they were being treated. As a result, ensuring that the indoor air quality (IAQ) is free of contaminants and dangerous substances requires controlling the flow of air inside the hospital environment and providing efficient ventilation (Ramaswamy *et al.*, 2010). There will not be enough air to dilute the contaminants created in a space where the ventilation rate is low. It was also revealed that air pollutants in a building's internal environment had an impact on the residents' reasoning, work efficiency and behavior (Clements-croome, 2008; Tang and Wan, 2011).

Different ways are being attempted by both designers and healthcare managers in order to ameliorate the evident effects of IEQ for improved performance in order to provide an atmosphere that is appealing to building occupants. Building occupants perceive a number of environmental elements to be factors that influence IEQ (Andrade *et al.*, 2012). These sources of effect might not be the same because people's psychological and emotional states vary.

The influence of the indoor environment on patient acceptance of hospital building IEQ can be measured in two ways: mental perception and physical complaints (Sadek and Nofal, 2013). Worries about illness, fear of medical procedures, stress and anxiety, the sterile hospital environment and other mental reactions, while physical complaints include irritation of the eyes, nose and throat, nausea and fatigue, dizziness and skin irritation, poor temperature, lack of fresh air, unpleasant odor and other physical complaints. The experience of thermal comfort within a building space is affected by human activities and clothes. It has also been demonstrated that a building tenant who has control over his environment will always feel thermally comfortable (Khodakarami and Knight, 2007). As a result, the design of hospital buildings should allow for personal management in reaction to changes in environmental quality. Thermal quality has played a significant part in ensuring a pleasant and healthy hospital environment for patients (Al-Harbi, 2005).

Researchers have paid less attention to sound or noise pollution in hospital facilities, despite the fact that it has a significant influence on patients (Hamillton and Nyberg, 2013) (Sadek and Nofal, 2013). In a hospital, sound quality has an impact on both patient recovery and staff productivity. In the hospital building environment, there are a variety of sound sources that might irritate and injure occupants, particularly patients. Activities and internal services are the most common sources of noise in hospitals. Unwanted sound can also enter an indoor location from an external source, such as a mechanical source, or through internal hospital barriers and walls (Dascalaki *et al.*, 2009; Salonen *et al.*, 2013). Busch-Vishniac *et al.* (2005) discovered that the sound level in the John Hopkins Hospital in the USA was on average 20dBA higher than the World Health Organization (WHO)'s recommended threshold, which is harmful to both patients and hospital workers.

The hospital building, unlike other types of structures, is considered noise sensitive (Luzzi *et al.*, 2008). Communication between patient care team members may be difficult if the sound level in a hospital building exceeds the appropriate comfort level, unless voices are raised (Busch-Vishniac *et al.*, 2005). As a result, the level of discomfort caused by noise in a hospital setting necessitates effective sound quality design and management (Blomkvist *et al.*, 2005; Ulrich *et al.*, 2008). Similarly, creating a comfortable acoustic environment in hospital facilities can improve occupant safety, health, healing and well-being, as well as reduce medical errors when sound privacy is maintained (FGI, 2010). This necessitates a redesign of design methods and material selection by design professionals in order to fulfill the needs of tenants in hospital buildings.

In determining the perceived performance of the IEQ, the occupant of a building for whom the indoor environment is intended must be taken into account. As a result, the hospital environment can be used to promote satisfaction and a healthy atmosphere for all building inhabitants (Andrade *et al.*, 2012). Similarly, the integration of all IEQ components throughout the design stage of hospital buildings is critical to achieving improved IEQ. As a result, architects, healthcare administrators and clinicians should work on creating a hospital environment that represents the needs and expectations of its occupants while also promoting patient healing processes. All four IEQ measures are clearly impacting factors in the hospital setting. However, it is necessary to determine which IEQ criteria are most closely associated to the indoor environment of hospital wards in terms of supporting patients' health and well-being.

2.1 Hypothesis

The impact of IEQ criteria on building occupants has been studied in various ways (Fabian *et al.*, 2012; Fabian *et al.*, 2014; Frontczak *et al.*, 2012a; Ramaswamy *et al.*, 2010; Salleh *et al.*, 2011; Stauss and Kumar, 2002). The current study, on the other hand, looks into the possibility that four IEQ parameters (thermal quality, auditory quality, lighting quality and IAQ) influence patients' overall satisfaction with hospital ward performance. The research provides a weighted structural model for IEQ that establishes a link between IEQ parameters, patient satisfaction and health outcomes. The following hypothesis is used to attain the goal:

(1) Hypothesis one: The IEQ criteria of the ward buildings have an impact on patients' overall satisfaction with their hospital wards.

(2) Hypothesis two: In hospital wards, patients' satisfaction with and perceptions of IEQ influenced their health outcomes.

(3) Hypothesis three: There is an association between IEQ values, overall patient satisfaction and patient health outcomes.

3. Methodology

The subjective assessment of occupants' perception of IEQ is based on their understanding or familiarity within the building, their sensation and/or perception of the indoor environmental variables. For an IEQ evaluation in hospital buildings to take into consideration the diversity and heterogeneity in occupancy views and perceptions as indicated by Turner and Krizek (2006), the questionnaire response was sought from the patients, as the main occupants in hospital wards. This survey is a combination of both transverse and longitudinal surveys. The same sample population of the case study hospitals was visited twice in a month. The study was carried out for a three-month period in order to investigate the short-term impacts of IEQ on patients' satisfaction with the hospital ward environment, caused by monthly variations in weather conditions. Subjective assessments of all the elements of IEQ are based on the satisfaction scale as published in BS EN ISO 28802 (British Standards Institution, 2012). To maximize data collecting efficiency, this study was conducted out at two selected case study hospitals located in Jos, Nigeria.

The sampling of the research location was based on deliberate sampling, picking a particular state as a representation of all the states in Nigeria, as the healthcare delivery structure is the same in all the states. Therefore, several considerations were made towards attaining the optimum sample size for this investigation. In addition, as structural equation modeling (SEM) is the statistical tool employed in reaching the major goal of this study, it is expedient to have a large sample of cases because of the sensitive nature of the instrument.

Hence, the respondents were recruited from two case study hospital ward buildings where both the longitudinal and transverse strategy of data collecting was applied. The same sample population of the case study hospitals were administered with the same questionnaire in three different months of April, May and June. The bed space capacity of the case study hospitals was in the ratio of 2:2.5 for the specialist hospital and teaching hospital correspondingly. A brief explanation of the architectural aspects of the case study hospital ward buildings is presented in Tables 1 and 2.

Using an online calculator (Creative Research Systems, n.d.), a sample size of 40 was computed for the 64 patient bed spaces available in the two ward buildings selected for this

Table 1. Summary of case study report on Plateau State Specialist Hospital

<table>
<tr><th>Hospital</th><th>Description</th></tr>
<tr><td>

Plateau Specialist Hospital
Location: Latitude 9°53’42.9”N and Longitude 8°53’02.2”E in the city centre
Orientation: Northeast-Southwest direction

Plate 1. Site location of Hospital Wards (Google Earth)

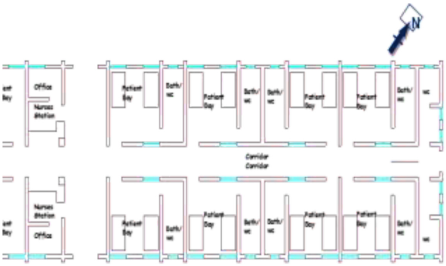

Plate 2. Typical Floor Plan of hospital ward building

Plate 3. Interior view of hospital ward building

Plate 4. Exterior view of hospital ward building

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General

A secondary healthcare facility run by the state government provides general and specialised medical services, residency in family medicine, and internship.

Bed capacity (Agwo & Wannang, 2014) is 176, staff strength of 633 and average patient inflow of 176/day.The ward buildings under study have a bed capacity of 64 (32 bed spaces each), with ward buildings partitioned into eight (8) single rooms accomadating a maximum of two (2) inpatients.

Architectural features:

Space organisation: corridor/continental form (James & Latten-Brown, 1986)

The plan configuration of the hospital wards has eight (16) units of solid partitioned internal walls accommodating two bed-spaces each. The partitioned ward room units are accessed through a corridor that separates them along two axes. Each of the ward room units is installed with two 1200mm x 1200mm louvres glass windows on the same wall façade. The window to wall ratio (WWR) on the fenestration façade is 15%, which is less than the optimum recommended by Zain-Ahmed et al. (2002). The windows have curtains which were installed for shading.

The ward buildings are naturally ventilated with windows and artificially with electrical ceilings. A walkthrough observation of the hospital buildings revealed a lack of proper ventilation and lighting. Also, drain pipe leakages and fittings breakdowns were observed. A typical floor plan and pictorial views of the specialist hospital are shown in Plate 2 and Plate 4.

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Table 2.
Summary of case study report on Jos University Teaching Hospital

<table>
<tr><th>Hospital</th><th>Description</th></tr>
<tr><td>

Jos University Teaching Hospital

Location: Latitude 9°54′27.5″N and Longitude 8°57′37.5″E, 14.3km away from the city-centre.

Orientation: Northwest and Southeast

Plate 5. Site location of JUTH (google map)

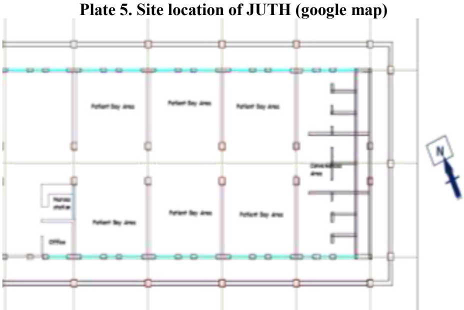

Plate 6. Exterior Views of Teaching Hospital Complex

Plate 7. Interior Views of Teaching Hospital Complex

Plate 8. Exterior Views of Teaching Hospital Complex

</td><td>

General

The facility is a tertiary hospital ran by the Federal Government that has a 620 bed-space capacity providing both inpatient and outpatient services, as well as medical personnel training and research. It is a two-storey building complex that houses all departments, offices, research laboratories, and instructional classrooms. The selected ward buildings in this hospital are located on the first and second floors of the complex.

Architectural Features:

The hospital complex was designed by InterState Architects Limited in the late 1970s with an initial size of 320 beds. The hospital layout was designed to expand to a 1000-bed teaching hospital at the appropriate time in the future. The first phase of construction work of the complex was completed in 2006. The ward buildings are both naturally and mechanically ventilated with electrical ceiling fans and also with split-level air-conditioning systems which are often not in use. This facility has three sources of power supply which enable uninterrupted electricity supply to the buildings. The orientation of the building allows for maximum utilization of daylighting. The hospital's space organization is the open-Nightingale type.

The hospital wards' spatial configurations are the multi-bed bays segmented into three. This provides the nurses with direct observation of patients but at the expense of patients' privacy. The facades and fenestration design of the wards were installed with glazed aluminium panelled windows on both axis facing Northeast and Southwest with a window to wall ratio (WWR) of about 50%. Also provided are top daylight windows for deeper penetration of light into the hospital ward. The glazing on the windows is double-pane clear glass used on aluminium panels. Plate 6 to Plate 8. Show a sketch of the hospital ward floor plan, views, and three-dimensional elevations of the hospital ward building.

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study in the specialist hospital. Because the bed space capacity ratio in the two hospitals is 2:2.5, a sample size of 60 patients was picked for the teaching hospital. For each month, a total of 40 and 60 samples were taken from the specialist and teaching hospitals, respectively. The transversal strategy to data collecting allowed for the same amount of surveys to be administered in each institution for three months. Because some patients were discharged from the hospital, the questionnaire was not necessarily given to the same patient in each of the months studied. Each of the case study hospitals received 120 samples in the specialist hospital and 150 samples in the teaching hospital. These two groups account for 44.4 and 55.6% of the entire sample population, respectively.

3.1 Data analysis

The relationship between patients' health outcomes, satisfaction and IEQ criteria has been discovered in studies on IEQ in hospital buildings. To understand the concept of this relationship and the predictive power of the variables involved, SEM techniques are used. SEM is a statistical tool that uses various models to depict relationships between measured variables as a theoretical quantitative test of defined concepts. SEM is a multivariate data analysis tool that permits the simultaneous investigation of the correlation among observable variables of a certain idea. SEM, according to Kline (2005), is a collection of related processes rather than a single statistical method. It offers a comprehensive method for quantifying and testing theories and concepts that is based on a confirmatory approach.

Because of their ability to analyze the interrelationship among IEQ parameters in hospital wards, which influence both patients' overall satisfaction and health outcomes, SEM techniques were used in this study. The specified model (IEQ parameters, patient overall satisfaction and health outcome) is used to test the ability of the various constructs (IEQ parameters, patient overall satisfaction and health outcome) to account for variations in the study data's measured (observed) and unobserved variables. The SEM was adopted as a tool for analysis because of its capacity to examine both influences and responses together. The construction of theoretical models of IEQ performance and overall occupants' satisfaction is based on SEM employing Analysis of Moment Structure (AMOS).

4. Results and discussion

4.1 Subjective patient survey

Patients' perceptions were measured subjectively using a questionnaire survey on two days each month for each of the case study hospitals. The patients in the two case study hospital wards were used to sample the survey population. Within the three-month period of the occupant survey, 268 of the administered questionnaires were collected from the two case study hospitals. Figure 1 depicts the distribution of the inhabitants' response rate in the various hospitals over the data collection period. Based on inpatient bed-space capacity, the

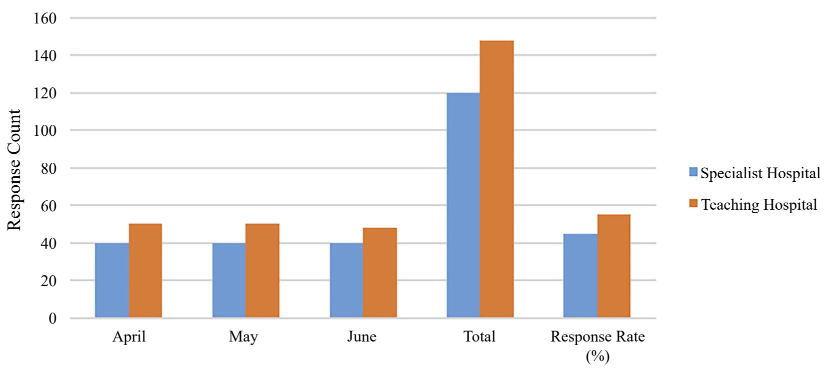

Figure 1.
Monthly distribution of patients' survey in the case study hospitals

number of surveys to be distributed in each hospital for each month was established. Only 268 of the 270 questionnaires distributed were entirely completed, accounting for around 99.3% of the total answer predicted. The specialist hospital had a response rate of 44.8%, while the teaching hospital had a response rate of 55.2%.

4.2 Overall patient response evaluation on indoor environmental quality (IEQ) in the hospital ward buildings

The results of tenants' perceptions of overall satisfaction with and perceptions of IEQ parameter performance in hospital buildings are reported in this section. The occupiers' satisfaction level was determined using five IEQ criteria, as indicated in Table 3. The end result is a summary of all of the patients' total parceled replies to each of the variables in the case study hospital wards. The average for the measurement period is represented by the parceled responses (April, May and June).

4.3 Statistical analysis for IEQ impact on overall satisfaction and health outcome

To understand the relationship between the IEQ parameters (thermal quality, acoustic quality, lighting quality and IAQ) and patients' overall satisfaction and health outcome, correlation and multiple linear regression analysis were performed on the subjectively measured data in each of the hospital wards. The relationship between IEQ parameters and patients' overall satisfaction and health outcomes was established for the two different case study hospitals based on their orientation and design configuration, as one of the goals of this study is to learn how hospital ward design features can affect IEQ. The results from the monthly polled patients were totaled together for correlation and regression analysis.

The AMOS computer software output was used to calculate the correlation and regression estimates rather than using the analytical hierarchy process (AHP) technique to calculate the relative weight of each parameter as adopted in a study by Eweda *et al.* (2021). The association between IEQ parameters and overall happiness and health outcomes was defined using SEM, which is based on the AMOS graphic output for estimation and analysis. The values of coefficients that describe the level of correlation and regression of the relationship in the selected model structure are shown in the AMOS graphic output estimates. The degree (magnitude) and direction of the relationship between two variables are represented by correlation coefficients (Narid, 2005). The values of the correlation and regression coefficients range from +1 to −1. A negative correlation or regression indicates that as one variable's features grow, the other variable's attributes decrease in the relationship. The coefficient value determines the amount or strength of this relationship.

In a separate investigation, Nimlyat *et al.* (2017) used exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) on the subjective surveyed data to establish the reliability and validity of the measured variables of IEQ parameters as the independent variables in this study. The association between the distinct indicator variables of the

Table 3. Average percentage ratings and response distributions in occupants' satisfaction with IEQ

Variable	Specialist hospital (NE–SW orientation)			Teaching hospital (NW–SE orientation)		
	% Dissatisfied	Neutral	% Satisfied	% Dissatisfied	Neutral	% Satisfied
Thermal quality	28.3	10.0	61.7	15.5	14.2	70.3
Acoustic quality	35.8	15.8	48.3	24.3	17.6	58.1
Lighting quality	15.8	5.8	78.3	2.7	4.1	93.2
Indoor air quality	33.3	36.7	30.0	24.4	27.0	48.6
Overall hospital ward	30.0	25.0	45.0	6.8	17.4	75.8

multiple IEQ parameters was established using EFA, while the convergent validity of the indicator variables measuring each IEQ parameter construct was determined using CFA.

The IEQ measurement construct model was put through a discriminant validity test by Nimlyat *et al.* (2017) to see if the four-factor parameters measure distinct constructs as indirect measures of IEQ. The correlation between the individual exogenous factor constructs was less than 0.85, indicating that the interplay of the four-factor characteristics as predictors of IEQ performance in hospital ward buildings had discriminant validity. They developed an IEQ performance assessment model design for hospital buildings, which comprises four-factor parameters (thermal, acoustic, lighting and IAQ) with a composite reliability (CR) better than 0.60 and an average variance extracted (AVE) greater than 0.50. Figure 2 depicts Nimlyat *et al.* (2017) proposed IEQ performance measuring construct model.

4.4 Relationship between indoor environmental quality (IEQ) parameters, patients' overall satisfaction and patients' health outcome

Using survey data, this study investigated the association between IEQ parameters and patient satisfaction with hospital ward architecture, as well as patient health outcomes. The level of patient happiness with their hospital ward buildings is a dependent variable that was measured by determining the degree of patient satisfaction with their hospital ward structures. Patient health result is a dependent unobserved latent variable that was measured

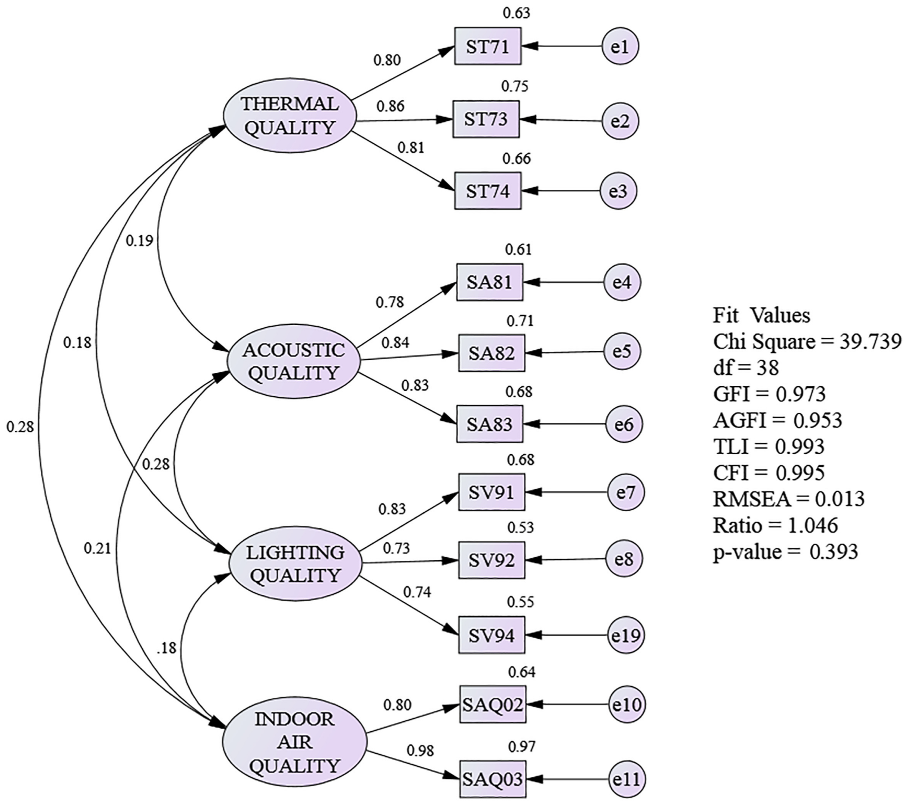

Figure 2.
Discriminant validity of IEQ performance (*Standardized*)

by the level of influence for each of the four indicators on patient health, as well as the length of stay of the patient. The following are the patient health outcome variables:

(1) INF11 – The influence of thermal quality on patients' health and well-being

(2) INF12 – The influence of acoustic quality on patients' health and well-being

(3) INF13 – The influence of lighting quality on patients' health and well-being

(4) INF14 – The influence of IAQ on patients' health and well-being

(5) LSTAY – Patients' length of stay.

This section examines the association between IEQ characteristics and the orientations of hospital wards. The association between IEQ parameters, patient overall satisfaction and patient health outcome is investigated using a structural regression model (SRM). The independent variables in the structural equation model are the four IEQ parameters confirmed using CFA, the dependent variables are patients' subjective happiness with their hospital ward buildings and the health result is also a dependent variable.

4.4.1 Correlation and multiple regression analysis of IEQ impact on patients' overall satisfaction and health outcome. In the distinct case study hospital wards with particular variances in their architectural elements, a SRM utilizing SEM was utilized to predict how perception of IEQ performance evaluation is changed by IEQ parameter stimulants (orientation and design configuration). The dependent (endogenous) variables are overall patient satisfaction and patient health outcome, while the independent (exogenous) variables are the four factor parameters of IEQ.

A two-tailed significance level was used to assess a combination of each independent variable (IEQ parameters) in the SRM (0.01 and 0.05). The SRM does not include independent variables that do not meet any of the two-tailed significance levels. Before accepting a model for correlation and regression analysis, it must first be verified for its fit to the data. Chi-square (X^2), degree of freedom (df), ratio (X^2/df), p-value, comparative fit index (CFI), goodness-of-fit index (GFI), Tucker-Lewis index (TLI) and root mean square error of approximation (RMSEA) are the fit indices used to determine the model's goodness-of-fit. Unlike multivariate linear regression analysis, which tests the acceptability of a linear relationship in a regression model using only a significance level of 0.05, the SRM takes into account other fit indices, such as those mentioned above, which measure how well the data fit into the defined model construct (Kline, 2005).

For each of the two case study hospital ward buildings, two models were defined. Figures 3 and 4 show the output of the specified models and estimated fit indices. Figures 3 and 4 show the goodness-of-fit indices for specialist hospital wards (Chi-square = 134.644, df = 106, ratio = 1.271, p = 0.031, GFI = 0.961, TLI = 0.980, CFI = 0.985 and RMSEA = 0.026) and teaching hospital wards (Chi-square = 179.644, df = 106, ratio = 1.695, p. As a result, for correlation and regression analysis and estimations, the provided models are accepted.

4.4.1.1 Correlation analysis in the specialist hospital wards (NE–SW orientation). All of the patient replies to all of the data obtained from specialty hospital wards during the measurement period were combined and examined (sample size 120). The strength (magnitude) and direction of the linear relationship between the variables in the model are shown by the signs and values on the arrows denoting those relationships. At the 0.01 and 0.05 levels, the level of significance employed to assess the variables' correlation is two-tailed significant. Table 4 shows the correlation results from the AMOS 22 output tool analysis of the SRM depicted in Figure 3.

Patient satisfaction with hospital wards had a substantial link with all four IEQ indicators, according to the findings. The correlation coefficient between patient satisfaction and

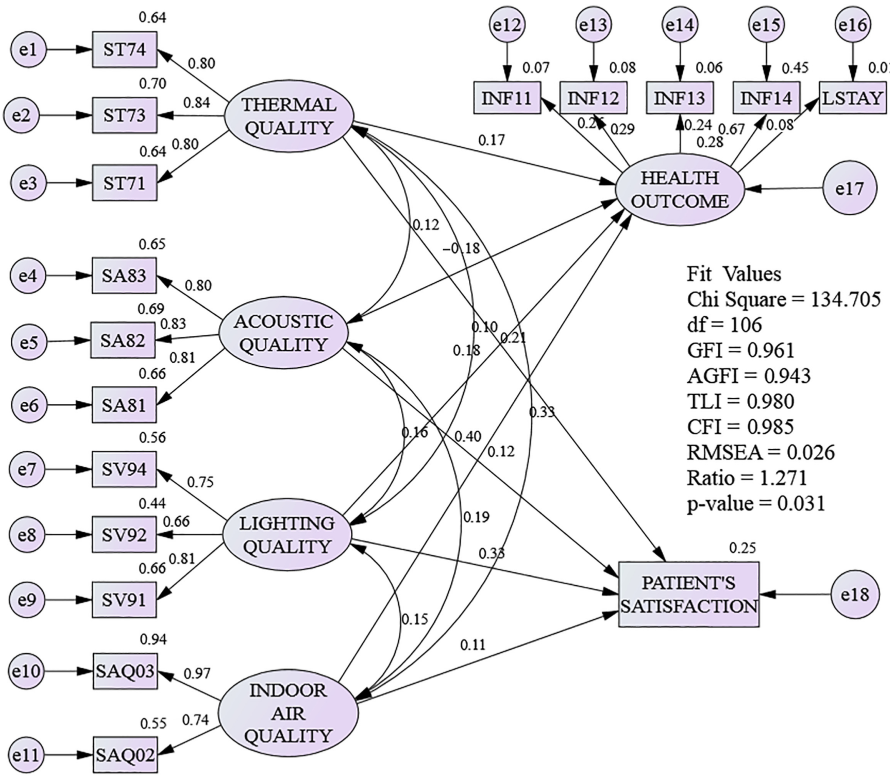

Figure 3.
Standardized structural regression model (SRM) of the relationship between IEQ parameters, patients' overall satisfaction and patients' health outcome (specialist hospital NE–SW orientation)

thermal quality is 0.299, while the correlation value between patient satisfaction and acoustic quality is 0.218. The illumination quality has a correlation coefficient of 0.389, while the IAQ has a correlation coefficient of 0.257. At the 0.01 level, all of these associations are significant. Because of the lack of cross ventilation and the hospital wards' northeast–southwest (NE–SW) direction, the level of association between patients' overall satisfaction with lighting and thermal quality is higher in specialist hospital wards. The correlation between total patient happiness and lighting quality has the greatest coefficient, indicating a strong relationship between the two. This means that patients in specialist hospital wards are sensitive to the quality of illumination in the ward's indoor area.

The correlation coefficient between thermal quality and lighting quality (0.099) is not significant at a 0.05 confidence level, according to the intercorrelation among the four IEQ indicators. Thermal quality (0.329, p 0.01) has a substantial relationship with IAQ. At the 0.05 level, the connection between temperature and auditory quality (0.119) is merely significant. Lighting and auditory quality both have a substantial connection with IAQ (0.152) and (0.185). The association between thermal quality and IAQ is the strongest among the IEQ metrics. The volume of air exchanged between the indoor and exterior spaces regulates both thermal quality and IAQ within a building space. With high temperatures and humidity, a building's inside environment becomes stuffy, resulting in poor IAQ. The relationship between thermal quality and lighting quality pleasure is meaningless.

Patients' health outcomes, on the other hand, exhibited a greater link with IAQ, with a significant correlation value of 0.449, which was higher than any other connection within the

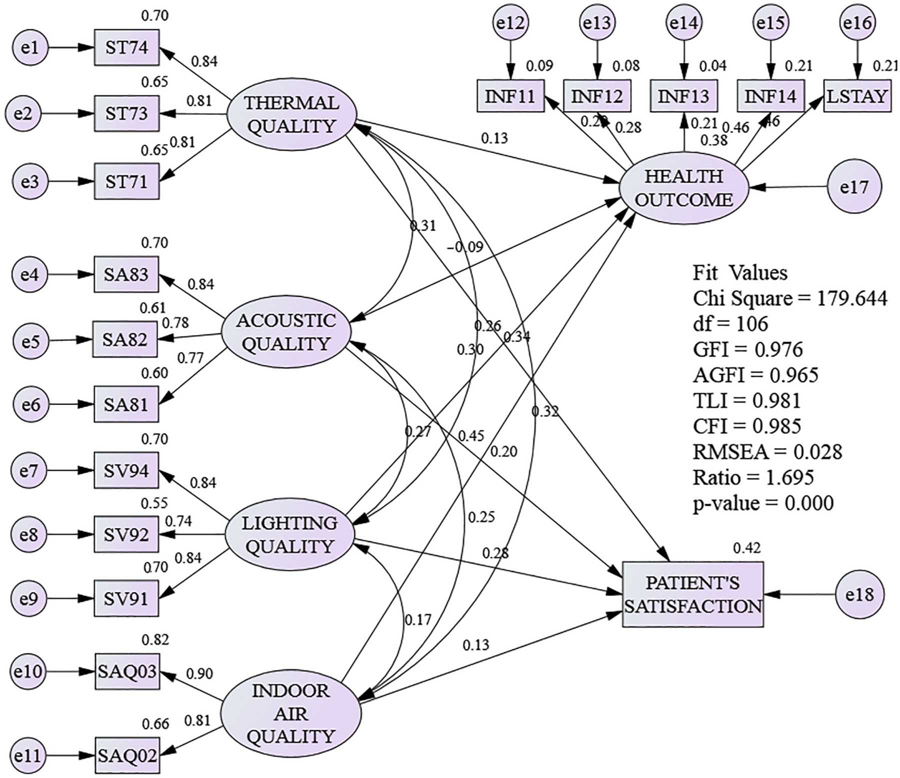

Figure 4.
Standardized structural regression model (SRM) of the relationship between IEQ parameters, patients' overall satisfaction and patients' health outcome (teaching hospital NW–SE orientation)

Table 4.
Correlation coefficients [specialist hospital: NE–SW orientation] (correlation between IEQ parameters, patients' overall satisfaction and patients' health outcome)

	Lighting quality	IAQ	Acoustic quality	Thermal quality	Health outcome	Patients' overall satisfaction
Lighting quality	1					
IAQ	0.152*	1				
Acoustic quality	0.157**	0.185**	1			
Thermal quality	0.099	0.329**	0.119*	1		
Health outcome	0.23*	0.449**	−0.057	0.298**	1	
Patients' overall satisfaction	0.389**	0.257**	0.218**	0.299**	0.185**	1

Note(s): *One-tail significance; **Two-tail significance

model construct. Patients in hospital wards have voiced discontent with scents and odors that have contributed to their dislike of the air quality. Their displeasure could have stemmed from the negative effects of IAQ on their health. This suggests that in the specialist hospital, patients' health outcomes were more susceptible to IAQ.

Patient's health result correlation coefficients for lighting, thermal and acoustic quality were 0.23, 0.298 and −0.057, respectively. The relationship between patient health outcomes and lighting quality is significant at the 0.05 level, while the relationship between patient health outcomes and thermal quality is significant at the 0.01 level. The fact that a patient's health outcome and acoustic quality have a negative correlation indicates that the link is based on how much one grows at the expense of the other. This connection, however, is insignificant. As a result, because the correlation coefficient is so near to zero, there is no meaningful association between patient health outcomes and acoustic quality. There is also a link between patient happiness with health results and their overall contentment with health outcomes, which has a correlation coefficient of 0.185 and is significant at the 0.01 level.

4.4.1.2 Correlation analysis in the teaching hospital wards (NW–SE orientation). Within the three-month survey period, the responses of patients in teaching hospital wards were evaluated to determine the correlation between factors (sample size is 148). The correlations were determined using a two-tailed threshold of significance (0.01 and 0.05). The IEQ parameters had substantial connections with the answer of patients' degree of satisfaction with their hospital wards (thermal, acoustic, lighting and IAQ). The coefficient of correlation between thermal quality satisfaction, 0.409 for acoustic quality satisfaction, 0.440 for lighting quality and 0.333 for IAQ satisfaction was 0.516 for thermal quality satisfaction, 0.409 for acoustic quality satisfaction, 0.440 for lighting quality and 0.333 for IAQ satisfaction. Table 5 shows that all of these correlations are significant at the 0.01 level (two-tailed).

In the teaching hospital wards, there was a stronger link between patients' overall satisfaction with the hospital wards and thermal quality. In the teaching hospital, patients' overall satisfaction with the hospital wards is more responsive to their health results than in the speciality hospital. Patients in these wards are more susceptible to temperature changes. In addition, the level of happiness patients have with their hospital wards is influenced by illumination quality. In the teaching hospital, patients' overall satisfaction with hospital wards had a stronger correlation with health outcomes (0.311), with a coefficient that is significant at the 0.01 level (two-tailed). As was the case at the specialist hospital, the relationship between patients' health outcomes and IEQ parameters revealed a larger correlation with IAQ. Patients' health outcomes had a correlation coefficient of 0.323 with thermal quality satisfaction and 0.383 with lighting quality, both of which are significant at the 0.01 level. The correlation coefficient for acoustic quality satisfaction, 0.139, is only significant at the 0.05 level. Despite the fact that the measured sound level in these hospital wards was outside of the permitted range for hospital wards, the structural equation model study of patients' perceptions revealed that patients' health outcomes are unaffected by their contentment with acoustic quality.

At the 0.01 level, the intercorrelation connection among the IEQ parameters in the teaching hospital wards is significant. The association between thermal quality satisfaction and IAQ (0.319) and acoustic quality satisfaction was greater (0.31). Lighting (0.27) and IAQ had a weaker connection with acoustic quality (0.249).

	Lighting quality	IAQ	Acoustic quality	Thermal quality	Health outcome	Patients' overall satisfaction
Lighting quality	1					
IAQ	0.172**	1				
Acoustic quality	0.27**	0.249**	1			
Thermal quality	0.26**	0.317**	0.31**	1		
Health outcome	0.383**	0.521**	0.139*	0.323**	1	
Patients' overall satisfaction	0.44**	0.333**	0.409**	0.516**	0.311**	1

Note(s): *One-tail significance; **Two-tail significance

Table 5. Correlation coefficients [teaching hospital: NW–SE orientation] (correlation between IEQ parameters, patients' overall satisfaction and patients' health outcome)

4.4.2 Regression analysis of IEQ impact on overall patients' satisfaction and health outcome. A correlation between two variables just hints at a possible relationship but does not prove causation. A SRM analysis was performed on the data obtained from the two case study hospital ward buildings in order to assess the causal effect of IEQ parameters on patients' overall happiness and health outcomes. The AMOS 22 computer software tool was used to anticipate how IEQ parameters affect or influence various variables relating to patients in hospital wards.

The dependent factors were the patient's overall happiness with their hospital wards and the patient's health outcome, whereas the independent variables were the IEQ parameters. Two prediction models (Figures 3 and 4) were created for specialist hospital wards and teaching hospital wards, respectively, based on patient responses to the surveyed factors. The two models were created to see how the orientation and design configuration of hospital ward buildings affect how IEQ parameters affect the evaluation model of patients' satisfaction with IEQ in hospital wards.

4.4.2.1 Regression analysis in the specialist hospital wards (NE–SW orientation). The specified model contained IEQ parameters as independent variables. A two-tailed significance threshold was used to identify the role of each variable in the model (0.01 and 0.05). The linear relationship's acceptability was also examined using 0.01 and 0.05 levels of significance in the regression structural model. Lighting quality, with a critical ratio (CR) of 5.913 (p 0.01), and thermal quality, with a CR value of 3.995 (p 0.01), were the stronger contributors to patients' overall satisfaction, according to the unstandardized regression weights estimates output of the SRM shown in Table 6. With CR values of 2.219 and 2.35, respectively, the amount of influence of both IAQ and acoustic quality was barely significant at the 0.05 level of confidence. The CR value indicates that each of the IEQ parameters contributing to the patient's overall happiness has a regression weights coefficient that is not zero (see Table 7).

The square multiple correlation (SMC), often known as the coefficient of determination for regression models, is shown in Table 8. This study implies that patient satisfaction and all four IEQ measures have a linear connection (thermal quality, acoustic quality, lighting quality and IAQ). This regression connection has a coefficient of determination (SMC) of only 0.25. This suggests that the impact of IEQ parameters on overall patient satisfaction accounts for 25% of the variance, which is statistically significant at the 0.01 level.

The patient's health outcome is the dependent variable in the second regression analysis in the given model, while the IEQ parameters remain the independent variables. Acoustic quality, lighting quality and IAQ all influenced patients' health outcomes considerably in this model, with critical ratios (CR) of 1.90 (p 0.01), 1.81 (p 0.05) and 3.104 (p 0.001), respectively.

Table 6. Linear regression weight (unstandardized) of relationship between IEQ parameters, patients' overall satisfaction, and patients' health outcome

Variable(s)			Unstandardized estimates Estimate	SE	CR	p
Health_outcome		Thermal_quality	0.051	0.027	1.898	0.056
Health_outcome	←	Acoustic_quality	−0.054	0.028	−1.929	0.003
Health_outcome	←	Lighting_quality	0.078	0.043	1.813	0.038
Health_outcome	←	Indoor_air_quality	0.111	0.036	3.104	0.001
Patients' overall satisfaction	←	Indoor_air_quality	0.109	0.049	2.219	0.027
Patients' overall satisfaction	←	Lighting_quality	0.497	0.084	5.913	0.002
Patients' overall satisfaction	←	Acoustic_quality	0.124	0.053	2.35	0.044
Patients' overall satisfaction	←	Thermal_quality	0.221	0.055	3.995	0.01

The quality of the heating and lighting did not have a substantial impact on the health of the patients. The presence of a negative sign on the acoustic quality critical ratio (CR) indicates that acoustic quality has a detrimental impact on a patient's health. Table 8 shows that the linear regression between a patient's health result and IEQ parameters has a coefficient of determination of 0.28. That is, the IEQ parameters account for 28% of the variation in a patient's health result.

4.4.2.2 Regression analysis in the teaching hospital wards (NW–SE orientation). In the analysis of the regression, the same SRM that was given for the special hospital's survey data was also specified for the teaching hospital's survey data, with the identical dependent and independent variables. Thermal quality, with a critical ratio (CR) of 10.14 (p 0.01), is the strongest contributor to the patient's overall satisfaction in the teaching hospital ward buildings, according to a regression model with the patient's overall satisfaction as the dependent variable and IEQ parameters as independent variables. Lighting quality comes in second with a CR-value of 8.67 (p 0.01). As shown in Tables 9 and 10, both acoustic quality and IAQ had a considerable impact on patients' overall satisfaction. According to the results of this model analysis, there was a linear link between patients' overall satisfaction with hospital wards and IEQ values. The coefficient of determination for this regression study was 0.42 (p 0.01), according to the SMC displayed in Table 11. The four IEQ variables account for around 42% of the variance in patients' overall satisfaction in hospital wards.

The patient's health outcome is the dependent variable in the second regression model, whereas IEQ parameters are the independent variables. The primary characteristics of influence on the patient's health outcome with a two-tailed significance of 0.01 are IAQ satisfaction with a CR value of 5.341 (p 0.01) and lighting quality with a CR value of 4.25 ($p = 0.001$). Thermal quality with a CR value of 2.12 influences a patient's health outcome, but only at a 0.05 level of significance. Acoustic quality has no substantial impact on patient health outcomes in teaching hospital wards, despite having a negative coefficient of the critical ratio (CR). Patients' health outcomes and IEQ parameters had a linear association with a coefficient of determination of 0.38 (p 0.01) (Table 11). This suggests that the IEQ parameters account for 38% of the variance in a patient's health result.

Variable(s)			Estimate	Standardized estimates Lower	Upper	p
Health_outcome	←	Thermal_quality	0.17	−0.024	0.389	0.087
Health_outcome	←	Acoustic_quality	−0.18	−0.32	−0.038	0.007
Health_outcome	←	Lighting_quality	0.18	−0.014	0.369	0.07
Health_outcome	←	Indoor_air_quality	0.399	0.153	0.578	0.004
Patients' overallsatisfaction	←	Indoor_air_quality	0.114	0.009	0.22	0.033
Patients' overall satisfaction	←	Lighting_quality	0.332	0.203	0.444	0.004
Patients' overall satisfaction	←	Acoustic_quality	0.12	0.004	0.225	0.037
Patients' overall satisfaction	←	Thermal_quality	0.215	0.092	0.33	0.004

Table 7. Linear regression weight (standardized) of relationship between IEQ parameters, patients' overall satisfaction and patients' health outcome

	SMC	Lower	Upper	p
Health_outcome	0.282	0.142	0.501	0.004
Patients' overall satisfaction	0.249	0.16	0.357	0.004

Table 8. Structural regression model summary: coefficient of determinantion (squared multiple correlations – SMCs)

4.5 Summary and discussion

Patients' overall satisfaction in specialist hospital wards had a correlation with thermal quality (0.299), acoustic quality (0.218), lighting quality (0.389) and IAQ (0.257), all of which were significant at the 0.01 level, according to an analysis of the correlation between IEQ parameters and patient satisfaction with hospital ward buildings (two-tailed). Because of their design configuration and poor ventilation, lighting and thermal quality have larger correlations to patients' overall happiness with hospital ward buildings. Lighting and thermal quality were also assessed as having considerable influence on the subjective perception of IEQ parameters impact on patient health and well-being. This could also explain why they have a higher link with patient satisfaction with their ward buildings. All IEQ measures, except acoustic quality, demonstrated a significant link with the patient's health outcome. Lighting quality has a 0.23 correlation with health outcome, 0.45 with IAQ and 0.30 with thermal quality. Patients' perceptions of poor air quality related to a greater association between their health outcomes and IAQ in these hospital wards.

Patients' overall happiness with ward buildings had the highest connection of 0.516 with thermal quality in teaching hospital wards with open-plan configuration and northwest–southeast direction, followed by a correlation of 0.44 with lighting quality. In both institutions, there is a stronger link between overall patient satisfaction with ward

Table 9. Linear regression weight (unstandardized) of relationship between IEQ parameters, patients' overall satisfaction and patients' health outcome

Variable(s)			Unstandardized estimates Estimate	SE	CR	*p*
Health_outcome	←	Thermal_quality	0.042	0.02	2.121	0.029
Health_outcome	←	Acoustic_quality	−0.034	0.022	−1.505	0.111
Health_outcome	←	Lighting_quality	0.103	0.024	4.249	0.001
Health_outcome	←	Indoor_air_quality	0.138	0.026	5.341	0.004
Patients' overall satisfaction	←	Indoor_air_quality	0.147	0.036	4.067	0.004
Patients' overall satisfaction	←	Lighting_quality	0.361	0.042	8.674	0.003
Patients' overall satisfaction	←	Acoustic_quality	0.264	0.044	6.032	0.003
Patients' overall satisfaction	←	Thermal_quality	0.412	0.041	10.138	0.006

Table 10. Linear regression weight (standardized) of relationship between IEQ parameters, patients' overall satisfaction and patients' health outcome

Variable(s)			Standardized estimates Estimate	Lower	Upper	*p*
Health_outcome	←	Thermal_quality	0.133	0.005	0.241	0.036
Health_outcome	←	Acoustic_quality	−0.094	−0.218	0.029	0.106
Health_outcome	←	Lighting_quality	0.297	0.124	0.417	0.004
Health_outcome	←	Indoor_air_quality	0.451	0.313	0.603	0.004
Patient's overall satisfaction	←	Indoor_air_quality	0.127	0.061	0.187	0.004
Patients' overall satisfaction	←	Lighting_quality	0.276	0.214	0.342	0.004
Patients' overall satisfaction	←	Acoustic_quality	0.197	0.129	0.264	0.004
Patients' overall satisfaction	←	Thermal_quality	0.343	0.262	0.414	0.004

Table 11. Structural regression model summary: the coefficient of determination (squared multiple correlations – SMCs)

	SMC	Lower	Upper	*p*
Health_outcome	0.378	0.202	0.582	0.005
Patients' overall satisfaction	0.422	0.364	0.468	0.012

structures and thermal and lighting quality. In the teaching hospital wards, however, the relationships were stronger. All four-factor indicators were connected with patient health outcomes in the teaching hospital, with IAQ being the strongest, as it was in the speciality hospital wards.

Lighting quality and thermal quality were the key IEQ characteristics that contributed significantly to patients' overall satisfaction with the specialty hospital wards, according to the SRM. Acoustic comfort and IAQ are the key IEQ factors that influence patients' health outcomes in the specialist hospital. As a result, acoustic quality had a detrimental impact on total patient satisfaction. Thermal quality is the most influential IEQ parameter on patients' overall satisfaction with IEQ in teaching hospital wards. The other three factors (acoustic quality, lighting quality and IAQ) all have an impact on patients' overall happiness with hospital wards. The acoustic quality of the teaching hospital had no effect on the health results of the patients. IAQ and illumination quality are the key influencing factors. According to the findings of this study, the dimensions of influence on patients' overall happiness and health outcomes differ depending on the hospital ward orientation and design configuration.

The extent of influence of IEQ characteristics on patients' overall happiness with hospital ward buildings and their health outcomes are two independent variables. According to the findings of this study, IAQ is the least important factor in a patient's overall happiness while being the most important factor in a patient's health outcome. According to O'Neal (2000), roughly 5% of patients have returned to the hospital for treatment of acquired infections due to poor air quality in hospital wards. The poor quality of IAQ in hospital wards, as reported by patients, contributed to IAQ's decreased contribution to patients' overall happiness with their ward buildings in this study.

Thermal and illumination quality have a significant impact on patient health outcomes, according to research conducted by Andrade *et al.* (2012) and Ulrich *et al.* (2004), respectively. According to the findings of this study, noise is a significant factor influencing patients' health and well-being, as documented in a study by Kibert (2012). However, a regression analysis of the link between IEQ characteristics and patient health found that acoustic quality has no effect on the patient's health. Other research (Ampt *et al.*, 2008; Mazer, 2012; Ulrich *et al.*, 2008) have found that the hospital auditory environment has a considerable impact on patients' health and well-being. However, this study has limitations because only the patients' length of stay was used as a measure of health outcome, with no consideration of other influencing factors.

5. Conclusion and recommendation

The main goal of this study is to see if patients' perceptions of their hospital wards' IEQ have a positive impact on their overall satisfaction with the wards and their health outcomes. The correlation analysis using the specified SRM revealed a very strong link between patient satisfaction and lighting quality in specialist hospital wards. This was due to the specialist hospital wards' orientation along the NE–SW axis, where the windows are only exposed to a brief period of daylight. Patients' health outcomes, on the other hand, had a stronger link to IAQ. Because of the poor IAQ, as expressed by the patients in their subjective responses, this was possible. The sensitivity of patients' health outcomes to IAQ necessitates that IAQ be considered in the design of hospital ward buildings at all times, particularly during the design stage. Patients' overall satisfaction had a strong correlation with thermal quality satisfaction in the teaching hospital, and patients' health outcomes had a stronger correlation with IAQ in the specialist hospital wards. Patients' overall satisfaction with their hospital wards and their health outcomes had a relatively strong correlation.

All four factor parameters are influencing factors on patients' overall satisfaction with the hospital wards in both case study hospitals, according to the SRM establishing the association between IEQ parameters, the patient's overall satisfaction and the patient's health outcome. In teaching hospital wards, each of these criteria has a larger level of influence on patient satisfaction than in specialist hospital wards. Only IAQ and acoustic quality were important contributions to patients' health outcomes in specialist hospital wards when it came to the link between IEQ parameters and patient health outcomes. However, acoustic quality had a negative impact on patients' health outcomes. In teaching hospital wards, only acoustic quality had no effect on patient health outcomes.

A study of the coefficients of determination of the specified regression model revealed that IEQ parameters accounted for more variation in both patient overall satisfaction and patient health outcome in teaching hospital wards than in specialist hospital wards. At a two-tailed significant level, all of the models were accepted (0.01 and 0.05). As a result, achieving enhanced IEQ in hospital ward buildings is heavily reliant on the integration of all IEQ components throughout the design stage. As a result, architects, healthcare managers and clinicians should focus on creating a hospital environment that represents occupants' needs and expectations while also facilitating patient healing processes.

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