PERFORMANCE OF A GREEN BUILDING'S INDOOR ENVIRONMENTAL QUALITY ON BUILDING OCCUPANTS IN SOUTH AFRICA

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ABSTRACT

Indoor environmental quality (IEQ) is important to the health, comfort, and well-being of building occupants. Unsatisfactory IEQ is associated with a number of phenomena, most notably, sick building syndrome (SBS), building-related illnesses (BRIs), and multiple chemical sensitivity (MCS), which have major negative effects on productivity. However, green building investors (owners) are not only concerned about reducing the negative impact of their buildings on the environment, but also about the potentially negative impact green buildings can have on their employees' productivity. This research sets out to address, through a questionnaire survey in South Africa, what constitutes the determinants of green building occupants' satisfaction with the IEQ elements of a green building and the health implications of a building's IEQ on the building occupants. Data analysis (involving a one-sample t-test) reveals some interesting findings in regard to what constitutes the determinants of green building occupants' satisfaction with the IEQ elements and the health implications of the IEQ elements of a five-star green rated building in South Africa. Findings from the survey revealed that the occupants of the building were not satisfied with the green building's IEQ, most especially the ineffectiveness of blocking natural and artificial lighting. Also, it was revealed that the IEQ with particular reference to the noise level and ventilation of the space has some serious health implications for the building occupants. The occupants' evaluation revealed that the major health issues from which they suffer include fatigue, headache, common cold, coughing, and influenza, and these affect their productivity and performance. Since building occupants are a rich source of information about IEQ assessment and its effect on productivity, the study can be used to assess the performance of green buildings, identify areas needing improvement, and provide useful feedback to designers and operators about specific aspects of green building design features and operating strategies that need improvement. This study adds to the body of knowledge on green buildings' IEQ performance.

KEYWORDS

Green building, Health implications, Indoor environmental quality, Post-occupancy evaluation

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1. INTRODUCTION

There has been an exceptional growth in human population and in the size of the global economy, with population quadrupling to seven billion and global economic output, expressed as gross domestic product (GDP), increasing about 20-fold in the past 100 years (Maddison, 2013). This significant change has been accompanied by fundamental changes in the scale, intensity and character of society's relationship with the natural world (McNeill, 2000; Steffen et al., 2007). This fundamental change in scale and intensity has come with negative consequences for the environment that can only be rectified by the collective, sustainable responsibilities of the world's population. For instance, cities account for two-thirds of global energy demand, 60% of water consumption, and 70% of greenhouse gas emissions (GHG). The GHG effect describes the natural phenomenon whereby certain gases in the atmosphere increase the earth's surface temperature owing to an ability to trap heat, similar to the way in which glass traps heat in a greenhouse (Department of Environment, Food and Rural Affairs, 2006). GHGs contribute immensely towards the greenhouse effect, which makes the need to design and construct environmentally friendly buildings critically important.

The building industry is a high resource consumption user of raw material, energy and usage of land (John et al., 2001). Excessive use of resources such as water, materials, energy and fossil fuels on a global scale has obliged countries to consider the implementation of sustainable assessment tools. In addition, designing and constructing energy-efficient buildings is not only aimed at reducing carbon dioxide (CO_2) and other GHG emissions but also involves cost-effective measures for end users (Gagon et al., 2002; Saidur at al., 2009). One of the most common negative impacts of CO_2 is its role in GHGs that contribute to global warming. These gases absorb the sun's energy re-radiated by the earth's surface and reflect this heat back to the earth. In reality, this functions like an insulator, transmitting and retaining sunlight energy in the form of heat. This process is called greenhouse gas emission.

Many countries have adopted strategies to limit GHG emissions. The first steps were taken in 1990 by the Building Research Establishment (BRE) through the creation of the Building Research Establishment Environmental Assessment Method (BREEAM) in England and continued by Leadership in Energy and Environmental Design (LEED) in 1996 (LEED, 2008). LEED is a third-party certification and has become a popular green building benchmark. LEED provides a clear direction for various phases in a project including the design, construction and operation of buildings. LEED is considered as a tool for all types and sizes of buildings to verify that they conform exactly to all the requirements of a high-performance green building. After LEED, various countries started to introduce country-specific solutions in the context of environmental sustainability; for instance, the South Africa Green Star Rating (Green Star SA) program. Other countries with green building rating programs include Australia (GBAS), Brazil (AQUA/LEED Brasil), Canada (Green Globes), New Zealand (Green Star NZ), Finland (PromisE), France (HQE), Germany (DGNB), the United States (LEED), Switzerland (Minergie), Singapore (Green Mark), the Netherlands (BREEAM Netherland), England (BREEAM), Malaysia (GBI), Japan (CASBEE), and Jordan (EDAMA). The policies are either compulsory or voluntary or a mix of both for building sectors in these countries. Each of these programmes ultimately leads to a certification that requires precise fulfilment of all terms and processes stipulated in the programme's documents. Despite the advent of the different rating systems, the human dimension of how the buildings function is necessary. Hence, the need for the present study, which studies the impact of green IEQ elements on occupants' productivity and their level of satisfaction with the various IEQ elements in a South African Green Star-certified building.

Fischer (2009) notes that the environmental impact of human activity has been a source of concern for decades, creating impacts such as pollution and the destruction of wildlife habitat and the ecosystem. Over the years, concerns about GHG, resource depletion and the degradation of ecological services such as the water supply have increased significantly (Fischer, 2009). Furthermore, Choi (2011) states that construction activities such as operation and demolition of buildings are increasingly recognized as a major source of environmental impact. Hence, without a significant transformation of building construction and operation, such impacts are expected to increase with population growth and changes in other demographic and economic factors.

One strategy for achieving that transformation is most widely known by the term 'green building' (Choi, 2011). Zigenfus (2011) describes green buildings as buildings that are designed to reduce or eliminate the impact of GHG on human health and the natural environment. This is accomplished by incorporating materials and operational elements that are environmentally responsible and resource efficient throughout the life cycle of the building. Zigenfus (2011) further observes that how 'green' a building can become depends upon the number of the incorporated elements that are used and their associated impact on human health and the environment. Huang (2009) mentions that the objective of these types of buildings is that they are designed to reduce the overall impact of the built environment on human health and the natural environment by efficiently using energy and water, and reducing waste, pollution and environmental degradation. Choi (2011) further advances that sustainable buildings have become an increasingly common practice for the benefit of both occupants and business owners by providing an enhanced quality of indoor environment and reduced energy costs compared to conventional building design. However, Yoon (2008) adds that although green buildings have proven to be efficient in reducing energy consumption, water wastage, and protecting the environment from degradation, there are still challenges for the indoor environmental quality of green buildings in relation to occupants' health and employee effectiveness; the aim of this present study.

The indoor environmental quality (IEQ) of green buildings is of outmost importance as buildings are designed and constructed to be habitable by humans. IEQ encompasses indoor air quality, thermal comfort, lighting, acoustics and ergonomics. Therefore, this article presents the results of a post-occupancy survey response to indoor environmental quality (IEQ) in a South African Green Star-rated office building. The article assesses the implications of the building's IEQ on the building occupants' health, and how it affects their productivity. It further investigates the building occupants' satisfaction with the green building's IEQ. The specific aim of the study reported herein is to assess the correlation between IEQ and the productivity of occupants in the building. The evaluation is based on occupant questionnaire data with regard to specific IEQ elements, such as the indoor air quality, thermal comfort and distraction from noise.

The assessment of the building is derived from the behaviour of building occupants; behaviour in this context is a broad term covering not only the occupants' actions and responses but also attitudes, feelings, expectations, values and beliefs. In this regard, it is useful to think of the user-environment relation as vital and interactive, meaning that part of the occupants' environmental experience includes the consequences of any occupant behaviour that may occur. Building occupants are not considered as passive objects for the purposes of this study whose reaction to the built environment is not a static experience but instead dynamic. The occupants' experience of the environment is itself heightened by the activities being performed in that environment, which Vischer (2008) referred to as 'transactional'.

The article commences with an overview of the literature on the topic of IEQ in relation to occupants' productivity. Thereafter, the methodology adopted for the study is presented, followed by the results of the occupants' questionnaire survey analysis and the findings of the research. Finally, the paper draws some conclusions and makes recommendations. The paper makes a significant contribution towards understanding the IEQ of green buildings and their effects on building occupants. This study provides significant insight into how green building occupants' satisfaction with spaces and offices could be improved through the active involvement of building users. Thus, the next section of the paper presents an overview on the theoretical framework of IEQ in relation to productivity.

2. INDOOR ENVIRONMENTAL QUALITY IN RELATION TO PRODUCTIVITY

Indoor environmental quality (IEQ) represents all environmental factors that affect the health and well-being of building occupants (Bluyssen, 2009), referring to the overall comfort of a building's interior and the comfort and health of its occupants. Under the category of indoor environmental quality in the LEED checklist, IEQ encompasses indoor air quality (IAQ), including environmental tobacco smoke, carbon dioxide monitoring, indoor chemical and pollutant sources, thermal comfort, daylight, ventilation effectiveness and views. However, IEQ consists of many more complex factors that may have an effect on the occupants, for example, noise, ergonomics, the quality of the artificial lighting and the spectrum of paints used. (John et al., 2001; LEED, 2008). The American Industrial Hygiene Association Ergonomics Committee states that the purpose of ergonomics is, for instance, to decrease worker discomfort and improve worker performance (DiNardi, 1998).

The context of workspace in this study includes places to meet or to use technology, public spaces where work occurs, amenities to support work, as well as office-type workspace; this study is based on an office building. Also, the IEQ elements explored in the current study are IAQ, thermal comfort, daylight, views, noise, and artificial lighting. In particular, IAQ and thermal comfort are two important aspects of IEQ that have received considerable attention from scholars and building designers. These factors are a focus in order to attain international and regional standards which prescribe conditions intended to foster environments that are acceptable to occupants. IAQ is closely related to ventilation: assuming outdoor air is less contaminated than indoor air, fresh outdoor air replaces indoor air through ventilation, thus removing and diluting contaminants generated indoors (Fischer, 2009; Choi, 2011). While there is considerable field data on air quality and thermal comfort according to Fisk (2000), there is far less data that evaluates occupant satisfaction across a large number of buildings using a systematic method such as POE protocols (Bordass & Leaman, 2005), and using occupant opinions as a measure of green buildings' IEQ performance.

Previous research has shown that the quality of office space can affect the productivity, health and comfort of workers. For instance, Evans and Stecker (2004) found that both severe and continuous exposure to uncontrollable environmental features such as noise, crowding, traffic congestion or air pollution can produce 'learned helplessness' in adults as well as in children. Clinical psychologists have comprehensively documented the role of positive or negative emotions on various individual outcomes, including productivity (Wright et al., 2002). They maintained that 'sad' or 'depressed' individuals have low self-esteem, and would exhibit reduced motivation and slowed thought processes.

Another study by Wright et al. (2002) on worker productivity found that psychological well-being (PWB) was positively related to job performance. In their field study, Wright et al. (2002) defined PWB as that which measures the 'pleasantness dimension' of individual feelings. While positive feelings were measured by terms such as 'active', 'alert', 'enthusiastic', and 'interested', negative feelings, on the other hand, were measured by 'afraid', 'hostile, 'irritable', and 'upset' (Wright et al. (2002). Moreover, Vischer (2008) states that ". . . how satisfied or not users are with the space they occupy is a notion that has guided environmental evaluation since its earliest efforts. This is the process whereby occupants evaluate their physical environment."

Through this evaluative procedure, the processes of IEQ evaluation are linked not only to observable physical features, but also to the perception that the occupants have of their workspace. This is the basic tenet of an environmental appraisal research, such as post-occupancy evaluation, which seeks to determine the extent to which certain environmental features affect users' satisfaction or dissatisfaction and their effects on the building occupants, which was also adopted in this study. Since the 1980s similar studies have been carried out over time in ordinary office environments (Marans & Sprecklemeyer, 1981; Ornstein, 1999) but not in green buildings.

There is no generally accepted definition of productivity by scholars, but it has been widely agreed to mean the relation between output and input, and has been applied in many different circumstances on various levels of aggregation in the economic system (Motwani & Kumar, 2000). It has also been found to be one of the major contributions to building economic growth in every country. Also, other scholars such as Dorgan and Dorgan (2006) state that productivity is all about the speed and accuracy of certain tasks but specifically it can actually be measured or subjectively estimated. Previous studies have sought to make direct links between the workers' environment, IEQ, workspace and productivity (Vischer, 2008).

The concept of worker productivity has been applied to a whole range of desired behavioural outcomes in the context of work. The study by the Commission for Architecture and the Built Environment (CABE) on the effects of environment characteristics on workers' productivity found that there is confusion about what productivity means; therefore, this has made it difficult to identify how environmental conditions affect worker performance. Despite this assertion, this does not render research on IEQ effects on productivity as irrelevant, but it does justify the reason why such research should be conducted.

There are at least three types of productivity that are influenced by IEQ. They are individual, group, and organisational productivity. Each category denotes a variation in scale of IEQ influence (Vischer, 2006; 2008). First, individual productivity is characteristically evaluated at the scale of the individual workspace (desk and office) and how the micro-environment influences individual task performance, that is, how fast and accurately a worker carries out his or her tasks (Vischer, 2008). Individual productivity, according to Vischer (2008), is affected by environmental conditions such as lighting and visual conditions, variations in temperature and humidity, furniture ergonomics, and, to some degree, acoustics. Positive individual productivity results denote an enhanced speed and accuracy of the tasks performed, whereas negative outcomes might include a higher error rate, slower time for task completion, or adverse health effects on workers, such as sore eyes, fatigue or upper respiratory problems (Vischer, 2008).

Second, Vischer (2006; 2008) states that the productivity of workgroups sharing workspace, such as a teamwork environment, is characteristically appraised in terms of the quality and quantity of group methods. Vischer (2006; 2008) further informs that teamwork is affected by the mid-range environment, that of the work-group or team, and it is measured in real terms such as the time taken to market a new product, or in terms of more qualitative results, such as an increase in the number of good new ideas or good recommendations coming out of effective business processes. In addition, Bordass and Leaman (2005) assert that the group process is affected by workgroup size and the relative proximity of team members. Other environmental determinants of workgroup effectiveness include the positioning of work areas and shared space, as well as access to shared tools and equipment (Heerwagen, 2000).

Lastly, productivity corresponds to the organization's entire workspace or office space, which represents the organization's macro-environment. There are several methodologies for assessing the degree to which workspace helps (or fails to help) a company to meet its business objectives and to increase its competitive advantage. Vischer (2006) relates that organizational effectiveness is influenced by locational advantages and ease of access, by balancing consolidation under one roof with a concentration of different groups in different facilities over manageable distances, and by building amenities such as faster elevators, convenient bathrooms, adequate parking, and attractive eating areas. Thus, numerous scholarship has shown that both worker productivity and organisational success are undermined when the physical environment (IEQ) interferes with actions taken towards the achievement of objectives (McCoy & Evans, 2005).

Studies have shown that when workers have control over their environment, they tend to be more satisfied. When their environment is improved, either through management initiatives or as a result of worker complaints, they take it as an indication that management cares about them, or it increases their job satisfaction, which indirectly increases productivity. Because most workers (office building occupants) spend almost twelve hours indoors daily, this positions good IEQ as very important in order to achieve workers' satisfaction and comfort. Surveys have also proven that IAQ, a subset of IEQ, plays an important role and has a strong and direct correlation with work efficiency output (Clements-Croome & Kaluarachchi, 2000). Also, the work of Olesen (2012) on offices and schools showed that comfortable room temperatures, increased ventilation above the normal recommendation, the reduction of indoor pollution sources and more effective ventilation increased the performance of people. Also, it has been reported that in developing countries alone 5000 people die daily from polluted indoor air, according to the World Health Organization. The cause, according to Olesen (2012), is indoor pollution from cooking without vents, or using wood or manure as fuel.

According to Kamaruzzaman et al. (2010), employees' performance and competence are dependent on indoor environmental surroundings, and factors such as concentration and alertness are vital for good work performance even though there are personal and external factors that could cause negative impacts depending on the physical and mental health of an individual. The more comfortable people are, the more productive they will be when other features are in place. Overall comfort is an umbrella variable which covers people's perceptions of heating, cooling, ventilation, lighting and noise taken together in an overall assessment (Bordass & Leaman, 2005). As such, light can influence building occupants' comfort level in several ways, namely through vision, and indirectly, because lighting may direct attention, or influence arousal and motivation; therefore, it is important in relation to productivity (Fisk, 2002). Also, poor quality lighting can cause fatigue, drowsiness, nausea, and eye irritation, amongst other problems. Poor lighting can be due to either excessive lighting or inadequate lighting, according to Kamaruzzaman et al. (2010). In general, a typical occupants' IEQ survey is a standardised survey instrument that can be applied widely to evaluate the performance of individual buildings as well as systematically comparing the performance of groups of buildings (Fisk, 2002) as it affects the productivity of its occupants.

3. METHODOLOGY

The data used in this study were derived from both primary and secondary sources. The primary data were obtained through the survey method, while the secondary data were derived from the review of literature and archival records. The primary data were obtained through the use of a structured questionnaire aimed at 95 occupants of a Green Star-rated office building in South Africa. The questionnaire survey was administered to both full-time and part-time staffs and occupants of the building. In order to meet the research objectives, the respondents were selected based on their having been resident in the building for a minimum of three months and having a personal or shared working space. The survey was based on a post-occupancy model where the direct experience of the building occupants of an environment is used as a fundamental principle to evaluate the quality and satisfaction of the use of a building. Using a simple stratified random sampling technique, the seven-floor building accommodation for 3,000 employees, with provision for retail spaces on the ground floor and seven levels of office space above, presents an active edge to the public realm. Three basements in the office building are provided for car parking space. The seven-floor office building was separated into five different levels, namely the 2nd, 3rd, 4th, 5th and 6th floors respectively. All the respondents on each floor had an equal chance of being drawn and being part of the sample. All 95 staff members (employees) on the five floors were chosen as the sample frame. This process was essential to obtain true representativeness of the entire sample.

Random sampling was used to select the building occupants. According to Kombo and Tromp (2006), random sampling is the probability whereby people, places or things are randomly selected. From the total 3,000 employees who use the building on a daily basis, 95 were randomly selected. This yardstick was considered vital for the survey in order to have a true representation of the Green-Star building's IEQ because all employees had an equal chance to be drawn and participate in the survey. Out of the 95 questionnaires sent out, all were received back, representing a 100% response rate and all were usable. A five-point Likert-type scale was used to determine the occupants' levels of satisfaction with their environment and the effect of the IEQ elements on their productivity. This was considered adequate for the analysis, based on the assertion by Mukuka et al. (2013) that the result of a survey could be considered as biased and of little value if the return rate was lower than 30% to 40%. Because the sample size for this study was relatively small, all groups of respondents were combined in the analysis in order to obtain significant results. The data were analysed by calculating frequencies, the mean item score (MIS) and one-sample t-test of the rated factors.

Five-point Likert scales were used to assess the implications of the Green Star-rated building's IEQ on the building occupants' health and productivity and to further investigate the building occupants' satisfaction with the green building's IEQ. The Likert scales were transformed to an MIS for each of the research objectives as applicable. The indices were then used to determine the rank of each item. These rankings made it possible to cross-compare the relative importance of the items as perceived by the respondents. The computation of the MIS was calculated from the total of all weighted responses and then relating it to the total responses on a particular aspect. This was based on the principle that respondents' scores on all the selected criteria, considered together, are the empirically determined indices of relative importance. The index of MIS of a particular factor is the sum of the respondents' actual scores given by all the respondents as a proportion of the sum of all maximum possible scores on the scale that all the respondents could give to that criterion. Weightings were assigned to each response, ranging from one to five for the responses of 'Strongly disagree' to 'Strongly agree'. The relative index for each item was calculated for each item as follows, after Aigbavboa, Thwala, and Lesito (2013), Kombo and Tromp (2006) and Eke et al., (2013). Following the mathematical computations, the criteria were then ranked in descending order of their relative importance index (from the highest to the lowest).

The next section of the article presents the findings of the survey as well as some discussion. The research was conducted between the months of July to October 2016. The questionnaire was designed based on the information gathered during the literature review and does not form part of an existing survey instrument.

4. FINDINGS AND DISCUSSIONS

4.1 Biographical data results

Findings from the questionnaire survey revealed that out of the 95 respondents that participated in the questionnaire survey, 45% were male and 55% were female. Further analysis showed that 27.5% of the respondents were between the ages of 26–30 years, 22.5% were between the ages of 20–25 years, 22.5% were between 31–35 years, 17.5% were between 36–40 years, 5% were between 41–45 years and 5% were 46 years old or older. Furthermore, it was revealed that 90% of the respondents were permanent employees and 10% were contract workers, 22.5% of whom have been working in the building for between 3–6 months, 7.5% for between 7–9 months, 27.5% for between 10–12 months, 22.5% for between 2–3 years, and 20% have been working in the building for three years or more.

Based on these finding, it can therefore be inferred that the respondents have an adequate knowledge of their office spaces and the indoor environmental qualities of the building based on their duration of engagement in the building. Therefore their views are a useful measure to appraise the green building's IEQ and its effect on the workers' performance. Also, the occupants' employment contract status further confirmed that the occupants' responses to the IEQ in the performance survey are based on a genuine motive, as they have credible working contracts with their various companies.

4.2 Findings on the green building IEQ elements

4.2.1 Lighting quality

The data obtained from the questionnaires revealed that 70% of the respondents were visually comfortable in their workspaces, which indicates that the lighting quality in the workspaces of respondents was to the respondents' satisfaction. Furthermore, 32.5% of the respondents considered the quality of natural light in their workspaces good, while 22.5% of the respondents considered the quality of natural light to be very good.

In addition, the findings revealed that 40% of the respondents had full control to block natural light if so desired and that 45% of the respondents agreed that the shutters or blinds were fully effective in blocking natural daylight if so desired. Thus, it can be inferred that the respondents had full control over the amount of natural daylight in their workspaces, indicating that natural light was not a problem/hindrance to the respondents. However, 67.5% of the respondents indicated they did not have control over artificial lighting in their workspaces. Also, 45% of the respondents considered the quality of artificial light in their workspace to be good and 22.5% of the respondents considered the quality of artificial light to be very good.

These findings are in agreement with the study conducted by Yun (2011), Choi (2011) and Nagib (2008) which reported that office workers prefer to have daylight and views in their work spaces, thereby enhancing their visual comfort and productivity. This points to the fact that controlling intense direct sunlight is key to ensuring comfort in daylight spaces. This finding implies that the selected green properties of the building's lighting were satisfactorily to the building occupants.

4.2.2 Acoustic quality

Although the majority of the respondents (52.5%) work in open-plan offices, the questionnaire aspect relating to the building's acoustic properties revealed that 27.59% of the respondents are disturbed by telephone noise, and 25.6% of the respondents experienced noise from neighbour's having conversations. Moreover, 42.5% of the respondents related that noise outside their workstation does not distract them, while 52.5% of the respondents indicated that the noise outside their workstation has no effect on them. In addition, 65% of the respondents revealed that they do not experience noise distraction outside the building which indicates that the respondents are satisfied with the acoustic quality of the green building as the respondents do not experience any noise distractions.

These findings do not correspond with the findings of the study conducted by Field (2008) which indicates that the acoustic environment, specifically the lack of adequate speech privacy and control of noise levels, has been a major cause of complaint with respect to the ability to carry out work tasks in open-plan office spaces. However, the findings are in agreement with studies conducted by Eke et al. (2013) which informed that, depending on the construction systems used in the building, most building occupants in an open-plan office space are affected by noise from known office sources such as telephonic conversations and neighbour's conversation.

4.2.3 Thermal comfort

The findings on this aspect of the building IEQ revealed that 62.5% of the respondents indicated that they have artificial temperature control equipment in their workspaces. However, the majority of the respondents (62.5%) revealed that they do not have direct control over thermal temperatures in their workspaces as these are controlled from a central source. Furthermore, 37.5% of the respondents informed that they experience slightly cold temperatures in their workspace in summer, while 62.5% of the respondents experience warm temperatures in their workspace in winter. This is a result of the respondents' inability to control the thermal temperatures in their workspaces, thus creating discomfort.

Therefore, these findings are aligned with the work of Heerwagen (2000) which pointed out that personal control could influence discomfort and also affect performance by reducing the amount of time and effort given to achieving comfort. In addition, Heerwagen (2000) states that occupants who were uncomfortable engaged in a number of coping strategies that were in themselves distracting and reduced their ability to concentrate at work, thus reducing their productivity. Other studies conducted by Rasha (2008) and Xiong (2011), however, contradict the current findings relating to the thermal comfort of buildings. Therefore, this aspect of the green building based on the post-occupancy survey needs urgent attention as this could be a source of low worker productivity and health-related problems when the exposure to cold temperatures is not controlled.

5.2.4 Air quality

The survey findings revealed that 82.5% of the respondents have no control over ventilation in the building. Also, the majority (37.5%) of the respondents reveal that there is enough air circulation within the building; 57.5% of the respondents noted that they do not experience any noticeable odours in the building; while 32.5% of the respondents rated the quality of air in the building as very good and 30% of the respondents rated the quality of air in the building as good, which indicates that the respondents are satisfied with air quality. These findings are thus in agreement with the work of Celik (2006) and Appleby (2011) who maintain that improved air quality in buildings reduces sick building syndrome and constitutes healthy environments for building occupants as well as enhancing the occupants' quality of life.

5.2.4 Ergonomics

Although 52.5% of the respondents revealed that there is no visual privacy in their workspace, 35% of the respondents indicated that the office layout enhances their ability to do their work, while a further 37.5% of the respondents revealed that the office layout sometimes enhances their ability to work. At least half (50%) of the respondents revealed that the amount of space available for individual work and storage in their work environment is acceptable from which it can thus be inferred that the respondents are satisfied with the ergonomics of their working environment. These findings support the work of Celik (2006) which points out that ergonomics strive to promote health, prevent injury and improve productivity and satisfaction of the building occupants. The findings also agree with the work of Rethaber (2011) and Miller (2012) who found that the application of ergonomics seeks to design and modify tools, materials, equipment, workspaces, tasks, jobs, products, system and environments to match the mental and physical abilities and needs of the workers which the currently assessed green building achieved.

5.3 Results of t-test showing one-sample statistics for factors that could influence occupants' health in a green building

The one-sample t-test was used to establish the relative importance of the variables influencing work performance and the occupants' health. The procedure, findings and relevant discussion follows. A summary of the test results is shown in Tables 1 and 4. The mean for each attribute, including the associated standard deviation and standard error, is reported in Tables 1 and 4 respectively. For each attribute, the null hypothesis was that the attribute was unimportant (*H0*: $U = U_0$) and the alternative hypothesis was that the attribute was important (*Ha*: $U > U_0$), where U_0 is the population mean (U_0 was fixed at 3.0, drawing from Ling [2002]). The significance level was set at 95% in accordance with conventional risk levels (Ling, 2002). Thus, based on the five-point Likert rating scale, a variable was deemed critical or influential if it had a mean of 3.0 or more.

Where two or more criteria have the same mean, the one with the lowest standard deviation was assigned the highest importance ranking (Field, 2005). The standard error is the standard deviation of sample means, and it is a measure of how representative a sample is likely to be of the population (Field, 2005). A large standard error relative to the sample mean indicates that there is a wide-ranging variability between the means of different samples, whilst a small standard error suggests that the sample means are similar to the population mean and so the sample is likely to be an accurate reflection of the population. In this study, the standard error associated with all the means was relatively close to zero, suggesting that the sample chosen is an accurate reflection of the population (Tables 1 & 2). Moreover, because the standard deviations are all less than 1.0, this indicates that there is little variability in the data and consistency in agreement among the respondents.

However, it is important to draw attention to the factor size of the workspace, which had a standard deviation of slightly more than one (1.004), suggesting that there is a variability in how the building occupants interpreted this factor. Further exploration on the t-test below provides a plausible explanation for the interpretation of the factor by the respondents.

The summary result as in Table 1 revealed that the factors that could influence the health of the occupants based on the building's IEQ are the size of the workspace, which was ranked first with a mean score of 3.50, the quality of natural and artificial light in the workspace, and the quality of space provided in the workstation which was ranked second with corresponding mean scores of 3.48. Also, the quality of air in the workspace was ranked fifth with a score of 3.13, while distraction from noise outside the workstation was ranked last with a score of 3.00. These findings generally concurred with the work of Celik (2006) and Appleby (2011) who both found that the main factor that influences the health of building occupants was IAQ; whilst the current study revealed that the size of the workspace and the quality of natural and artificial light, including the quality of the work space, are the major factors that could influence the green building occupants' health as shown in Table 1.

5.4 Illness experienced while working in the building

Furthermore, Table 2 revealed the common illnesses the office building occupants have experienced since they started working in the green building. Table 2 also reveals the frequency of the occurrence. The results indicated that fatigue was ranked first with a score of 2.88, headache was

TABLE 1. Results of t-test showing one-sample statistics for factors that could influence occupants' health.

FACTORS	*N*	Mean	Std. deviation	Std. error mean	Sig. (1-tailed)
Size of your workspace	95	3.50	1.004	0.117	0.00013
Quality of natural light in your workspace	95	3.48	0.885	0.106	0.00013
Quality of artificial light in your workspace	95	3.48	0.893	0.103	0.00013
Quality of space provided in your workstation	95	3.48	0.894	0.104	0.00013
Temperature in your workspace	95	3.28	0.771	0.090	0.00013
Distraction from noise outside the building	95	3.23	0.681	0.081	0.00013
Quality of air in your workspace	95	3.13	0.621	0.031	0.00013
Noise level in your workspace (ability to have conversation without neighbours overhearing it)	95	3.08	0.557	0.091	0.016
Distraction from noise outside your workstation	95	3.00	0.741	0.081	0.019

TABLE 2. Illness experienced while working in the building.

ILLNESS	Experienced		Frequency experienced	
	% YES	% NO	Mean	RANK
Fatigue	60.0%	40.0%	2.88	1
Headache	60.0%	40.0%	2.70	2
Common cold	65.0%	35.0%	2.63	3
Cough	67.5%	32.5%	2.53	4
Influenza	42.5%	57.5%	2.13	5
Nausea	17.5%	82.5%	2.00	6
Fever	20.0%	80.0%	1.95	7
Dizziness	35.0%	65.0%	1.88	8

ranked second with a score of 2.70, the common cold was ranked third with a score of 2.63, coughing was ranked fourth with a score of 2.53, influenza was ranked fifth with a score of 2.13, nausea was ranked sixth with a score of 2.00, fever was ranked seventh with a score of 1.95, and lastly, dizziness was ranked eighth with a score of 1.88. The findings imply a direct correlation with the levels of control the occupants have over certain IEQ elements such as thermal and acoustic control. As found under the thermal comfort assessment above, the respondents informed that they experience slightly cold temperatures in their workspace in summer, while others informed that they experience warm temperatures in their workspace in winter.

These results are further in agreement with studies conducted by Syal et al. (2010), where it was found that IEQ can negatively affect occupants' physical health, thus causing illnesses such as asthma exacerbation and respiratory allergies through poor air quality, extreme temperatures, excess humidity, and insufficient ventilation. In addition, psychological health (e.g. depression and stress) was affected through inadequate lighting, acoustics, and ergonomic design. However, these findings did not concur with the work of Taeyon and Jeong (2012) which indicated that fatigue is the main problem that the respondents experience when they do not have control over certain IEQ elements in a building. This was followed by headaches, the common cold and coughing whereas in the current study, coughing was not indicated as a frequently experienced problem Also, the work of Heerwagen (2000) informed that asthma, dry eyes and respiratory allergies are the most common conditions experienced by building occupants when there is a deficiency in the building's IEQ elements.

Furthermore, Table 3 below shows the results of the section in which the respondents were asked to state whether the above illnesses reduced their ability to do their work and also to rank how frequently the illnesses reduced their ability to do their work. The results as shown in Table 3 indicated that the common cold was ranked first with a score of 2.53, headache was ranked second with a score of 2.45, coughing was ranked third with a score of 2.25, influenza was ranked fourth with a score of 2.10, fever was ranked fifth with a score of 1.90, dizziness

TABLE 3. Illness reducing ability to do work.

ILLNESS	Experienced		Frequency experienced	
	% YES	% NO	Mean	RANK
Common cold	65.0%	35.0%	2.53	1
Headache	60.0%	40.0%	2.45	2
Cough	57.5%	42.5%	2.25	3
Influenza	40.0%	60.0%	2.10	4
Fever	25.0%	75.0%	1.90	5
Dizziness	25.0%	75.0%	1.88	6
Nausea	22.5%	77.5%	1.68	7

was ranked sixth with a score of 1.88 and lastly, nausea was ranked seventh with a score of 1.68. These findings likewise correspond with the previous results relating to the assessed individual IEQ elements. The findings thus support the work of Heerwagen (2000) and Syal et al. (2010) which noted the effect of the common cold, headache and influenza on building occupants when they do not have some level of control or regulation of the IEQ elements. These studies all found that that employees with adverse health conditions are often absent from work, lose more work hours, and are less productive than employees without adverse health conditions.

5.4 Results of t-test showing one-sample statistics for the influence of IEQ on occupants' performance and productivity

In addition, when the respondents were asked to rate the factors which could influence workers' performance and productivity, the following information was obtained as shown in Table 4. Office layout in enhancing the ability to work (MIS = 3.35; R = 1); noise levels in the workspace (ability to have conversation without neighbour's overhearing it) with (MIS = 3.33; R = 2); air quality in the workspace, enhancing the ability to work; and acoustic quality in the workspace in enhancing the ability to work (MIS = 3.20; R = 3) were all ranked as the highest. Other findings included lighting quality in the workspace, enhancing the ability to work (MIS = 3.13; R = 4); and thermal comfort in the workspace, enhancing the ability to work (MIS = 3.10; R = 5). These results were at variance with the studies conducted by Heerwagen (2000), Miller et al. (2009) and Smith and Pitt (2008) who identified that privacy, windows and lighting, amongst others, are the main factors that enhance occupants' productivity and performance; whilst the present study identified office layout and personal control as the main factors that enhance occupants' productivity and performance.

Overall, the present study estimated that there is a simultaneous relationship among occupants' satisfaction with the green building IEQ factors. The corollary from the findings was that when occupants were satisfied with the sustainable IEQ of their work environments, such as thermal comfort, IAQ, lighting quality, acoustic quality, privacy conditions, personal control, and office layout, they were also satisfied with the overall facility environment.

TABLE 4. Results of t-test showing one-sample statistics for factors which influence work performance.

FACTORS	*N*	Mean	Std. deviation	Std. error mean	Sig. (1-tailed)
Office layout, enhancing your ability to work	95	3.35	0.712	0.159	0.00045
Noise level in your workspace (ability to have conversation without neighbours overhearing it)	95	3.33	0.523	0.161	0.00045
Air quality in your workspace, enhancing your ability to work	95	3.20	0.341	0.143	0.00045
Acoustic quality in your workspace, enhancing your ability to work	95	3.20	0.389	0.165	0.00045
Lighting quality in your workspace, enhancing your ability to work	95	3.13	0.571	0.012	0.00045
Thermal comfort in your workspace, enhancing your ability to work	95	3.10	0.769	0.034	0.00040

6. CONCLUSION

The study assessed a Green Star-rated building's IEQ elements and their effects on the building occupants. Findings from the study revealed that there is a correlation between occupants' productivity and the green building's IEQ elements. The findings suggest that there is considerable evidence that buildings have far-reaching impacts on human well-being and on workplace performance. Although the empirical study is based on a single Green Star-rated building in South Africa, the findings provide an understanding of the effects of the assessed IEQ on green building occupants. Findings in this study have vast policy implications. Firstly, it is clear from the result that the IAQ, which is a major component of IEQ, affects workers' productivity. The policy implication is that future design and construction of green buildings should be responsive to the occupants' need for adequate quality air circulation and, most especially, a measure of control over the building's ventilation. Previous research has shown that occupants spend up to 90% or more of their working time indoors, and since people rely on air for proper functioning, this will reduce the occurrence of common illnesses arising from the lack of control of the building's ventilation.

Secondly, the thermal elements should be designed to ensure the building occupants have some measure of control. It is known that when building occupants have control over the thermal temperature in their offices, there is usually no negative effect on their efficiency. Therefore, this verifies the study carried out on Dutch office buildings which revealed that a negative thermal effect on productivity can be reduced by 34% when individual workers can control their own thermal environment. Similar studies in UK offices also indicate that self-estimation of efficiency is significantly higher in such cases.

Lastly, 'noise-based annoyance', which raises feelings of anger, discontentment, uneasiness, or offence among workers through noise interference with thoughts, feeling and daily activities, should be eliminated through the use of eco-friendly acoustic materials in order to make sure that the office building is an efficient and comfortable working environment. To this end, green buildings where various office activities take place should be adequately designed with good acoustic properties in order to handle the disruption caused by noise, amongst other irritants.

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