INDOOR ENVIRONMENT QUALITY AND PRODUCTIVITY: FABLE OR FACT? A REVIEW OF PAST STUDIES

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ABSTRACT

Extensive research that observed a positive relationship between occupant productivity and indoor environment quality (IEQ) in offices emerged in the early 2000s. Since then, it has successfully suggested that as a result of a causal link, the productivity of occupants is determined by the IEQ of an office building mainly Lighting and Temperature. Productivity is thus, the market technique that has accelerated the adoption of green rating tools as a result of it's commercial value - the extra investment required to construct a 'Green' physical office building not only helped the environment but the investment is also recovered by increasing the productivity of its occupants.

Through an extensive review of relevant literature, this paper illustrates the gap in research of the measurement of office occupant productivity. It presents the limitations of indicators used in measuring the relationship between IEQ and Productivity in the workplace. It concludes that while IEQ might have a relationship with comfort/satisfaction; there is no substantial evidence in research to state that this relationship exists with productivity. As such, the use of this claim in promoting green buildings is unsubstantiated. This study is part of an on-going doctoral research in New Zealand, that explores deeper the relationship between occupant productivity and Green office buildings.

Keywords: Indoor Environment Quality, Occupant, Productivity, workspace.

INTRODUCTION

Green office buildings are propelled to provide the best environment for workers. With all the potential benefits a well-designed and constructed "Green intent" office building presents, recent findings have provided a platform which includes "productive occupants" as one (if not the most

marketable) benefit of a green rated office building. The enticement of this proclamation by propellers of the green rating system in the industry is intensified as more people spend more time indoors – from home to office; from the office to the vehicle; and from the vehicle to home- requiring the best that an indoor environment can offer. As the cycle of indoor living continues, it becomes an advocate for a certain environment that will not only support vast and complex activities of the workplace but can increase the occupant's productivity to or above expectation. A news release by Property Council New Zealand (Tunstall, 2012) showed Green Star-rated office buildings reported 8.9% in total returns in 2012 as against 6.4% for non-rated buildings. This increase in total returns is said to be the result of 'green' indoor environment quality which makes increases the productivity of occupants.

Past reviews of literature have concentrated on finding absolute effects of physical and non-physical components of IEQ on occupant comfort and satisfaction (Abdou et al, 2006; Frontczak & Wargocki, 2011; Hauge et al; 2011 etc.) that can be related to productivity. While these reviews have enormously influenced the claim that green buildings' IEQ increases the productivity of their occupants, none has been critically investigated studies based on the productivity measurement methods applied. As such, there is the need to examine these studies and establish the strengths and limitations of this area of research. This paper aims to ascertain if past studies have actually proved that there is a positive correlation between IEQ and productivity as propelled by evaluating the methods of measurement employed. It covers various studies that have been carried out from the year 2000 (the inception of Green buildings) to 2013. The author acknowledges that there might be other studies not covered in this article, but it is assumes that all studies are represented herein.

LITERATURE SELECTION

Past research on IEQ and productivity from the year 2000 to April 2013 sorted electronically from various journals using the web search databases. The key words "*productivity*", "*Indoor environment quality*", "*performance*", "*work*" and "*job*" were used to search for studies that have endeavoured to establish a relationship between indoor environment quality and productivity. Using the keywords mentioned, 41 studies showing empirical evidence and an element of job performance were selected for analysis. This limitation to the scope of works is to enable the author apply a critical analysis of study methods and outcomes. Although this method has been employed in related past reviews (Frontczak & Wargocki, 2011; Sensharma et al., 1998; etc.), none has investigated the reliability of measurement methods employed.

Table 1: Overview of Studies carried out empirically on the relationship between IEQ and productivity (2000 -2013) Adapted from: Onyeizu (2012)

	Study	Findings that Propose/Oppose a positive correlation	Method applied
1	Leaman & Bordass (2001)	Propose	Qualitative
2	Heschong Group (2002)	Propose	Quantitative
3	Heschong Group (2003)	Propose	Quantitative
4	Smith and Bayehi (2003)	Oppose	Quantitative
5	Hepner & Boser (2006)	Propose	Qualitative
6	Roulet et al., (2006)	Propose	Qualitative
7	Venetjoki et al., (2006)	Propose	Combined
8	Boyce et al., (2006)	Oppose	Combined
9	Juslen et al., (2007)	Propose/ Oppose	Quantitative
10	Kim and Kim (2007)	Oppose	Combined
11	Haynes (2008)	Oppose	Qualitative
12	Paevere & Brown (2008)	Propose	Qualitative
13	Lan and Lian (2009)	Propose	Combined
14	Kaarlela-Tuomaala et al., (2009)	Propose	Qualitative
15	Haka et al., (2009)	Propose/ Oppose	Combined
16	Meijer et al (2009)	Oppose	Qualitative
17	Kolarik et al., (2009)	Oppose	Qualitative
18	Moshagen et al., (2009)	Oppose	Quantitative
19	Hameed & Amjad (2009)	Propose	Qualitative
20	Liu et al.,(2010)	Propose	Combined
21	Baird (2010)	Propose	Qualitative
22	Thomas (2010)	Propose	Qualitative
23	Kekalainen et al.,(2010)	Propose	Qualitative
24	Hedge & Gaygen (2010)	Oppose	Quantitative
25	Lee & Brand (2010)	Oppose	Qualitative
26	Drake et al., (2010)	Oppose	Qualitative
27	Brauer & Mikkelsen (2010)	Oppose	Qualitative
28	Linhart & Scartezzini (2011)	Propose	Quantitative
29	Zhang et al., (2011)	Oppose	Qualitative
30	Baird & Thompson (2012)	Propose	Qualitative
31	Baird et al., (2012)	Propose	Qualitative
32	Lenoir et al., (2012)	Propose	Qualitative
33	Haung et al., (2012)	Propose	Qualitative
34	Leblebici (2012)	Propose	Qualitative
35	Mak & Lui (2012)	Propose	Qualitative
36	McCunn & Gifford (2012)	Oppose	Qualitative
37	Healey & Webster-Mannison (2012)	Oppose	Qualitative
38	Tanabe et al., (2013)	Oppose	Qualitative
39	California Energy Commission (2003)	propose	Quantitative
40	Grady et al., (2010)	propose	Qualitative
41	Zhu et al., (2013)	propose	Quantitative

The studies are grouped according to the measurement method applied in table I above. Qualitative methods are based on subjective measures such as questionnaires and interviews. While interviews are more rigorous and demand a direct communication between the interviewer and the person interviewed, questionnaires are less demanding and cover larger population within a short time frame. Various questionnaires are applied to building evaluation with the aim of retrieving the feedback of building performance from the perception of occupants. They include the CBE occupant questionnaire, NABERAS, BUS etc. Whereas all questionnaires may differ in composition, the common traits is that the respondent

(usually the occupant) is expected to make a judgment based on his/her experience with the IEQ of the sample building and thus rate if his/her productivity has increased or decreased. In other words, if they felt that by increasing the temperature or lighting in the room that their productivity increased or decreased, they were expected to say so through the questionnaire or during the interview. On the other hand, Quantitative methods employed the use of various forms of tests to identify the effect of IEQ on the productivity of occupants. They may be experimental or embedded in normal daily activities that have been recorded over time.

CRITICAL EVALUATION OF MEASUREMENT METHODS

The area of research investigating the effects of the working environment on its occupants' productivity can be traced back to the 1930s (Haynes, 2008). Since then, there has been struggle in identifying how the indoor environment of a workplace makes occupants more productive. While it is majorly thought to be the dependent on the physical environment component of IEQ (lighting, temperature, noise etc.), very recent findings suggest the presence of other factors that might have greater influence on productivity. This discrepancy has made it difficult to put a lasting word on the relationship between occupant productivity and IEQ. A major reason is the description of productivity. This is explained in the sections below:

Comfort, Satisfaction or Productivity in Qualitative methods: Results from the qualitative studies reviewed dwelt more on the comfort and satisfaction of occupants than their productivity. As such, deductions were made based on the comfort and satisfaction of the occupants. The relationship between comfort, satisfaction and productivity has been a major contributor (if not the main propeller) to this claim of a correlation between the physical office environment and worker productivity. Brager & Baker (2009) observed that occupants' comfort and satisfaction correlated with their health and productivity while Leaman and Bordass (2001) maintain that health and productivity of occupants is positively correlated with comfort and satisfaction. Vischer (2008b) noted that the link between the satisfaction and productivity categories is the notion of comfort, specifically functional comfort which is an environmental support for users' performance of work-related tasks and activities. An example of such study is Huizenga et al (2006). The authors related the productivity of workers to thermal comfort and air quality with its high correlation to satisfaction. From their analysis, it was assumed that since satisfaction had a correlation with productivity, it then meant that the more satisfied occupants were with thermal comfort and air quality, the more productive they will be.

While these studies tend to make convincing statements, it is yet to be proven if comfort amounts to productivity (Abdou et al., 2006). For instance, a person can be comfortable yet unproductive in an environment and vice versa. Also, factors that amount to a comfortable environment might not be the best for a productive environment. An example is that of Pepler and Warner (1968) who found that young people worked best (and were thus more productive) for short periods when they were uncomfortably cold. The aim to escape the discomfort of the cold environment is in this case, a positive factor to arouse greater productivity. The implication of such a finding especially amongst young people who make up about 90% of most organisations and are regarded as the healthy age group is that it might not be far-fetched to suggest a bit of discomfort as a positive enabler to productivity.

It was also observed that respondents perceived their productivity to increase irrespective of their complaints about the IEQ. For instance, the book 'Sustainable buildings in practice: what the users think' written by George Baird (2010), reported a 4% increase in productivity of occupants in a study of occupant perception of 30 commercial and institutional green buildings in the world through self-reports (questionnaire) to measure occupants' perception of their productivity. This deduction was irrespective of the higher negative comments against positive comments on the effects of IEQ (1.83:1). This indicates that despite the high dislike of the IEQ in these buildings, the respondents reported that they were more productive in these buildings (Haka et al., 2009; Juslen et al., 2007).

IEQ criteria and comfort/satisfaction: The determination of what indicates a comfortable environment is also subject to much debate. While some authors stipulate certain criteria for indoor environment quality as the best for comfort, others suggest that there are no context-free indicators for indoor climates. A workspace cannot be designed to be a one-time, final and permanent ergonomic support for all office tasks but rather needs to be adaptable and 'negotiable' to be supportive to users (Vischer 2008b). This is because people differ and respond differently to the same conditions (Frontczak & Wargocki, 2011). Roaf (2005) pointed out that the conditions which people will find comfortable are influenced by the climatic, cultural, social and economic circumstances in which they find themselves. She added that even if it is possible to suggest appropriate indoor temperature for various types of building purposes, it depends on the social and climatic context. As such, studies that measure productivity under varying conditions and through different methods are oblivious of the possibility that even though IEQ criteria are met not all building occupants are satisfied and motivated by the same physical conditions. Majority of firms and organisations are made up of workers from different backgrounds and cultures with different past experiences

and expectations. Hence, it is becoming hard to find a workplace without diverse cultures and experiences. This diversity brings with it difference in preference and subsequent productivity determinants/indicators. This is discussed further in Onyeizu & Byrd (2013).

It is possible that an occupant's response to any given environmental condition might be influenced by one's perception of what an ideal environment should be from one's past experiences of which might not be the same with another person. For instance, an occupant who has spent most of one's lifetime in a warm climate with less artificial lighting might prefer an indoor environment closer to this situation unlike an occupant who has experienced the opposite most of his/her life. Also, an occupant whose past experience has resulted in a preference for an individual space with minimal communication/ interference with colleagues might find an open plan workspace undesirable and can state that such an environment reduces his/her productivity. These and many more can offer an explanation as to why some studies found evidence to propose a correlation between productivity and IEQ, and others did not. In respect to satisfaction, Monfared & Sharples (2011) observed that there is certainly more to occupants' satisfaction with a building than their environment comfort. The authors noted that the expectations of occupants in buildings were inevitably based on their previous experiences of conventional workplaces and lack of control over environmental conditions. Bluyssen et al (2011) also noted that social and personal factors influence one's perceived health and comfort.

Productivity indicators/determinants: Productivity indicators are measurable entities that represent the productivity rate of an individual. They include performance tests, absenteeism, embedded tasks retrieved from regularly work duties, self-appraisals etc. (table 2). The most common indicators applied have been self-appraisals and performance tests. Absenteeism and sick leave reports have also been employed on the basis that productivity is affected by absence to work. However, it is important to ascertain if presence at work means productivity. Being present in a workplace cannot represent productivity until an actual work (presenteeism) is accomplished by the occupant unless in an organisation where presence is regarded as some form of actual work done. It is also important to determine when actual work is accomplished by the occupant especially with computer tasks in an office. The amount of time spent in front of a computer does not necessarily represent the amount of work done by the occupant. Actual work that amounts to productivity can only be achieved when the time spent in front of a computer is used to accomplish designated tasks. It is not farfetched to say that most workers spend substantial amount of their work time doing things (such as going on Facebook, checking personal mails and chatting with friends etc.) other than their assigned task in a normal working day. As observed by

Haynes (2008) matching office environments to work processes requires a greater understanding of what people actually do when in the office, which is still a subject of much debate. Also, absenteeism or sick leave might not the result of only a bad Indoor environment quality but can be related to other conditions in the workplace such as interpersonal relationships with colleagues and boss etc., personal engagements outside the workplace, health of the occupant or even the preference of the occupant. For instance, if given the option to work from home, most workers might prefer to work from the comfort of their home sofas than work in an office.

Table 2: Productivity indicators applied in reviewed studies

Productivity Indicator	**Studies applied**
Absenteeism (perceived and actual)	California Energy Commission (2003); Grady et al, (2010) etc.
Performance tests (computer based, paper based etc.)	Heschong et al., (2002); Juslen et al., (2007); Liu et al., (2010); Linhart and Scartezzini (2011); Paevere & Brown (2008); Lan and Lian (2009); Kekalainen et al (2010); Venetjoki et al (2006); Haka et al (2009); Meijer et al (2009); Boyce et al (2006); Hedge and Gaygen (2010); Kolarik et al (2009); Drake et al (2010); Kim and Kim (2007); Zhu et al., (2013) etc.
Embedded tasks (Call quantity, sales entry etc.)	Heschong et al., (2003); Smith and Bayehi (2003); etc.
Self-appraisal (questionnaires/ interviews)	Hepner & Boser (2006); Baird & Thompson (2012); Baird (2010); Thomas (2010); Baird et al., (2012); Lenoir et al (2012); Roulet et al (2006); Hameed & Amjad (2009); Haung et al., (2012); Leblebici (2012); Tanabe et al, (2013); Leaman and Bordass (2001); Kaarlela-Tuomaala et al (2009); Mak & Lui (2012); McCunn & Gifford (2012); Lee & Brand (2010); Haynes (2008); Brauer & Mikkelsen (2010); Drake et al (2010); Healey and Webster-Mannison (2012); Brager & Baker (2009) etc.

Measuring actual behavioural outcomes that can be associated with or that represent productivity, is not yet a clear and straight forward research area. Research is yet to ascertain the best way to calculate the performance of workers especially for task that cannot be represented in numbers. Leaman and Bordass (2005) understood this problem when they aptly put in that "in buildings, people are the best measuring instruments: they are just harder to calibrate". As such, most research have depended on self-assessment as the best way to retrieve this information. Despite the success of self-assessed productivity in providing an indication on how the productivity of an occupant is affect, this ability is limited as a result of the various sources of bias explained above. Self-assessment cannot be a replacement of an actual assessment of productivity. Most studies that have found a direct correlation between IEQ and productivity have based their findings on self-assessment and this is dangerous in drawing conclusions of a direct link when this method only provides an indication of perception and not an actual measurement. It is important that the boundaries of such research findings be clearly stated to avoid misinformation. In order to avoid and eliminate research

bias as much as possible, studies have employed performance tests whereby the respondents are subjected to complete some task and the quality and quantity of their work calculated. As mentioned above, these tasks may include paper and computer tests etc. This does not represent a normal working condition as it is possible that when a participant's working ability is being tested and he/she will endeavour to perform to the best of his/her ability. As such, although an effect might be found during these tests, the same might not be accounted for in a normal working condition. Most tasks performed in a normal daily office work are not all capture in the tasks given and at times these tasks do not represent exactly the nature of work being carried out in the firm or organisation.

Studies that show increased productivity that are attributed to IEQ have been criticised on the point that humans tend to be influenced by predominant trends (Frontczak & Wargocki, 2011). As such, they dislike certain environmental conditions of which they are naturally adaptable to. Also, it's been noted that the introduction and use of new technology have affected workers' perceptions of and attitude towards their physical environment and workspace (Cascio, 2000; Lai, et al., 2002). Thus, they demand for specific conditions that are supported by these recent trends. For instance, Brager & de Dear (2000) observed that occupants of buildings with centralized HVAC systems become finely tuned to the very narrow range of Indoor temperatures presented by current HVAC practices. They develop high expectations for homogeneity and cool temperatures and soon become critical if thermal conditions do not match these expectations; a contract to occupants in naturally ventilated buildings that are more tolerant to wider range of temperature.

Conclusion

The discord on the relationship between IEQ and productivity is a function of several factors. The first reason is that there is still a mist if indeed this relationship exists. The correlation between comfort and productivity creates a possible illusion that the relationship between IEQ and comfort is transferable to productivity. Also, the exhausting controversy on what levels of IEQ than can achieve occupants' comfort compounds the problem. The second reason is the confusion on a definite description of what productivity means (CABE, 2004). While it might be possible to illustrate productivity in an industrial setting as simple input versus output, it is almost impossible to represent in quantity, all aspects of a worker's activities in the workplace. The complexity of a work environment makes it almost impossible to determine how the productivity of occupants can be increased or maximized by the manipulation of the physical environment (architecture). As such, research is yet to provide appropriate productivity indicators that are can

capture in entity workplace activities. Other reasons are the muddle on which indicators in the indoor environment represents an occupant's perception of the effect of IEQ on their productivity and how the factors of IEQ can be isolated to illustrate their respective influence on occupant productivity. These issues are discussed in details in another paper by the author.

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