STUDY OF BUILT ENVIRONMENT FACTORS INFLUENCING OCCUPANTS' PRODUCTIVITY: GREEN CERTIFIED OFFICE BUILDINGS IN SRI LANKA

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Degree of Master of Philosophy

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Thesis submitted in partial fulfillment of the requirement for the degree

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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ABSTRACT

Building occupants seek to be comfortable and productive in their workplace. Occupants with local control over their environment generally have an improvement in their work effort and productivity. However, work productivity of occupants may be de-motivated and interrupted due to poor environmental conditions. Thus, the intervention to ensure a healthy working environment should always be the first step towards improving productivity. In the governing concern on improving occupant's working environment, Green Building movement is fast becoming a necessity. Many researchers said that there is a potential link between green building environment and occupants' productivity. However, most of them have focused only on single aspects of the built environment. Further, no evidences were found on to which factors can critically influence occupants' productivity in green built environment. Further, different factors can have different degree of influence on occupants' productivity where it still remains debatable. In this context, this research intends to identify built environment factors critical for occupants' productivity in green buildings and their degree of influence. Therefore, the aim of this research is to investigate the built environment factors critical for green buildings and their degree of influence on occupants' productivity in green certified office buildings in Sri Lanka.

Two research hypotheses were tested by approaching the survey method under the quantitative phenomenon. The questionnaire survey was conducted among randomly selected occupants in green certified office buildings in Sri Lanka. The survey data was analysed by using the Spearman's Correlation and Ordinal Logistic Regression analysis techniques to modeling the relationships of research variables. The SPSS v20 software was used in data analysis. The findings confirm the relationship between built environment and occupants' productivity. According to the results of correlation, five factors such as; system control, open plan office design, air quality, acoustical partitioning and amount of space were selected as critical built environment factors which showed statistically significant monotonic correlation to occupants' productivity. It was further verified thorough ordinal regression analysis. As the test results verify, an improvement of the system controls, air quality, acoustical partitioning and amount of space in green buildings may increase the perceived productivity of occupants whilst open plan office design showed negative association. According to the calculation of exponential values of log-odds in the model, air quality is 5.783 times, system control is 1.822 times, acoustical partitioning is 16.428 times, open plan office design is 0.038 times and amount of space is 63.434 times more likely effect to result in much higher level of occupants' productivity. The research findings were implied as a basis to evaluate the Indoor Environment Quality criteria in national green certification. Accordingly, probable enhancements were proposed to enhance the existing criteria.

Key words: Occupants' Productivity, Built environment factors, Green buildings, Effect

DEDICATION

I dedicate this piece of research to all my loved ones who encouraged me, with emotional and spiritual effort in this endeavour…

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LIST OF ABBREVIATIONS

Abbreviation	Description
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BREEAM	Building Research Establishment Environmental Assessment Method
BUS	Building Use Studies
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
CBE	Center for the Built Environment
ETS	Environmental Tobacco Smoke
GBCSL	Green Building Council in Sri Lanka
GBI	Green Building Index
HK-BEAM	Hong Kong Building Environmental Assessment Method
HR	Human Resource
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
ICW	Institute for a Competitive Workforce
IDHP	Illinois Department of Public Health
IEQ	Indoor Environment Quality
LEED	Leadership in Energy and Environmental Design
OSHA	Occupational Safety and Health Administration
PLUM	Polytomous Universal model
PO	Proportional Odds
SPSS	Statistical Package for the Social Science
USEPA	United States Environmental Protection Agency
USGBC	United States Green Building Council
VOC	Volatile Organic Compound

1. INTRODUCTION

1.1 Background to the Research

Sustainable environment is a major concern today, for people who need a place to live with healthiness and comfortability. Specially, building occupants are looking for comfortability to be productive in their workplace. Further, occupants prefer comfortability in using their facilities and services as it must be fit for their purpose of use (Khalil & Husin, 2009). Occupants with such individual control over their working environment generally show an improvement of the work effort and productivity (Abdou & Lorsch, 1994 cited Clements-Croome, 2000).

According to a study by Nayeri, Nazari, Salsali and Ahmadi (2005), productivity can be defined as “the ratio of output to inputs or as the relationship between inputs and outputs.” As Dorgan (1994) defines, “the improved functional and organisational output including quality is productivity.” However, this increase could take place due to substantial reduction in non-attendance, early leaving or taking breaks more frequently by employees. Further, productivity of employees has become a key concern for individual companies as well as in the national economy. It is because 70–90% of the running costs of an organisation are consisting of the high salaries of the workforce with less worker productivity (Clements-Croome, 2000).

Occupants’ productivity can be decreased and disrupted due to poor environmental conditions. Since occupants’ efficiency and work productivity can be de-motivated due to disruption of indoor working environment (Heerwagen, 2000; Khalil & Husin, 2009). Thus, the concern on ensuring healthier working environment should always be the first step towards improving productivity. Thus, improving the quality of work environment ultimately increases the productivity of its occupants (Clements-Croome, 2000). While there is no proof that maximum comfort leads to maximum worker productivity, ample evidences show that an improved environmental conditions would decrease complaints and absenteeism of workers, therefore ultimately improving productivity (Abdou, Kholy & Abdou, n.d.). The occupants who satisfied with their indoor environmental conditions are broadly assumed to be highly productive (Leaman & Bordass, 2007; Humphreys, 2007 cited Kim & Dear, 2011). As Abdou et al. (n.d.) further stated, several previous researchers proved that there are measured improvements in occupants' productivity of 2.8% to 9.5% due to improved environmental conditions whilst some other researchers claim productivity increases of up to 15%. Aforementioned studies on occupants' productivity showed that improved work environment quality can increase the productivity of its occupants.

Whilst quality of working environment affects occupants' productivity, number of other factors such as, organisational management, level of empowerment, and individual recognition, the design of working environment could also be influenced. They can significantly improve or decline the effectiveness and productivity (Bluyssen, 2009; Mendell, 2003 cited Huang, Zhu, Ouyang & Cao, 2011; Jones Lang LaSalle, 2011). Further, building occupants expect quality indoor environment while having various densities and configurations of workstations (Loftness et al., 2009 cited Choi, Loftness & Aziz, 2011). Furthermore, access to the natural environment and improving work environment have been linked to improvements in individual productivity (Woods, 1987 cited Clements-Croome, 2000; Loftness, Hartkopf & Gurtekin, 2000). As the governing concern on improving the quality of occupants' working environment, facilitating quality indoor environment is rapidly becoming a necessity (Prakash, 2005; Singh et al., 2009). Thus, the modern work environment has designed in the expectation of spatial and technological changes. The provisions of responsive thermal and air quality delivery systems, flexible technology infrastructures are possible changes exhibit in modern buildings (Loftness et al., 2009 cited Choi et al., 2011). Consequently, modern work environments have benefited from modified indoor environmental conditions that have highly increased satisfaction and work productivity of building users (Choi et al., 2011).

Green building concept became prominent in such modern building designs, focusing on the reduction of carbon emissions from and carbon footprint of buildings in order to minimise the environmental effects. However, the foremost benefits of such green concepts also include the reduction of health costs and the improvement of occupants' productivity through their perceived satisfaction towards work areas due to improved Indoor Environmental Quality (IEQ) conditions (Edwards, 2003; Kats, 2003; Ries, 2006 and Ross & Lopez-Alcala, 2006 cited Lacouture, Sefair, Florez & Medaglia, 2008). It is therefore inspiring that there is already a rising national consensus on green buildings. Further, the number of green building projects in both public and private sectors has rapidly increased while much evidence are existed on rental premiums and occupancy differences for green buildings from previous research studies. However, the real impact on occupants' productivity due to green building approach in these buildings has not been evaluated adequately. One widely cited early study by Greg Kats (2003) stated that "present value benefits of $37 to $55 U.S. dollars per square foot as a result of productivity gain from less sick time and greater work productivity in green buildings" (Miller, Pogue, Gough & Davis, 2009). However, the level of improvement of occupants' productivity and the effect of green built environment are still not well addressed in previous researches (Singh et al., 2009). Hence, the identification of critical built environment factors affecting occupants' productivity and its influence on occupants' productivity make this study really momentous.

1.2 Research Problem Statement and Rationale

Many buildings are fast moving into green buildings from their traditional phenomenon due to its social, economical and environmental benefits. Especially, green building design makes sure that the buildings are more efficient, productive and healthy, as a result of the reduction of carbon footprint and indoor environmental conditions. Even though the green building designs came into practice as a solution for carbon footprint of buildings, previous studies verified that there is a potential link between green building environment and occupants' productivity. However, many studies have considered the impact of the design and organisational features of built environment. Much previous research has been of concern in recent years has conducted in the similar research setting; most of them have focused on the single aspects of built environment. There are many other factors that could have critical influence on occupants' productivity in green buildings. Further, no evidences were found on which factors can critically influence occupants' productivity in green built environment. Even though people tend to move towards green from non-green environment in order to obtain its benefits, there is no much concern its effect on occupants' productivity. Therefore, in the line of thinking, the necessity has been emerged to conduct this research and to investigate this gap to identify critical built environment factors influencing occupants' productivity in green certified office buildings. Further, different factors can have different degree of influence on occupants' productivity where it still remains debatable.

In this context, this study intends to identify built environment factors critical for occupants' productivity in green buildings and their degree of influence. Thereby, the following research problem was formulated.

"What are the built environment factors critical for green buildings and its degree of influence on occupants' productivity?"

Based on research question, the research aim and objectives were developed.

1.3 Research Aim and Objectives

The aim of this research is to investigate the built environment factors critical for green buildings and its degree of influence on occupants' productivity in green certified office buildings in Sri Lanka.

In order to achieve the aim, four objectives are formulated as follows;

1. To identify occupants' expectations of green building environment
2. To identify built environment factors influencing occupants' productivity and develop a conceptual framework based on the identified factors
3. To determine built environment factors critical for green buildings and its degree of influence on occupants' productivity
4. To propose probable suggestions to enhance the evaluation criteria of Indoor Environment Quality (IEQ) in national green rating system

1.4 Research Design

The research design is driven by the research aim and objectives which were explored in a quantitative phenomenon. As this research needs quantitative base, survey research method was selected. First two objectives of this study were achieved through comprehensive literature survey and preliminary study. The conceptual framework which was developed based on the literature findings fulfills the second objective of the research. With the deductive intention, two research hypotheses were developed to test. Third objective is achieved through questionnaire survey; it required identifying productivity influencing factors which are critical for green buildings. In fourth objective, the degree of influence of the critical factors on occupants' productivity was determined. Finally, probable suggestions were proposed on national green certification system to enhance the IEQ evaluation criteria. Correlation and ordinal regression analysis techniques were selected as appropriate data analysis tools. The Statistical Package for the Social Science (SPSS) v20 software was used in statistical analysis.

1.5 Scope and Limitations

The scope of this research was to identify the critical built environment factors influencing occupants' productivity in green buildings and its degree of influence. Hence, this study was aimed to study about the effect of built environment on occupants' productivity in green buildings in Sri Lanka.

The study was limited to three green certified office buildings which have obtained green gold certification, to collect the data by considering the similarity of green features, availability of green certified office buildings in Sri Lanka, accessibility and the limited time.

1.6 Thesis Structure

CHAPTER ONE provides an introduction to the research by giving literature background in initiating this study. Further, it presents research problem, aim and objectives as well as the research methodology adopted in this study.

CHAPTER TWO provides the review of literature relating to the research area of occupants' productivity in green buildings by justifying the importance, significance and the value of conducting this research. It consists of the discussions on research domains, paradigms and theories as well as definitions of related key research terms of formulating the research question.

CHAPTER THREE presents the discussion of existing literature relating to the built environment factors influencing occupants' productivity. The main objective of this chapter is to identify built environment factors which required to be considered in research analysis.

CHAPTER FOUR presents the proposed conceptual framework of this research which is developed based on literature review. The developed conceptual framework consists of three levels which are described in this chapter. Hence, this chapter addresses the second objective of this research which guides remaining research questions and objectives of the study.

CHAPTER FIVE presents the research methodology adopted in this research, including the research philosophy, research approach, data collection and analysis techniques with the justifications and the measures of research validity.

CHAPTER SIX intends to present the data analysis and findings (stage one). This chapter will solely present the data analysis and findings to identify significant and critical built environment factors in the deductive research approach.

CHAPTER SEVEN presents the data analysis and findings of stage two. This chapter contains the findings of main research analysis including ordinal logistic regression results and findings, models and the evaluation of the effects of built environment factors on occupants' productivity in green buildings.

CHAPTER EIGHT provides the discussion of test results and research findings by correlating them to the existing literature to fill the research gaps identified. Finally, the test summaries of research hypothesis are presented together with the graphical representation of research findings.

CHAPTER NINE presents the critical review of GREENSL® national green rating system in order to identify its present applications, gaps and the need for further improvements. As the main objective of the chapter, enhancements are suggested based on research outcomes and expert opinions collected through semi structured interviews.

CHAPTER TEN gives conclusions to the overall research by demonstrating the achievement of each and every objective and the aim of this study. It further researches the implications for the theory and practice, recommendations as well as the future research directions.

1.7 Summary

This chapter intended to furnish an introduction to the research through a comprehensive background study. Further, key researches were reviewed and research gaps were identified. Since there is an important area of the research about the relationship between the green built environment and occupants' productivity, the research was aimed to identify significant and critical built environment factors influencing occupants' productivity in green buildings. Based on literature findings, value and rationale of the study, the main research question, aim and objectives were formulated. Four objectives were formulated to achieve the aim of the research. The research scope and limitations and structure of the thesis were described subsequently.

2. OCCUPANTS' PRODUCTIVITY IN GREEN BUILDINGS

2.1 Introduction

This chapter intends to combine the current level of knowledge regarding the research area for further refining of the research problem. Two major sections are included in order to provide a comprehensive literature review on green buildings and occupants' productivity. Green building is defined in comparison to conventional buildings. The benefits and expectations of green buildings, related green environment strategies and measures are also described. Definitions of occupants' productivity and types of productivity measurements are key attributes reviewed in the Section 2.5.

2.2 Green Buildings

2.2.1 Evolution of green buildings

Environmental issues have become an explicit and important matter in the last decade where it has become a key consideration in building design (Cole, 1998). In response to the serious and irretrievable climatic changes, the green revolution has taken place in the building sector. It proposes to basically alter the built environment by creating energy efficient, healthy and productive buildings that cut back the significant impacts of buildings on urban life and global environments (United States Environmental Protection Agency (USEPA), 2009; United States Green Building Council (USGBC), 2009 cited Gou, Prasad & Lau, 2013). While the green construction campaign has gathered momentum in the last decade, the origin can be traced backward to the late nineteenth century.

A paper on sustainable development (2006) mentioned that in 1950-60s, as "green movement" was lifted and performed among western countries, the "green" thought began to be accepted worldwide. The "green" thought intended to protect the natural resources, alter human behavior, convene the ecological virtuous cycle of nature, and make sure the safety of human existence (Xue & Qiu, 2012). In the growing stage of the green concept, the "glass box" style high rise building had become the image of the American metropolis, which was a forward thinking group of Architects and

Environmentalists. It finally has been resulted in the modern build green movement. By the end of 1980s, "sustainable development" had become the worldwide program of action, and at the same time, ecology, sociology, and other subjects extended to the architecture domain, and then "green architecture" concept came out naturally. Sustainable growth is "the development which fulfills the demands of the present without compromising the ability of future generations to satisfy their own needs" (World Commission on Environment and Development, 1987). As it further mentions, there are three essential aspects of sustainable development, such as, economical, environmental and social sustainability. The global sustainability goals have led to the development of the green building movement. Further, green building is the status of the effort in achieving sustainability in construction practices (Sinha, Gupta & Kutnar, 2013).

"Green architecture" is an inevitable effect of the architectural development and the specific reflect on sustainable development in architecture, and also it expands the purpose and functions of building in ecosystem from the ecological viewpoint, and makes us re-know the building. The first appearance of the green building concept has made new changes in understanding of the building wher the building cannot satisfy people's growing needs (Xue & Qiu, 2012). Hence, green building has become one of the greatest and emergent concepts today. Architects, Designers, and homeowners are becoming guaranteed with the cost saving potential, prominence of energy saving, contemporary look, and the symbiotic relationship with environment that green buildings possess (Isnin, Ahamad & Yahya, 2012). Thus, construction activities may not include new building projects or infrastructure and utilities alone, there is a emergent demand for converting buildings towards green (Douglas, 2006 cited Isnin et al., 2012).

2.2.2 Definitions of green building

A survey by Edward (1998 cited Karkanias, Boemi, Papadopoulos, Tsoutsos & Karagiannidis, 2010) noted that the concept of green building had applied in most of the countries to trim down the impact of buildings on the environment and human wellness. As Cheng (2007) stated 'green building is called "Environmental Co-

Habitual Architecture" in Japan, "Ecological Building" or "Sustainable Building" in Europe and 'Green Building' in North American countries. Many terms such as 'green consumption', 'green living', and 'green illumination' have been mostly used. In Taiwan, green has been used as an icon of environmental protection. According to a study by Kohler (1999), giving exact definition to the term 'green' is difficult. However, there is no doubt that the term has a very positive implication (Rees, 1992 cited Kohler, 1999). The term 'green building' is defined in various ways as mentioned in Table 2.1.

Table 2.1: Definitions of Green Building

Year	Source	Definitions
1997	Robert and Vale	'an approach to the built environment which involves a holistic approach to the design of buildings; that all the resources go into a building, be they materials, fuels or the contribution of the users need to be considered if a sustainable architecture is to be produced.'
2000	Batuwangala	'a building, which is designed, built, operated, maintained or reused with objectives to protect occupant health, improve employee productivity, use wisely natural resources and reduce the environmental impact.'
2006	Thormark	a new building philosophy, encouraging the use of more environment friendly materials, and implementation of techniques to save resources and specially the improvement of indoor environmental quality, among others.
2009	Ali et al	'an integrated approach of design, which is used to reduce the negative impact of building on the environment and occupants.'

	Edwin, Qian & Lam	'the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition.'
2012	Deuble & Dear	'green buildings (also referred to as green-intent buildings) by definition, aim to reduce their environmental impact by using less energy in both their construction and operation. Thus, buildings featuring natural ventilation capabilities are typically defined nowadays as green buildings.'
2013	Gau et al	'as those featuring natural ventilation capabilities, i.e. low-energy or free-running buildings, are now at the forefront of building research and climate change mitigation scenarios.'

Granting to the definitions, green building offers an opportunity to create environmentally efficient buildings. Further, it is an integrated approach of design used to diminish the negative effect of buildings on nature and people (Ali et al., 2009 cited Hikmat & Nsairat, 2009). Accordingly, in this study, green building is referred to 'a structure in which using a practice that is healthier, environmentally responsible and more resource-efficient throughout the whole building life cycle including construction, renovation, operation, maintenance and demolition.'

Green construction practices are perceived by many construction industry professionals to be part of the answer to problems affecting the indoor environment of buildings (Hashim, Hashim, Saleh & Kamarulzama, 2011). Keeping and Shiers (1996) further found that recent data had shown that there is an occupier demand for "green" buildings. Still, no light evidence that the level of occupants' comfort and satisfaction are greater in green buildings compared conventional buildings (Hirning, Isoardi, Coyne, Hansen & Cowling, 2012). As stated by Batuwangala (2000), green buildings did not only ensure a sustainable construction and the environment, but also it is beneficial to the building owners and its users.

2.2.3 Green certification

The success of green buildings depends on the quality and efficiency of the green systems introduced. If the building installed with less quality system, it will neither reach the environmental goals nor create the estimated benefits. Therefore, the market demands a usual direction to differentiate green buildings from traditional buildings through the use of standard, transparent, objective, and verifiable measures of green, which guarantee that the minimum green requirements have been reached (Lacouture et al., 2008). Hence, a range of green building evaluation systems, protocols, guidelines and measures have been grown in the past twenty years, which are used to assess and benchmark the levels of achievement in building the green revolution (Yudelson, 2008, 2010 cited Gou et al., 2013). According to a study by Westerberg and Glaumann, (2002) and McKay (2007), green assessment tools were primarily introduced to evaluate specific aspects of a building, relating to sustainability goals. Once measured, buildings could be more easily compared with current and past building practices and other green buildings. Wallhagen (2010) further verified that the green assessment tools could also be employed to create guidelines, benchmarks, ratings and incentives for building construction practices with low environmental impact and for environmental management. Further, green rating tools establish a common language and standards of measurement to delineate green buildings differentiating from traditional buildings (Yudelson, 2008, 2010 cited Gou et al., 2013).

Further, once the appraisal of the environmental impact of a building is extended out before it built and when only the representation of the building is available, environmental impacts of that building could be prevented. Hence, knowledge about the environment and building has to be incorporated. Environmental assessment tools for buildings are projected to provide objective evaluation of resource use, ecological loadings and indoor qualities (Cole, 2005 cited Wallhagen, 2010) and make it possible to measure a number of different environmental aspects of constructions in a systematic manner. The first assessment tool was the Building Research Establishment Environmental Assessment Method (BREEAM) (Baldwin, 1998 cited Lacouture et al., 2008) and, the most representative and widely used green assessment tools are Leadership in Energy and Environmental Design (LEED), Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), Green Star, Green Building Index (GBI) - Malaysia, Green Mark - Singapore, Hong Kong Building Environmental Assessment Method (HK-BEAM) and the Pearl Rating System for Estidama (Sustainability) (Roderick, McEwan, Wheatley & Alonso, n.d.; Boonstra & Pettersen, 2003; McKay, 2007).

Very comprehensive inventories of such available tools for environmental assessment methods can be found in the Whole Building Design Guide and the World Green Building Council. Although the existing methods and tools have an extensive use, LEED has established strong credibility among the experts by increasing its affiliates (Pulselli et al., 2007 and Ding, 2008 cited Lacouture et al., 2008). In general, these tools are characterized by assessing the number of building features and combined these results with the environmental rating. In this process fundamentally different aspects like indoor climate and energy use have been added (Assefa, Glaumann, Malmqvist & Eriksson, 2010). In order to develop the green assessment tools, existing sustainable practices, such as increased day lighting, operable windows, and native plants; improved efficiencies (energy and water use), monitoring and commissioning; and promoted biodiversity, material reuse, recycling and urban infill or densification have been used (McKay, 2007). Among those sustainable aspects, IEQ is a major concern in developing such green assessment tools due to its substantial effect on the wellbeing of the building occupants. Thus, most of green assessment tools specially LEED, BREEAM, Green Star and CASBEE techniques have been introduced by concerning IEQ as a major criterion in green buildings. Specially, in CASBEE and LEED assessment tools, IEQ has been considered as one of most significant criteria compared to other techniques. Furthermore, each assessment tool consists of various IEQ aspects in order to guarantee a high quality indoor environment within buildings. According to such green assessment tools, namely, LEED, BREEAM, CASBEE and Green Star, indoor air quality, day lighting and lighting quality are highly considered as IEQ measures in each technique while CASBEE contains many other factors such as, temperature and humidity, acoustic and ventilation. Furthermore, thermal comfort and access to views are considered in IEQ criteria of LEED, BREEAM and Green Star tools excepting CASBEE. Consequently, different nations have implemented different green assessment tools to facilitate high quality indoor environment for building occupants.

2.3 Green Certification in Sri Lanka

Similarly, in Sri Lanka, there is a local rating system called GREEN$^{SL®}$ introduced by the Green Building Council in Sri Lanka (GBCSL). GBCSL launched in November 2009 as a non-profit organisation that is devoted to extend a sustainable building industry in Sri Lanka by encouraging the adoption of green building practices. The Green Building Council of Sri Lanka (GBCSL) came into practice as a result of a growing demand of applying the greener concepts for building environment. Moreover, it is exclusively supported by both industry and government institutions across the country. According to Green Building Council of Sri Lanka (GBCSL, 2011), eight domains were considered in green certification. Each domain category contains number of aspects. The number and nature of aspects vary from one category to another as per the category itself and its importance in matching the local context. The GREEN$^{SL®}$ rating system further defines the concept of green buildings as "a way of increasing the efficiency with which buildings use resources such as energy, water and materials while reducing the impact of buildings on human health and its surrounding environment during its lifecycle, through better design, construction, operation, maintenance and removal and recycling of waste." Hence, such concept will promote high performance, healthy, durable, affordable, and environmentally sound practices for both new and existing buildings (GBCSL, 2011).

Many studies have found that occupants are more favorably disposed to green buildings (Paul & Taylor, 2007). However, according to a study by Lacouture et al (2008), green building design would become a more common practice once the human benefits are identified. Noticeably, human benefits should become more prominent where occupants' comfort and satisfaction lay the foundation for a healthy and productive building (Gau et al., 2013). However, there is little understanding of how such benefits might accrue.

2.3.1 Domains of GREEN$^{SL®}$ rating system

There is a local rating system called GREEN$^{SL®}$ introduced by the Green Building Council in Sri Lanka (GBCSL). The main purpose of the GREEN$^{SL®}$ rating system is to encourage the design of buildings in an environmentally acceptable manner. Further, the GREEN$^{SL®}$ rating system is used as a tool to evaluate the efficiency of the built environment in several aspects such as management, energy, indoor environmental quality, materials etc. According to GBCSL (2011), eight domains were identified in GREEN$^{SL®}$ rating system as illustrated in Table 2.2.

Table 2.2: Points assigned for domain categories

Domain category	Number of points
Management	04
Sustainable sites	25
Water efficiency	14
Energy and atmosphere	21
Material and resources	21
Indoor Environmental Quality	13
Innovation and design process	04
Social and cultural awareness	03

Source: GBCSL (2011)

The domains of GREEN$^{SL®}$ rating system include management, sustainable sites, energy and atmosphere, water efficiency, indoor environment quality, materials and resources, innovation and design process, and social and cultural awareness. Each domain category has number of aspects. The number and nature of aspects vary from one category to another. Further, the points are assigned for each category and the rating is given upon the total marks earned by each design or building solution as mentioned in Table 2.2.

Building owners can obtain points for each and every domain by implementing aspects and strategies within their built environments given under the GREEN$^{SL®}$ rating system handbook.

2.3.2 Indoor Environmental Quality in GREEN$^{SL®}$ rating system

The certifications from the GREEN$^{SL®}$ rating system for the built environment are awarded according to the following scale;

- Certified, 40–49 points
- Silver 50–59 points
- Gold 60–69 points
- Platinum 70 points and above

Henceforth, building owners have tended to obtain green certification based on above certification levels expecting several benefits. IEQ is one of the main goals of GREEN$^{SL®}$ certification to provide healthy interior spaces for building occupants. The IEQ consists of several aspects with number of points assigned as mentioned in Table 2.3.

Table 2.3: IEQ aspects and points assigned

INDOOR ENVIRONMENTAL QUALITY		13 Total Points Available
Prerequisite 1	Minimum IAQ performance	Required
Prerequisite 2	Smoke (ETS) control	Required
Credit 6.1	Outdoor air delivery monitoring	1 Point
Credit 6.2	Increased ventilation	1 Point
Credit 6.3	Construction IAQ Management Plan	
	Credit 6.3.1 - Construction IAQ management plan before and after construction	1 Point
Credit 6.4	Low - emitting materials [1-3 Points]	
	Credit 6.4.1 - Paints and coatings	1 Point
	Credit 6.4.2 - Carpet systems	1 Point
	Credit 6.4.3 Composite Wood and Agrifiber Products	1 Point
Credit 6.5	Indoor Chemical & Pollutant Source Control	1 Point

Credit 6.6	Controllability of Systems [1-2 Points]	
	Credit 6.6.1 Lighting Controls	1 Point
	Credit 6.6.2 Comfort Controls	1 Point
Credit 6.7	Thermal Comfort, Design	1 Point
Credit 6.8	Thermal Comfort, Verification	1 Point
Credit 6.9	Daylight & Views [2 Points]	
	Credit 6.9.1 - Daylight	1 Point
	Credit 6.9.2 - Views	1 Point

Source: GBCSL (2011)

2.4 Expectations of Green Building Environment

Green building design creates potential links with organisational performance, while taking on a major role in the expectations expressed by the owners and occupants and in its fulfillment by designers and building operators. The difference between expectations and fulfillment are uncontrollable throughout the building delivery process. The improved match between these two is an important intention for the building industry to become more clients' driven. Further, it helps to provide better overall value and to increase occupants' satisfaction and productivity (Koskela, 2000 cited Augenbroe & Park, 2005).

As many studies found, occupants are more favorably moved to green buildings rather than for conventional energy-intensive buildings (Leaman & Bordass, 2007; Abbaszadeh et al., 2006 cited Deuble & Dear, 2012). It is widely thought that green buildings are more comfortable than conventional buildings; there is a little empirical evidence to endorse this belief (Paul & Taylor, 2007). The past decade marks a transformation from thinking of facilities as a way to house the workforce to think about the entire building portfolio of a company in strategic terms in order to enhance organisational effectiveness and productivity. Many owners-occupied buildings have been designed or modified to insure that they match the owners' needs. Owner-occupiers have a substantial vested interest in energy efficiency, low running costs and a low environmental impact (Barlett & Howard, 2000). In conditions of the building owner's financial budget, energy prices are still comparatively low compared to workers' salaries, which represent over 90% of the yearly operating costs per square foot of a commercial building (Kats et al., 2003 cited Brager & Baker, 2009). In addition, the cost of workers' recruitment and retention is significant (Institute for a Competitive Workforce (ICW), 2001 cited Brager & Baker, 2009). As per the owner's perspective, most convincing argument for sustainable design in general is operable windows in particular, where applicable, is one that makes the connection between a higher quality indoor environment and increased comfort, health and productivity (Yu & Kim, 2011). Henceforth, it is vital to ensure that the occupants' needs are being addressed and that claims of performance are acceptable in green buildings as it can be directly affected on occupants' productivity.

Further, it is necessary to guide positive decision-making and action, interest in understanding the quality of experience that buildings afford their users (Cole, 2010; Borgeson & Brager, 2011). As Paul and Taylor (2007) verifies for all actors involved in planning, developing and managing green buildings, the environmental impact relating to energy use and the quality of the indoor environment are both aspects of major concern. Many studies stated that the high quality indoor environment is the major expectation of building occupants as it was directly affected on their health, well-being and the productivity.

2.4.1 Indoor Environmental Quality improvements

The quality of the built environment is one of the main goals in many green certification systems. This is because green building certification schemes require building designers and managers to consider the impact of the indoor environment on the health and wellbeing of the office worker. The Table 2.4 shows that the level of consideration of green building certification systems on indoor environment.

Table 2.4: Indoor Environmental Quality criteria in green assessment tools

% of IEQ							
CRITERIA	**LEED**	**BREEAM**	**CASBEE**	**Green Star**	**GBI Tool**	**Green Mark**	**GREEN$^{SL®}$**
Management	04	16	05	09	39	-	04
IEQ	21	16	23	19	11	04	13
Energy	23	15	18	18	23	56	22
Transport	06	13	00	19			
Water	10	05	03	12	12	09	14
Materials	18	11	12	19	09		14
Land use	08	08	19	06	-	-	-
Environment protection	10	15	20	07	-	26	-
Innovation	-	-	-	-	06	-	04
Sustainable sites	-	-	-	-	-	-	25
Social and cultural awareness	-	-	-	-	-	-	04
Other features	-	-	-	-	-	05	-

Sources: Boonstra and Pettersen, 2003; Haapio, 2008; Wallhagen, 2010; InBuilt, 2010; GBCSL, 2011; BCA Green Mark, 2013

The indoor environment is one of the major criteria in many green certification systems such as, LEED, and CASBEE, which is required to ensure by building designers and managers to obtain the green certification for buildings. Whilst a certified green building does provide a high quality indoor environment with a number of built environment features, the overall certification does not robotically assure that all key features are fulfilled. According to the level of the certification chosen, for example "gold" or "platinum" for LEED or "excellent" or "outstanding" for BREEAM and the profile of credits reached, the actual indoor environmental quality can be different (Jones Lang LaSalle's Global Sustainability Perspective, 2011). However, due to the explicit formulation of the existing green building certification systems, the key stakeholders of a new office development, a refurbishment or fit-out project will necessarily need to address these quality features. Many researchers believed that the green building design would become more common practice once human benefits had been identified. The concern on human benefits has become a hot spot of research on green buildings because, occupants comfort and satisfaction on built environment may lead towards healthy and productive buildings (Heerwagen, 2000).

2.4.2 Green building design and occupants' productivity

A well understanding of human and organisational benefits of green buildings insists a broader perception that links building design, organisational performance, and human factors together (Paul & Taylor, 2007). "It creates an importance to identify what are the key green building features and attributes? How do these physical elements affect the physiological, psychological, cognitive, and social functioning of building occupants? Just as important from a business perspective: can green buildings affect high level organizational outcomes, such as profitability, customer satisfaction, and innovation?" (Heerwagen, 2000).

Heerwagen (2000) further states, many studies provide evidence that there was a potential link between sustainable design and operations associated with green buildings and organizational performance. Such potential connections between green buildings and overall organizational success are still in the formative stages; nonetheless, case studies as well as theoretical considerations suggest multiple links. Green building design can potentially affect the organizational performance; financial stability, business process, stakeholder relations and Human Resource (HR) development.

Figure 2.1 shows that green building design can affect organisational performance outcomes.

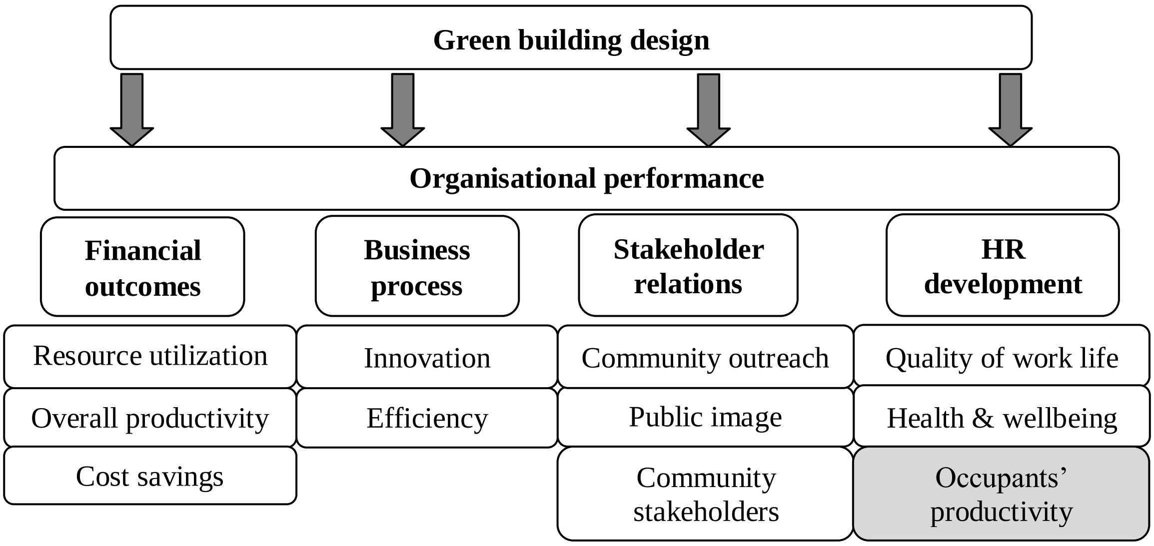


Figure 2.1: Potential links between green building design and occupants' productivity

Source: Heerwagen (2000)

In the perspective of impacts of green building, it could mainly influence strategic performance and human resource development in any organisation. Strategic performance relates sustainable design to financial attainments, stakeholder relations, and business process development. Human resource development focuses on enhancing indoor environmental quality towards human factor outcomes. Conversely, better indoor environment is likely to have the utmost impact on wellbeing and personal productivity.

2.4.3 Occupants' productivity in green buildings

A number of case studies proposed that productivity enhancement through better quality indoor environment may be possible. While the question of a consistent definition and measurement of office productivity is still far from being solved, there is market acceptance of a relationship between an office's indoor environment, its layout and comfort factors, and the level of occupant wellbeing and resultant productivity levels. The extent of importance of the specific factors is still being debated. However, today most organisations are looking at the occupants' needs as the health and productivity of occupants is positively correlated with comfort and satisfaction (Leaman & Bordass, 2001). Further, they are interested in proactively linking occupants' productivity and wellbeing to the office environment. Granting to the case studies by Urban Catalyst Associates (2005), occupant productivity is a most important benefit of green buildings, even though the value of improved occupant productivity and healthier built environments is difficult to estimate. The study further mentioned about 1%-1.5% productivity gain from healthier working environment after moving to green buildings. According to the Jones Lang LaSalle's Global Sustainability Perspective (2011), green buildings and their attention to high quality indoor environment provide a perfect background for such considerations. Whilst green developers and builders create healthier working, learning, and living environments, it is not only reducing utility bills, operation and maintenance cost but also increasing occupants' productivity.

Hence, green building shows an improved indoor environment compared to traditional buildings and, it many lead towards productivity improvements of green occupants. The interplay between green buildings and occupants' productivity can be illustrated in this regard, however; the most critical built environment factors affecting occupants' productivity in green buildings and its degrees of influence are still remaining ambiguous.

2.5 Occupants' Productivity

Based on previous research, "one of the most significant impacts of green buildings is expected to be on occupants' productivity. However, productivity is usually one of the hardest measuring concepts due to data requirements and lack of well defined metrics" (Ries, Gokhan, Needy & Lascola, 2006. p. 5).

2.5.1 The concept of productivity

> "Productivity is not everything, but in the long run it is almost everything."
>
> (Krugman, 1994)

Productivity is commonly defined as a ratio between the output and inputs. In other words, it measures how efficiently the production inputs, such as labour and capital, which are being used in an economy to produce a given level of output (Krugman, 1994). As Rutkauskas and paulavicien (2005) further mentioned, productivity in economic position could be defined as the relation between output and inputs.

Productivity is defined as a ratio of output to input;

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

Productivity has become a domestic word as almost everyone talk about it. Yet, the term 'productivity' means differently to different persons. As a phenomenon, it ranges from efficiency to effectiveness, to rates of turnover and absenteeism, to output measures, to measure of client or consumer satisfaction, to intangibles such as disruption in workflow and to further intangibles such as team spirit, loyalty and business satisfaction. "The concept of productivity has linked with quality of output; input and the interacting process between the two. An important element is the quality of the work force, its management and working conditions as it has come to be observed that rising productivity and improved quality of working life go hand in hand" (Oyeranti, n.d. p.1). Further, there is a direct relationship between productivity and the standard of living (Miller et al., 2009).

2.5.2 Occupants' productivity in office environment

Many drivers of occupants' satisfaction also lead to occupants' productivity. If they are easily educated and understand the business, occupants can play their part in the business activities and in team efforts to maximizing their productivity. Rolls (1997 cited Hameed & Amjad, 2009) defined the occupant productivity as a something, which can produce by people with less exertion. Productivity is also defined by Sutermeister (1976 cited Hameed & Amjad, 2009) as an output per employee hour where the quality is considered. According to Dorgan (1994), productivity is the increased functional and organizational performance, including quality. In this case, performance will increase when there is less absenteeism, less frequency of breaks obtained by employees etc.

However, there is no clear definition for productivity in the office environment. It is because that the office can consist of different jobs and tasks, making it difficult to compare or aggregate and thus, there is a large variance among them (Sullivan, Baird & Donn, 2013). Many researchers have shown that the definition of productivity in the context of the agency is highly problematic (Leaman & Bordass, 1999; Oseland, 1999). Farther, the productivity can be amended by increasing the quantity of what one produce or by improving the quality of what is brought forth. Nevertheless, specifying these for office work can be very hard and potentially impossible to do objectively (Leaman & Bordass, 1999).

Satisfied occupants work in a friendly environment, where they enjoy the mutual respect of fellow workers and employers (Centre for the Study of Living Standards, 1998). In such movement of occupants towards favorable and quality work environment, especially moving to green buildings from conventional office settings have become one of the most significant impacts expected to be on occupants' productivity (Ries et al., 2006). Studies by Kroner, Stark-martin and Eillemain (1992) and Wyon (1996 cited Heerwagen, 2000) proved that more skillful control of workplace conditions produced a three percent productivity growth compared to less quality working environments. Henceforth, increased personal control and comfort needs of occupants triggered the concern among organizations to furnish them with an environment and office design, which fulfills the occupants' needs and helps to boost their productivity (Hameed & Amjad, 2009). Hameed and Amjad (2009) further verified that better results and increased productivity was assumed to be the result of healthier workplace, as the better physical environment would increase the occupants' productivity.

2.5.3 Measurement of productivity

There are numerous ways to measure productivity. Most of the methods are based on quantitative data on operations. In many cases, it is somewhat difficult and sometimes even impracticable to collect the data essential for productivity measurement. Kemmila and Lonnqvist (2003 cited Miller et al., 2009) pointed out that measuring productivity directly is a big challenge, especially in the office environment. While productivity was at its roots an objective and quantifiable measure, relating inputs to end products, objective criteria are often highly limited and inappropriate for many office related tasks. Factors such as quality and interpersonal relationships are not widely countable, but may be very important (Sullivan, Baird & Donn, 2013). So, overall productivity in the office cannot really be measured because productivity cannot be measured simply; it is often defined more vaguely, in terms of several constituents such as behavior, cognitive performance, absenteeism, job satisfaction and sleepiness etc (Koopmans, Bernaards, Hildebrandt, Schaufeli, De Vet Henrica & Van Der Beek, 2011). Most of those measures are subjective and this makes estimating overall productivity problematic, as individual task productivity cannot simply be aggregated. Even though productivity could be expressed in quantitative terms, applying financial and economic criteria, such as sales turnover per employee, rather than assessing subjectively, based on occupants' perception, time lags and other extraneous elements that need to be brought into account.

Hadi (1999 cited Miller et al., 2009) believes productivity measures should be divided into three sections: quantifiable and tangible measures, indirect measures, and organizational measures such as teach-work and creativity using data collection methods such as questionnaires, observational techniques, structured interviews, focus groups and job/labor analysis. Accordingly, various ways have been applied in similar previous researches to measure occupants' productivity in the context of office works.

2.5.3.1 Use of neurobehavioral approach

Neurobehavioral approach can be effectively used in environmental and occupational decision making to find out safe exposure levels, preventing the arrival of untimely bad effect on the nervous system and to evaluate the productivity of office workers (Lan, Lian, Pan & Ye, 2008; Lan & Lian, 2009). In this approach, the behavioural changes of office workers may evaluate as the effect of environmental factors. As Lan et al. (2008) further verified "the behavior may be conceptualized in terms of three functional systems such as cognition, which is the information-handling aspect of behaviour; emotionality, which concerns feeling and motivation; and executive functions."

2.5.3.2 Objective measurements of productivity

According to the studies by Hadi (1999 cited Miller et al., 2009) and Hameed and Amjad (2009), occupants' productivity can be assessed by objective measures. These objective measures are based on occupants' performance. For example, revenue calls handled, number of flight segments arranged by reservation personnel for delivery, the average time a reservation clerk is unavailable between calls, measuring the speed of working and the accuracy of the outputs by designing very controlled experiments with well focused tests can be considered as objective measures in assessing occupant productivity in an office working environment (Bluyssen, 2010).

2.5.3.3 Subjective measurements of productivity

The measures of this method are not based on quantitative operational information. Instead, they are based on personnel's subjective assessments. Wang and Gianakis (1999 cited Hameed & Amjad, 2009) have defined subjective performance measurement as an indicator to assess individuals' aggregated perceptions, attitudes or assessments toward an organizations product or service. Subjective productivity data are usually collected using survey questionnaires. Subjective data can also be descriptive or qualitative collected by interviews (Clements-Croome & Kaluarachchi 2000). As a result, research in office settings often resorts to self ratings of perceived productivity or to combinations of self administered methods (Heerwagen, 2000). "As an example of this situation is the work of professionals and experts. Their work is knowledge-intensive and the inputs and outputs are not easily quantifiable. Essentially, this is because direct measurement for professionals in an office environment requires the ability to monitor things such as the ability to focus and think, synthesize and add value to the firm, ability to measure the contribution of individuals that likely work in a team environment and the ability to monitor quality of work as well as efficiency and output" (Kemmila & Lonnqvist, 2003 cited Miller et al., 2009).

Subjective ratings of productivity are used in many studies (Leaman & Bordass, 1999; Lee & Guerin, 2010; Mak & Lui, 2012). The use of simple surveys measuring subjective productivity has many advantages such as, quick, easy and convenient, relatively cheap and, specially, questions about general productivity can be given to people in different buildings and jobs without being tailored to the specific situation; large samples can be analysed across many buildings; and the development of databases containing the results from many buildings measured with the same general questions allow results to be compared to benchmarks (Leaman & Bordass, 1999). Further, it is an attractive option to measure the productivity of office workers due to the difficulty of defining any generally useful objective measure of office worker productivity. Indeed, one of the key arguments about subjective measures has introduced by Haynes (2008) as "a self-assessed measure of productivity is better than no measure of productivity." Accordingly, due to the difficulty in defining office worker productivity in a quantitative way, the current consensus seems to be to accept subjective productivity measures.

2.5.3.4 Perceived productivity (self-rated productivity) measurement

Work output is impossible to measure meaningfully for all building occupants. The use of the scale of perceived productivity is the better way rather than measuring productivity directly. It has been used in many occupants productivity related studies mainly in Building Use Studies (BUS) survey questionnaires in the year 1987 with its intended advantages as a subjective method of productivity measurement. However, there are a variety of variables used to rate the perceived productivity of occupants in office buildings. As an example, the same question on occupants' productivity has been developed in different ways in different scales.

Clements-Croome and Kaluarachchi (2000):

> *"Rate their level of productivity on a seven-point scale, from extremely dissatisfied to extremely satisfied"*

Building Use Studies Survey (1987 cited Clements-Croome, 2000):

"Please estimate how you think your productivity at work is increased or decreased by the environmental conditions in the building?"

Similarly, the scales used also vary in previous studies, including many numerical and ordinal scales as mentioned below,

Building Use Studies Survey (1987 cited Clements-Croome, 2000): The BUS survey uses a 9-point scale, from -40% to 40%.

"Please estimate how you think your productivity at work is increased or decreased by the environmental conditions in the building?"

-40% -30% -20% -10% 0% 10% 20% 30% 40%

Center for the Built Environment (2013 cited Lan, Lian, Li & Ye, 2009): CBE survey uses a smaller scale.

-20% -10% -5% 0% 5% 10% 20%

Humphreys and Nicol (2007): Use of ordinal scales with five point scale.

"Do you feel that at present your productivity is being affected by the quality of your work environment and if so to what extent?"

1. *Much higher than normal*
2. *Slightly higher than normal*
3. *Normal*
4. *Slightly lower than normal*
5. *Much lower than normal*

Hence, perceived productivity can be used as a suitable way to assess productivity of office workers as it is evident that perceived productivity may reflect actual productivity.

2.5.4 The occupants' productivity measurement technique used in this study

Measuring productivity of occupants in an office environment is a big challenge as it incorporates the kind of different tasks and projects. Accordingly, various ways have been applied in similar previous research studies to measure occupants' productivity in the context of office works such as neurobehavioral approach, objective and subjective measurements including perceived productivity measurement. The technique of perceived productivity was selected as the best approach for this study as it evaluates occupants' productivity in green office buildings selected in the sample. Further, it is widely used rating technique, being relatively simple, quick and cheap.

Considering the measures and scales used in similar previous studies, five point ordinal scale was developed to rate perceived productivity of occupants and the influence of built environment factors in this study.

The developed question and the scale used for rating perceived productivity of occupants' in green office buildings are given as follows,

Please score the level of your productivity, which is influenced (increased or decreased) by the built environmental conditions in the building?"

1	2	3	4	5
Much Lower	Slightly Lower	Normal	Slightly Higher	Much Higher

Accordingly, the questionnaire was developed in consideration of the perceived productivity rating, to evaluate the occupants' productivity in green buildings (Refer Appendix 5.2 for questionnaire developed).

2.6 Summary

This chapter intended to describe the existing literature domains, paradigm and definitions relating to green buildings and occupants' productivity. Firstly, green building was defined by considering various definitions given by previous research studies. The definition for green building in this research is 'a structure in which using a practice that is healthier, environmentally responsible and more resource-efficient throughout the building life cycle including construction, renovation, operation, maintenance and demolition.' The available local and international green assessment tools such as BREEAM, LEED, CASBEE, GBI tool, HK-BEAM and GREEN$^{SL®}$ rating systems were reviewed to identify provisions for indoor environment quality evaluation. The expectations of the green building environment were also described. Many studies stated that the high quality indoor environment is the major expectation of building occupants as it directly affects on their health, well-being and the productivity. According to the reviewed literature, green building design can potentially affect the organizational performance; financial stability, business process, stakeholder relations and Human Resource (HR) development. Based on literature findings, the relationship between occupants' productivity and green buildings was identified. As a key term in this research, occupants' productivity was defined and both subjective and objective measures were identified. The perceived productivity measurement was selected as the suitable approach for this research.

3. BUILT ENVIRONMENT FACTORS

3.1 Introduction

This chapter presents the review of existing literature relating to the built environment factors influencing occupants' productivity. As the main objective of the chapter, drivers of occupants' productivity, the importance of the built environment for productivity improvements related literature was reviewed. Accordingly, built environment factors are identified relating to the major dimensions of built environment whilst relevant quality measures and standards are also appraised subsequently.

3.2 Driving Factors of Occupants' Productivity

Better results and increased occupants' productivity are taken for granted to be the result of better workplace environment. Many of the drivers of employee satisfaction also drive employee productivity. If they are well trained and understand the business, employees can play their part in the business activities with team effort so that they can exploit their productivity. Prompted by the regard of their employer, a balanced scorecard, and a sensation of accomplishment, employees hit their best attempt to be productive (The Layers of Veterinary Financial Success, n.d.). Hence, many factors could affect productivity to increase or decrease. The Hawthorne studies identified that establishing a link between the performance of employees and their working environment was a complex one (Roethlisberger & Dickson, 1939 cited Haynes, 2008). Nevertheless, both the physical and the social components existed in the working environment can have a respective effect on productivity in the end user's perspective (Haynes, 2008). Further, the better physical environment of the office will boost the employees and ultimately improve their productivity (Hameed & Amjad, 2009). Among the other studies, Clements-Croom and Kaluarachchi (2000) propose that the productivity depends on healthy buildings and therefore productivity measurement should be incorporated with health, wellbeing and comfort. Clements-Croom and Kaluarachchi (2000) further verified that among the other factors, there were four main factors influencing productivity, namely, personal, social, organizational and physical environmental factors (refer Figure 3.1).

Personal	Career achievement, home/work interface intrinsic to job
Social	Relationship with others
Organisational	Managerial role, organisational structure
Environment	Indoor climate, workplace, Indoor Air Quality

Figure 3.1: Driving factors of occupants' productivity
Source: Clements-Croom & Kaluarachchi (2000, p.11)

The studies identified that the physical factors of the working environment were not the only factors involved in impacting productivity. The social factors, and the wider issues of human relations, played a significant role in determining occupants' productivity. Duffy (1992 cited Clements-Croom & Kaluarachchi, 2000) further argued that many organisational factors, and distractions and mismatch between occupiers work activities and working environment provided by an organisation could also be the major causes affecting productivity.

3.3 Importance of Built Environment for Occupants' Productivity Improvement

The human-made surrounding has become a most sensitive indicator as it provides the setting for human activity, ranging in large scale civic surroundings to the personnel places. The built environment is a material, spatial and cultural product of human labour that combines the physical elements and energy in forms for living, working and playing. Further, it has been defined as 'the human-made space in which people live, work, and recreate on a day-to-day basis'. The built environment, which is a space consisting a complex and dynamic combination of physical, biological, and chemical factors that can affect the occupants health and physical reactions anytime whether realize it or not (Kamaruzzaman & Sabrani, 2011). As the majority of people spend most of their time indoors, there is a continuous and dynamic interaction between the occupants and their surroundings that produce physiological and psychological effects on the person (Lan & Lian, 2009; Kamaruzzaman, Egbu, Zawawi, Ali & Che-Ani, 2011). In buildings, however, a person usually shares the built environment with other occupants (Frontczak & Wargocki, 2010; Deuble & Dear, 2012).

The quality of buildings, including their performance in a range of indoor environmental attributes, is influential to the living quality of habitants (Lai & Yik, 2008). Numerous studies have shown that indoor climate impacts both health and performance, which in turn affect productivity (Mahdavi & Unzeitig, 2004). Some research results showed that the indoor environment had the biggest influence on productivity in relation to the job stress and job dissatisfaction. It is due to that the bad quality of indoor environments may cause health problems to employees in office buildings, thus, decreasing productivity (Ries et al., 2006 cited Lacouture et al., 2008). As Clements-Croome (2000) stated that it has been consistently argued that the quality of built environments can significantly affect the health, comfort, satisfaction, and productivity of office workers. Further, Eschenbach et al, (1989 cited Mahdavi & Unzeitig, 2004) verified that this would be of major social and economic consequence, as a large fraction of the work force in modern societies spent the bulk of their productive time in indoor environments.

According to a study by Kamaruzzaman et al. (2011), it is essential for buildings to have a good quality indoor environment, as it affects the productivity and health of the occupants of the building. It is also critical that sustainable development results not just in resource conservation, but also in increasing productivity and occupant well-being. Accordingly, the significant impact on creating change in terms of improving the building environment can be achieved in two ways. Firstly, by providing lessons and feedback for owners or those involved in the environmental improvement works. This could lead towards the enhanced quality of indoor environment by addressing the changing needs of occupants. Secondly, it could empower end-users and provide a benchmark and a pool of analysis to show how the end product, including the building design and its environmental management meets the needs of its client and users. Therefore, improving indoor environment is deemed to be the most important factor in the office productivity study (Lan & Lian, 2009). It has been shown that the possibility to control indoor environments can lead to an increase in occupants' productivity (Wyon, 1996 cited Heerwagen, 2000).

3.4 Built Environment Factors Influencing Occupants' Productivity

According to the studies by Menzies et al (1997) and Mahdavi and Unzeitig (2004), the quality and efficiency of indoor environments can be substantially improved with proper planning, including that of interior design. On the other hand, it also showed that when space use is improved significantly, measures must be taken to guarantee a sufficient level of Indoor Air Quality (IAQ) and climate quality. Mahdavi and Unzeitig (2004) further stated such improvement in the quality of indoor climate is cost-effective when its economic impact on health and productivity are taken into account in addition to the investment, operation and maintenance costs. Even though indoor environment attributes have great influence on occupants' productivity, the assessment of the effect of the indoor environment on productivity remains to be the major challenge (Lan et al., 2008). Further, fewer studies have considered the impact of the design and organizational features of the built environment (Mahdavi & Unzeitig, 2004). Importantly, built environment can be highly affected on occupants' productivity among the other factors as there is clear evidence that the health and productivity of occupants is positively correlated with comfort and satisfaction (Leaman & Bordass, 2001 cited Brager & baker, 2009).

Most of the previous research studies have been considered mainly on indoor environmental quality factors, including thermal quality, day lighting, Indoor Air Quality, ventilation and acoustic quality (Augenbroe & Park, 2005; Ries et al., 2006; Lai & Yik, 2008; Lan & Lian, 2009, Bluyssen, 2009; Hui, Wong & Mui (2009). According to a study by Raw (1998), ventilation, thermal quality, day lighting and lighting quality are major built environmental factors influencing occupants' health and productivity. In addition, spatial comfort, office layout, general building maintenance, appearance of the workplace, office type, building materials used were identified as other influencing factors.

Once most of the numerous studies have been verified the relationship existed between the built environment factors and occupants' productivity. The main and sub factors of built environment influencing occupants' productivity were identified by critically reviewing the previous literature.

The followings are the major dimensions of the quality of built environment.

- Thermal quality
- Indoor Air Quality (IAQ)
- Visual quality
- Acoustic quality
- Spatial quality
- Ventilation
- Appearance of the workplace
- Building maintenance and cleanliness
- Office type
- Building materials used
- Office layout
- Social engagement

Workplace arrangement, office layout and furniture are major attributes that need to be considered in planning the workplace arrangement. Further, personal control on ambient conditions, building maintenance and cleanliness are other factors influencing occupants' productivity. A study by Clements-Croome (2000) identified that the quality of office space could have significant impact on the health, comfort, satisfaction and productivity of office workers. As Clements-Croome further verifies, provisions of day lighting and lighting quality have a great influence on occupants' productivity as some electronic lighting devices can generate radiation and electromagnetic fields would badly affect occupants; health and productivity. Further, the appearance of the workplace, including art and aesthetic and building materials used in building can also have an influence on occupants' productivity. A study by the Clements-Croome in year 2002 had identified another built environment factors such as, thermal quality, Indoor Air Quality and acoustic quality (Clements-Croome, 2002).

As Bartlett & Howard (2000) mention, thermal quality, Indoor Air Quality and day lighting are the major built environment factors influencing occupants' productivity. However, a study by Heerwagen (2000) had come up with different views by identifying the influence of thermal quality, Indoor Air Quality and especially the influence of spatial comfort on occupants' productivity. As Heerwagen further stated that, the provisions for personal control workstations, privacy, psychological restoration and relaxation and provisions to avoid distractions were the main features which can have greater influence on occupants' productivity. Further, sensory variability has identified as a major criterion under thermal comfort of office environment. Contact with nature and views, art and aesthetic provisions are other built environment factors identified in this study. A previous environmental study conducted by Muhi & Butala in the year 2003 identified the ventilation can have a high influence on occupants' productivity as the amount of ventilation flowing into a building is the amount which would satisfy the majority of occupants. As they further identified, IAQ, maintenance and cleanliness are other factors where special comfort has been identified as the main factor that needs to be considered in designing the workspace. Hence, ergonomics, work instruments and aids, architectural arrangement of the workplace, floor coverings and wall hangings are required to be considered (Muhi & Buthala, 2003).

A study by Mahdavi and Unzeitig (2004) stated that six major factors influencing occupants' satisfaction and productivity, including space arrangement, office layout, thermal quality, social engagement, visual comfort and acoustic quality. As they further analyse, access to window, orientation of the office towards outdoor environment, contact with the nature and view to outdoor environment are sub factors of space arrangement whilst ergonomics, screen positions of work station, furniture flexibility and space flexibility are major attributes of office layout. Thermal quality includes several sub factors such as, temperature, opening windows, air quality, ventilation possibility, thermal control whilst day light, electric lighting quality, visual control and glare are sub factors for visual comfort, background sound level, acoustical partitioning are factors under acoustic quality and space for informal meetings, access to documents are sub attributes of social engagement.

According to the previous productivity related studies by Ries et al. (2006), Kim et al. (2007 cited Lee, 2010) and Codinhoto, Tzortpoulos, kagioglou, Aouad & Cooper (2009), furniture, office instrumentality, personal control on ambient conditions, building materials used, office layout, symbolism, building maintenance, cleanliness, art and aesthetic are other built environment factors influencing occupants' productivity. In addition, visual comfort can be facilitated to occupants by providing controllable task-lighting, illuminance on visual performance and controllable lighting installations (Juslen, Wouters & Tennerb, 2006). As stated by Saari, Tissari, Valkama & Seppanen (2005), natural ventilation and mechanical cooling could provide for proper ventilation of a building, whilst indoor temperature, background noise levels, interior design are sub attributes of thermal quality, acoustic quality and spatial comfort respectively. Further, air temperature was deemed to be one of the most important indoor environmental factors that affected office productivity (Lan et al., 2008).

As Bluyssen (2010) identified in his study, temperature, activity and clothing of occupants, lighting intensity, colour, illuminance, view to outdoor environment, dust, odor, distractions, background noises, sound absorption materials are other sub attributes of thermal quality, visual quality and acoustic quality. Further, daylight and views, personal thermal system controls, available personal lighting/task lighting, system controls, proximity to a window and direction of closest window are other built environment sub factors (Lee & Guerin, 2010). Kim and Dear (2011) has studied on IEQ factors on occupants' satisfaction based on the CBE occupant survey database. As it showed, several sub factors have been identified. Temperature for thermal quality, air quality for IAQ, amount of light for lighting quality, noise level and sound privacy for acoustic quality, amount of space, visual privacy, ease of interaction for office layout, comfort of furnishing, adjustability of furniture, colour and texture for office furnishings, building cleanliness, workspace cleanliness, building maintenance for cleanliness and maintenance and office type including open plan or cellular office types.

The built environment related factors were identified by reviewing key research papers by considering the ambiguity surrounding the terminology used by the different authors' best judgment (refer Table 3.1).

Table 3.1: Built environment factors influencing occupants' productivity

Main dimensions	Built environment factors
Thermal quality	Personal control on ambient conditions
	Temperature
	Opening windows
	Personal thermal system control
Visual quality	Provisions of day lighting
	Radiation and electromagnetic fields
	Electric lighting quality
	Glare
	Controllable task-lighting
	Illuminance
	Controllable lighting installations
	Lighting intensity
	Colour
	Personal/task lighting
	Proximity to a window
	View to outdoor environment
Indoor Air Quality	Indoor air temperature
	Air quality
	Dust
	Odour
	Air freshness
	Air movement
Ventilation	Amount of ventilation
	Natural ventilation
	Mechanical ventilation
Acoustic quality	Background sound level
	Acoustical partitioning

	Sound privacy
	System controls
	Sound absorption materials
Spatial quality	Distractions
	Personal control workstations
	Privacy
	Office instrumentality
	Space arrangement
	Orientation of office
	Space flexibility
Appearance of the workplace	Art and aesthetic
	Contact with nature and views
	Symbolism
	Floor coverings and wall hangings
	Architectural arrangement of workplace
Building maintenance and cleanliness	Building Maintenance
	Cleanliness
Office type	Open-plan design
	Cellular design
Building materials used	Use of low emitting materials
Office layout	Ergonomics
	Screen positions of work station
	Adjustability of furniture
	Amount of space
Social engagement	Space for informal meetings
	Access to documents
	Psychological restoration and relaxation

As the above Table 3.1 mentions, fifty four (54) built environment factors were identified relating to twelve (12) major dimensions of the built environment.

Thermal quality

As stated in the ASHRAE standard 55-2004, thermal comfort is "the condition of mind which expresses satisfaction with the thermal environment". When thermally comfortable, a building user will wish to feel neither warmer nor cooler, if asked about thermal state and preference (Frontczak & Wargocki, 2010). Research on environmental stress and adaptation has identified associations between extremes of temperature and sound with physiological and psychological stress (e.g., chronic illness and psychological impairment) and with coping and adaptive behaviours that reduce stress or its impact. Further, high temperatures and low humidity can affect the release of organic dust and allergens from carpets and other building surfaces (Frontczak, Schiavon, Goins, Arens, Zhang & Wargocki, 2012). Further, personal control over ambient conditions is especially important to reduce discomfort coping and to achieve conditions appropriate to personal preferences and task needs. Brager and Dear (1998 cited Paul & Taylor, 2007) reported a link between personal control of environmental conditions, especially temperature and ventilation, and work performance. Further, the possibility of delegating such control to occupants and customizing possibility can be influenced on occupants' productivity.

Visual quality

Visual comfort is defined as "a subjective condition of visual well-being induced by the visual environment" (EN 12665 standard, 2002 cited Frontczak & Wargocki, 2010). Although the definition implies that there is a psychological dimension of comfort, a number of physical properties of the visual environment are defined and used to evaluate its quality in an objective way. Visual conditions are characterized by such parameters as luminance distribution, illuminance and its uniformity, glare, colour of light, colour rendering, flicker rate and amount of daylight (Bluyssen, 2009). According to Clements-Croome (2000), indoor environmental quality should take into consideration additionally on radiation and electromagnetic fields generated by electronic lighting elements.

Indoor Air Quality (IAQ)

Air quality can define as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction" (ASHRAE Standard 62.1, 2007 cited Atkin & Brooks, 2000). Improved IAQ is likely to have the greatest impact on wellbeing and personal productivity. Further, studies using self-assessments of productivity have found strong relationships to air quality factors. Nonetheless, the existing studies show a strong link between IAQ, Sick Building Syndrome symptoms and work performance (Heerwagen, 2000). The requirements illustrated in Table 3.2 have been identified by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE), Occupational Safety and Health Administration (OSHA) and Illinois Department of Public Health (IDHP) to fulfill IAQ in buildings.

Table 3.2: Indoor Air Quality related standards

Parameter	Standards		
	IDPH	ASHRAE	OSHA
Humidity	20% - 60 %	30% - 60 %	N/A
Temperature	68 - 75 (winter) 73 – 79 (summer)	68 - 75 (winter) 73 - 79 (summer)	N/A
Carbon Dioxide	1,000 ppm (<800 ppm preferred)	1,000 ppm	5,000 ppm
Carbon Monoxide	9 ppm	9 ppm	50 ppm
Hydrogen Sulfide	0.01 ppm	N/A	20 ppm
Ozone	0.08 ppm	N/A	0.1 ppm
Particulates	0.15 mg/m 3 (PM 10) (150 µg/m 3) 24-hr 0.065 mg/m 3 (PM 2.5) (65 µg/m 3) 24-hr	50 µg/m3, annual average (PM 10)	15 mg/m 3 (total) 5 mg/m 3 (resp.)
Formaldehyde	0.1 ppm (office) 0.03 ppm (home)	0.1 ppm (office) 0.04 ppm (home)	0.75 ppm
Nitrogen Dioxide	0.05 ppm	N/A	5 ppm

Pressure relationship with Zones	N/A	Restroom mechanically exhausts with no recirculation	N/A
Outdoor air floor rate	N/A	10 L/s (20 cfm) per person	N/A

Source: Arnold (2010)

Ventilation

The importance of good ventilation increases with a more efficient use of space, especially in conjunction with high-value work. Insufficient ventilation without mechanical cooling may cause substantial loss of productivity. Thus the additional costs of a quality upgrade of an office building's ventilation and air-conditioning systems impact the space costs minimally making such investments cost-effective (Lai & Yik, 2008).

Acoustic quality

Noise in occupancies is typically not at a high enough level to be harmful to human hearing level. Noise is distracting the concentration on work or study and provides less than ideal working and learning environments. Navai and Veitch, (2003 cited Frontczak & Wargocki, 2010) defined acoustic comfort as "a state of contentment with acoustic conditions". The quality of the sound environment is linked to numerous physical parameters, which include both the physical properties of sound itself and the physical properties of a room.

Spatial quality

Spatial comfort is achieved through proper space planning and management. Space planning and management is the process of deciding how office space uses most flexibly, efficiently and effectively (Frontczak et al., 2012). As Frontczak et al. (2012) further verify, the satisfaction with the amount of space was ranked to be the most important for workspace satisfaction and ultimately for occupants' productivity. Spatial comfort is achieved through proper spatial planning and management.

A study by Menzies et al. (1997 cited Paul & Taylor, 2007) concluded that the productivity of occupants was high when they gave a control over their workstations.

Another frequently cited field study with objective measures of productivity assessed the impact of workstations with personal controls. A study has found productivity increases with the use of personal control workstations (Kroner et al., 1992 cited Heerwagen, 2000). Further, the distraction another factors considered in space arrangement of office space where it is “anything that takes attention away from the task to be performed, including noise, visual disturbance or being too hot or too cold environment” (Heerwagen, 2000). Office environment should be free from distractions otherwise, which can create disturbances on work performance. According to a study by Ries et al. (2006), instrumentality concerns the degree with which physical attributes of the office support the desired activities. The possibility to provide high quality office materials can create a positive effect on work performance and productivity.

Appearance of the workplace

Daylight access, indoor sunspots, variation in colour, pattern, and texture can be provided within buildings. Further, colour and pattern on walls or carpeting can be used to provide location and movement cues. Also appropriate signage and visual displays can be provided to develop an overall sense of space (Heerwagen, 2000). Views of nature outdoors, careful use of indoor sunlight, interior plantings, nature decorations, and nature patterns in spatial layout can be provided to enhance occupants’ productivity. Researches show that building environments that connect people to nature are more supportive of human emotional well-being and cognitive performance than environments lacking these features. Aesthetics refer to the beauty of the office (Vilnai-Yavetz et al., 2005 cited Paul & Taylor, 2007). Previous researchers found that there is a statistically significant association between aesthetic and the job performance and productivity of occupants. Symbolism refers to the associations elicited by the space.

Building maintenance and cleanliness

Building maintenance is another factor affecting occupants' productivity. Poor maintenance of building systems can lead to build up bacteria and other pollutants in the air ducts, or water leakages in walls or ceilings. It can be affected on occupants' health and ultimately on their productivity (Frontczak et al., 2012). Cleanliness includes general cleanliness of the overall building and cleaning service provided to the workspace and general maintenance of the building. Insufficient cleaning and general neglect can be badly affected on occupants' productivity.

Office type

The building type and its design features can also be affected on occupants' productivity. Further, the buildings should be designed for easy maintenance.

Building materials used

A building which free of hazardous material (e.g. lead and asbestos) and having the capability of fostering health and comfort of the occupants during its entire life cycle, supporting social needs and enhancing productivity (Bluyssen, 2009).

Office layout

The term office layout means how the arrangement and boundaries of workspaces are laid out (Oldham et al., 2005 cited Lee, 2010), which can determine the type of offices as well as performance of a space laid out in a particular arrangement and boundary. This is one of the most significant factors that affect employee behaviors (Mahdavi & Unzeitig, 2004; Maher, 2005 cited Lee, 2010; Codinhoto et al., 2009). New furniture, carpets or painted surfaces that produce gaseous substances and large areas of soft furnishings (carpet, partitions, chairs) and shelves/files should be properly produced otherwise it can threat on occupant health and ultimately on productivity. Enclosure or screening, distance from others, ability to regulate the desired degree of social interaction by moving between spaces or by manipulating personal space can be applied. Further, incorporating ergonomics in the design process can benefit both building occupants and overall building operations. Ergonomic has been used by many organizations to reactively address injuries and/or losses in occupants' productivity. Further, it influences job performance and satisfaction, recruitment and retention of staff, risk of injury, and can even impact occupant health outcomes (Codinhoto et al., 2009).

Social engagement

Comfortable meeting places, indoors and outdoors circulation systems and layouts that support informal interaction, attributes that draw people to space and encourage conversation can be influenced on occupants' productivity (Frontczak & Wargocki, 2010). Providing psychological restoration and relaxation opportunities for occupants would benefit to improve productivity. Celebratory spaces, artifacts and symbols of cultural and group identity, a sense of uniqueness, quiet spaces with low sensory stimulation, connections to nature, distant views, outdoor seating or walking paths in visually appealing landscapes can be provided to ensure Psychological restoration and relaxation (Heerwagen, 2000). Further, a variety of informal social spaces can be provided to encourage relationship development.

These factors are taken place due to high individual variability in environmental sensitivities. However, as more of these factors are present in a built environment which is disruptive enough to lead to absenteeism or reduced personal productivity. Since, on average, people spend 80-90% of their time in buildings, quality of the built environment is an important building feature which refers to the interactions among many factors in indoor environments (Ries et al., 2006). In indoor environments, a number of physical and chemical parameters have been identified that influence the comfort of building occupants. Standards dealing with Indoor Environmental Quality have been developed to define the acceptable ranges of these parameters such as, ASHRAE, OSHA and IDHP etc. (Frontczak & Wargocki, 2010). As a number of articles and case studies show, there is a strong positive correlation between IEQ and the work performance of employees. In which significant productivity gains by improved quality of the indoor environment, workers' "overall positive feeling about the environment" have been increased by 60% in green buildings (Bluyssen, 2009).

3.5 Formulation of the Research Problem

The occupants' productivity relating to green buildings was reviewed through the literature available and the research problem was further verified by identifying the gap between past researches and current research. The literature declares that there is a relationship between occupants' productivity and green buildings. However, there are no sound criteria for the evaluation of critical built environment factors influencing occupants' productivity. Thus, the researcher formulated the research problem as;

"What are the built environment factors critical for green buildings and its degree of influence on occupants' productivity?"

3.6 Summary

The quality of the built environment is an important building feature which refers to the interactions among many factors in indoor environments. As a number of articles and case studies showed, there is a strong positive correlation between the work environment and work performance of employees, in which significant productivity gains by improved quality of indoor environment. According to the existing literature, twelve major built environment related factors were identified, such as, thermal quality, acoustic quality, Indoor Air Quality, ventilation, visual quality, spatial quality, office layout, appearance of the workplace, social engagement, general building maintenance, building materials used and office type. Relating to the major dimensions, 54 built environment factors were identified, such as opening windows, personal thermal system controls, air quality etc. Finally, the researcher verifies the research problem further, by identifying the research gap. Accordingly, the next chapter will present the conceptual framework and research hypotheses, which were developed to address the research problem.

4. RESEARCH HYPOTHESIS AND CONCEPTUAL FRAMEWORK

4.1 Introduction

Chapter two and three contained the literature syntheses, which refines the research problem while, this chapter presents the research hypothesis and the conceptual framework. It was developed to guide this research based on literature review. Considering the aim of this research, hypotheses were developed (Section 4.2) to test whilst the conceptual framework (Section 4.4) illustrates the way of achieving research objectives to achieve the research aim. The framework consists of four major levels, namely, Identification, Evaluation, Outcomes and Application. Accordingly, the developed conceptual framework fulfills the second objective of the research.

4.2 Research Hypotheses Developed

In the first instance, it has been shown from the literature that there is a productivity improvement of occupants in green buildings and, built environment has a main effect on occupants' productivity. Built environment consists of many factors such as, thermal quality, visual quality, IAQ, ventilation, acoustic quality, spatial quality, appurtenance of workplace, building maintenance, office layout, office type and social engagement, etc. In terms of these factors, occupants' productivity has improved by moving to green environment from non-green environment with a possible relationship and significant influence which are likely to exist. From this argument, it is reasonable to propose that:

H_1: There is a significant relationship between the built environment and occupants' productivity in green buildings.

H_2: Green built environment has a significant influence on occupants' productivity.

As it is not clear from the empirical evidence provided in the literature what the nature of the relationship between the built environment and occupants' productivity in green buildings, it is necessary to establish it clearly by way of doing this empirical study. Further, it has demonstrated through the examination of the literature on occupants' productivity and built environment. There are many built environment factors influencing occupants' productivity improvement in green buildings. These factors have been captured in the conceptual framework, relating to the 12 major built environment factor categories. The implications of having these various factors could have greater influence and significant relationship on occupants' productivity in green buildings. Hence, it is necessary to establish the H_1 hypothesis that need to examine in the data analysis of this study.

Even though the literature demonstrated a base of the relationship between occupants' productivity and built environment, the significant relationships and influences between built environment and occupants' productivity in green buildings exist are still not well addressed in previous researches. Whilst such an association between occupants' productivity and built environment has alluded within the literature, it has not much provided beyond anecdotal evidence to back this assertion. Given that the aim of this research as outlined in Chapter 1, was looked for empirical evidence of a relationship between the built environment and occupants' productivity in green office buildings. The H_2 provides an appropriate hypothesis that must be examined in the light of data collected to achieve the aim of the research. The subsequent data collection, analyses and discussion will focus on testing the validity of these hypotheses. Considering the all above existing literature and hypotheses developed, the conceptual framework was designed.

4.3 The Conceptual Framework

A theoretical or conceptual framework can be thought of as a map or travel plan thus, at the start of any research study, it is important to consider (Sinclair, 2007). According to a study by Miles & Huberman (1994 cited Jabareen, 2009), a conceptual framework "lays out the key factors, constructs, or variables, and presumes relationships among them" (p.440). However, Jabareen (2009) argued that a conceptual framework is not merely "a collection of concepts, but, rather, a construct in which each concept plays an integral role." Hence, it is a challenge faced by the researcher to develop a conceptual framework at the early stages of the research study, as it requires identifying exactly the facts which need to be studied. Further, it articulates the way of research by which an intervention is expected to cause the desired outcomes. Therefore, the conceptual framework should be developed by closely linking to the research aim and research questions formulated (McGaghie, Bordage & Shea, 2001). The next section attends to discuss the basis for developing a conceptual framework and its stages dealing with research objectives and the research hypothesis developed along with the research questions. The developed conceptual framework is presented in Figure 4.1.

4.4 Conceptual Framework of the Research

The review and discussion of the key literature in the previous chapter made it evident that there is a positive relation between occupants' productivity and green buildings. Green buildings facilitate a quality indoor environment, it highly influences on occupants' productivity. Further, among the drivers of occupants' productivity, built environment is one of the major contributors. Even though, occupants' productivity can be influenced by many built environment related factors, the identification of factors critical for green buildings and their degree of influence on occupants' productivity is still remaining researchable specially in Sri Lankan context. Accordingly, to fulfill the identified gap in previous research studies in occupants' productivity and green buildings, the researcher formulated the research problem as "What are the built environment factors critical for green buildings and their degree of influence on occupants' productivity?" The conceptual framework was developed to address the main research question and sub questions that need to be investigated. Further, it represents as a guide to fulfill the research objectives to achieve the aim of the research. Figure 4.1 illustrates the conceptual framework of this study, comprising four stages as mentioned below,

Level One - Identification

Level Two – Evaluation

Level Three – Outcomes

Level Four – Application

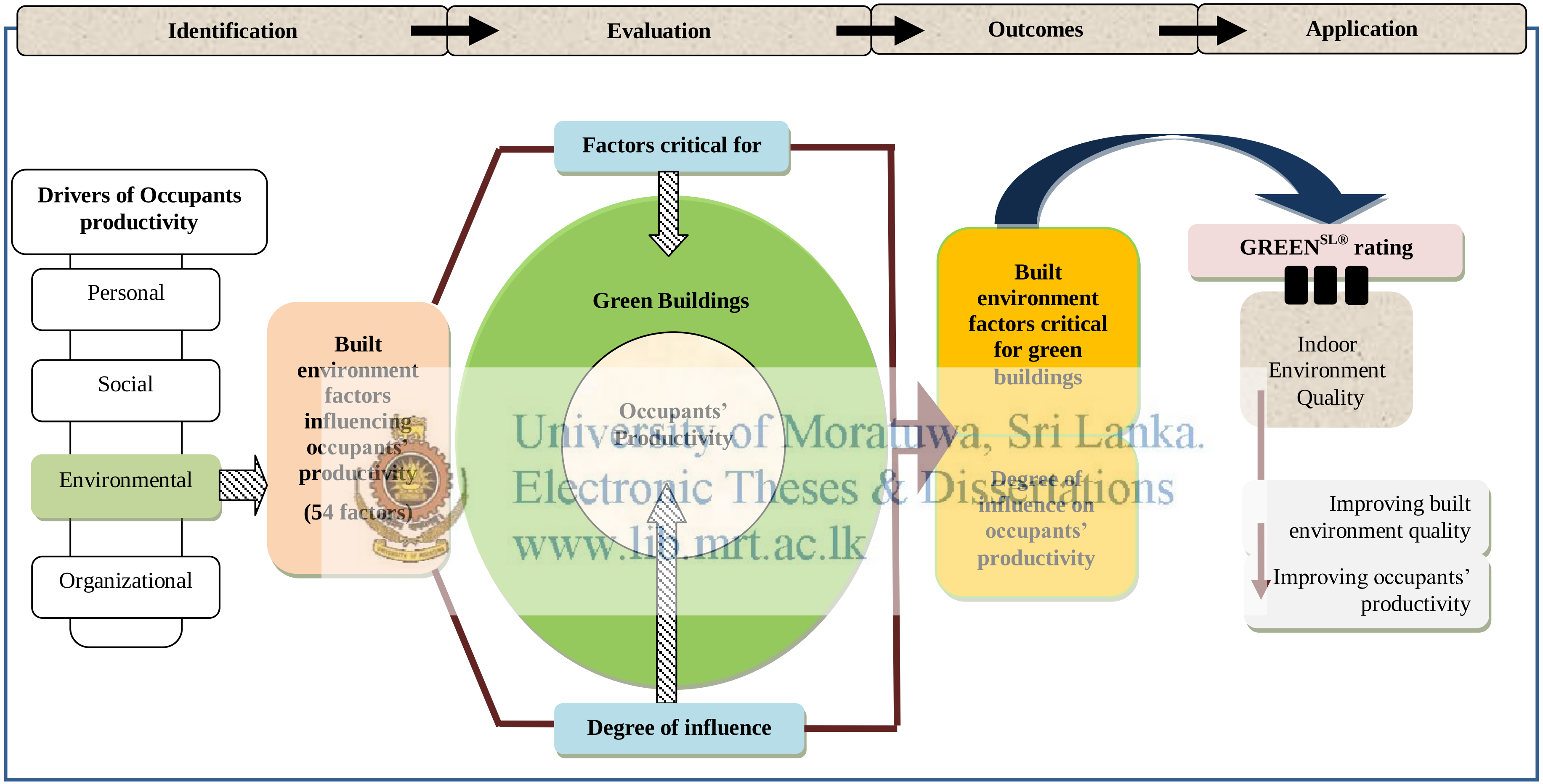


Figure 4.1: The conceptual framework

The factors identified, evaluation procedure, possible outcomes and application of research outcomes are clearly illustrated in the framework developed.

4.4.1 Level One - Identification

The first level or identification stage of the framework investigates the comprehensive theoretical background for the research (refer Figure 4.2). The researcher reviewed the literature specifically focusing on the research area. Henceforth, drives of occupants' productivity, such as, personal, social, environmental and organisational factors were identified. The key literature was reviewed by specially focusing on the built environment to identify built environment related factors influencing occupants' productivity.

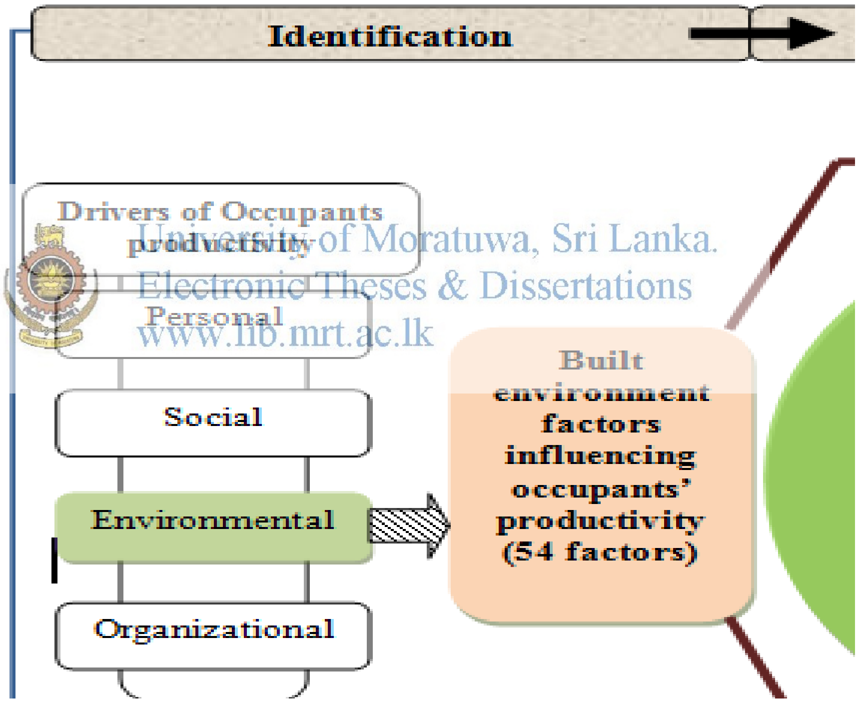


Figure 4.2: Identification of built environment factors

The built environment, which is a space consist with complex and dynamic combination of physical, biological, and chemical factors that can affect the occupants' health and physical reactions anytime whether realize it or not (Kamaruzzaman & Sabrani, 2011).

According to a study by Lai and Yik (2008), the quality of buildings, including their performance in a range of indoor environmental attributes, was influential to the living quality of the habitants. Numerous studies have shown that indoor climate impacts both health and performance, which in turn affect productivity (Mahdavi & Unzeitig, 2004). Therefore, improving indoor environment is deemed to be the most important factor in the office productivity study (Lan & Lian, 2009). Once most of the numerous studies have been verified the relationship between the built environment and occupants' productivity; several built environment factors which can be influenced on occupants' productivity are identified. The conceptual framework was developed based on the built environment factors identified.

The researcher identified 54 built environment factors under 12 major dimensions such as, thermal quality, IAQ, visual quality, acoustic quality, spatial quality, ventilation, appearance of the workplace, building maintenance, office type, building materials, office layout and social engagement by reviewing the key literature (refer Table 3.1). In considering above key literature findings, level one of the conceptual framework fulfills the second objective of the research (refer Section 1.3).

4.4.2 Level Two – Evaluation

The identified built environment factors influencing occupants' productivity were evaluated under the level two of the framework in order to identify factors critical for green buildings and their degree of influence on occupants' productivity (refer Figure 4.3).

A number of case studies suggest that productivity gains through better quality office environments may be possible. According to case studies by Urban Catalyst Associates (2005) occupants 'productivity is the most significant benefit of green buildings, even though the value of improved occupant productivity and healthier built environments is difficult to calculate. The case study further mentioned that, occupants could gain 1%-1.5% productivity in a healthier indoor environment by moving to green buildings from their traditional work settings.

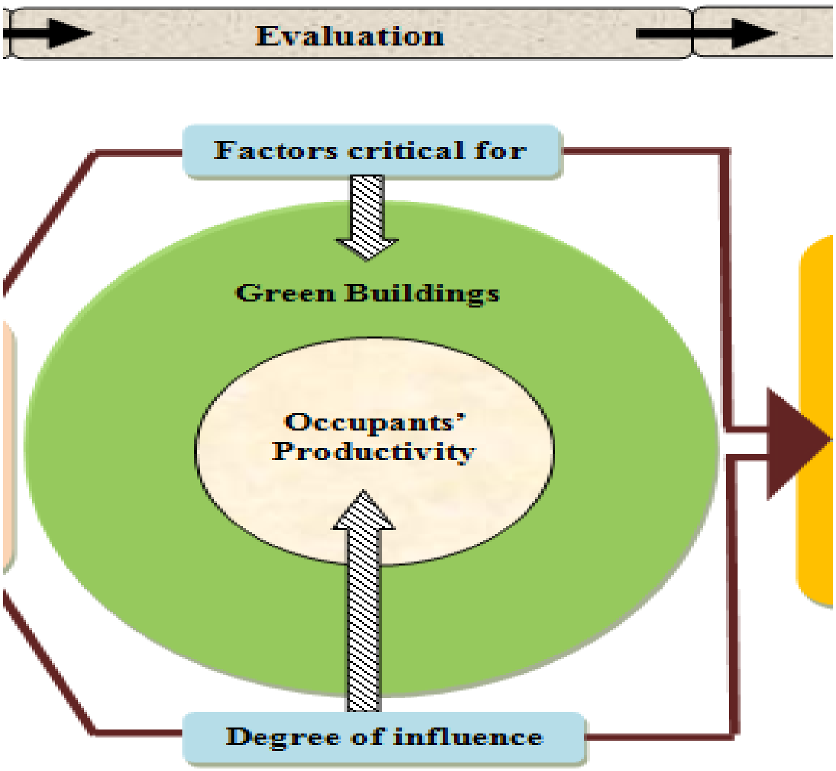


Figure 4.3: Evaluation of built environment factors

Green building design creates potential links with organizational performance, while it plays a major role in the expectations expressed by the owners and occupants. Many studies stated that the high quality indoor environment is the major expectation of building occupants as it is directly affected on their health, well-being and the productivity. Hence, it is widely believed that Green Buildings are more comfortable than conventional buildings which enhance organizational effectiveness and productivity (Barlett & Howard, 2000). Previous studies mention the occupants' needs are being addressed and that claims of performance are warranted in green buildings (Cole, 2010; Borgeson & Brager, 2011).

Whilst green developers and builders create healthier working, learning, and living environments, it is not only reducing utility bills, operation and maintenance cost but also increasing occupants' productivity. Hence, green building leads to enhance the productivity of green occupants.

The interplay between green buildings and occupants' productivity can be illustrated in this regard, however; the built environment factors critical for green buildings and their degree of influence on occupants' productivity are still remaining ambiguous thus, researchable. Henceforth, identified 54 built environment factors are evaluated through questionnaire survey conducted among the selected sample of occupants in green buildings in Sri Lanka.

The evaluation consists of two components as follows,

i. Identifying the built environment factors critical for green buildings
ii. Measuring its degree of influence on occupants' productivity in green buildings

Identifying the built environment factors critical for green buildings

To fulfill the fourth objective of the research, the researcher identifies the built environment factors influencing occupants' productivity, which are critical for green buildings. The identified built environment factors identified through literature review were evaluated through occupants' survey and expert survey. The questionnaire was developed based on built environment factors identified. By evaluating the relative importance of these identified factors, the researcher identifies the factors which are more critical for green buildings to enhance occupants' productivity. The questionnaire findings are analysed by using statistical data analysis techniques (refer Section 5.4.6).

Measuring its degree of influence on occupants' productivity

The critical built environment factors identified are evaluated again to measure the degree of influence of each identified factor on occupants' productivity in green buildings. Hence, the factors which are more critical for green buildings are evaluated and analysed by using the rank correlation and ordinal logistic regression analysis techniques. The identified critical factors were considered as independent variables whilst the occupants' productivity acts as the dependent variable. Accordingly, it is investigated as the major research question of this study by achieving research objectives.

The major research question is “What are the built environment factors critical for green buildings and its degree of influence on occupants’ productivity?”

4.4.3 Level Three – Outcomes

This research gives quantitative outcome, as it finally identifies the degree of influence of built environment factors on occupants’ productivity by fulfilling the third objective of the research (refer Section 1.3). Hence, the built environment factors were evaluated and critical built environment factors and their degree of influence on occupants’ productivity are determined as shown in Figure 4.4.

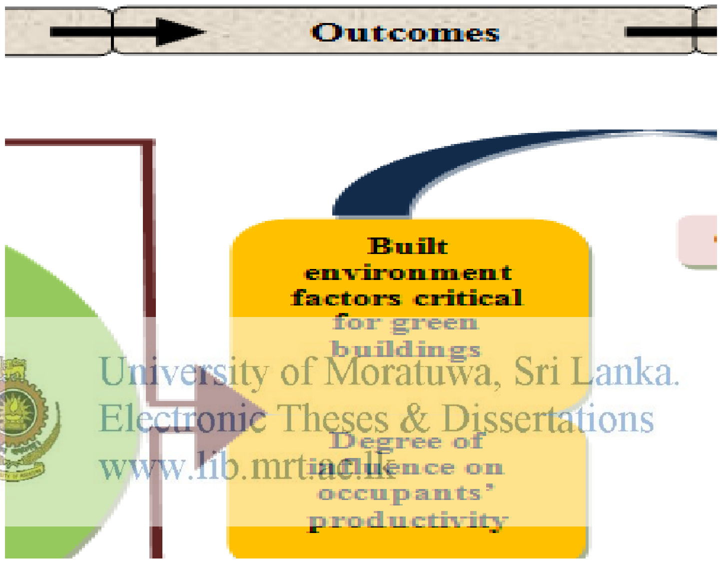


Figure 4.4: Research outcomes

4.4.4 Level Four – Application

The research provides a beneficial contribution to the building industry as it finally tends to enhance the green certification system in Sri Lanka. As the final objective (refer Section 1.3), new attributes are suggested for the GREEN$^{SL®}$ rating system in Sri Lanka based on research findings to enhance the built environment in green buildings. The existing attributes relating to built environment criterion in the GREEN$^{SL®}$ rating system are reviewed and major gaps are identified. Finally, the new attributes of the built environment are suggested in order to enhance the occupants’ productivity in green buildings in Sri Lanka. The identification of domains of green certification, gaps and suggestions on indoor environmental criteria in the GREEN$^{SL®}$ rating system of Sri Lanka fulfills the final objective of the research as illustrated in Figure 4.5.

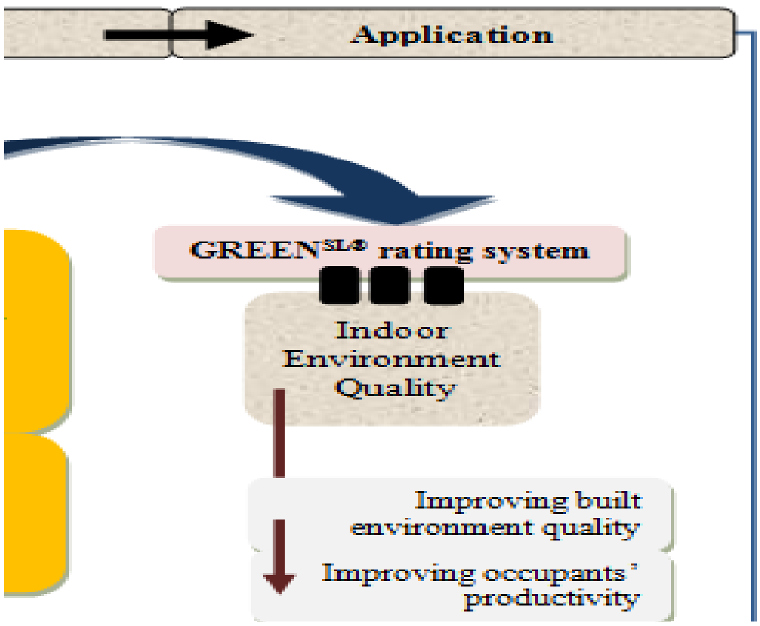


Figure 4.5: Research application

4.5 Summary

This chapter explained the levels of conceptual framework, which was developed to fulfill the second objective of this research. It was developed based on the literature review conducted. The framework consists of four levels namely, Identification, Evaluation, Outcomes and Application. At the first level, researcher has identified the built environment factors influencing occupants' productivity by reviewing key literature. It provides a basis for evaluation by directly focusing on the aim and objectives of the research. The survey findings are evaluated and analysed during the evaluation and, the relation and effect of built environment factors are determined as the final outcome. Based on research outcomes, new attributes are proposed on IEQ criteria in the GREEN$^{SL®}$ rating system. Hence, the developed framework despites the achievement of research objectives by investigating related research questions and hypotheses developed. The next chapter presents the research methodology which is adapted within this study to answer the formulated research questions.

5. RESEARCH METHODOLOGY

5.1 Introduction

Whilst chapter four consists of the conceptual framework and hypotheses of the research, this chapter clarifies the methodological framework which is used to conduct the research. In relation with the research problem the research was designed by containing suitable methods, which have adopted into the three phases. Hence, the research approach, research design, including sample selection, data collection and analysis techniques contrived within the research are discussed. Further, the measures taken to certify research validity are also conversed in the latter part of the chapter.

5.2 Research Design

Research design is the blueprint for fulfilling research objectives and answering research questions (Adams, Khan, Raeside & White, 2007). Yin (2009) identified the research design as the logical sequence that connects the empirical data to a study, initial research questions and, ultimately to its conclusions. As Yin (2009) further verifies, a research design is not just the work plan. It helps avoiding the situations in which the research evidence does not address the initial research questions. According to a study by Nachmias and Nachmias (1992 cited Yin, 2009), research design is a plan which guides the investigator in the process of collecting, analysing and interpreting observations and which is a logical model of proof that allows the researcher to draw inference concerning causal relations among the variables under the investigation. Hence, it specifies the methods and procedures for collecting and analysing the needed information (Adams et al., 2007). However, the selection of a research design is based on the nature of the research problem or issue being addressed, the researchers' personal experiences, and the audiences for the study (Creswell, 2009).

Considering the above statements, this research was designed to conduct within three phases illustrating research methods and techniques used which are mentioned in Figure 5.1.

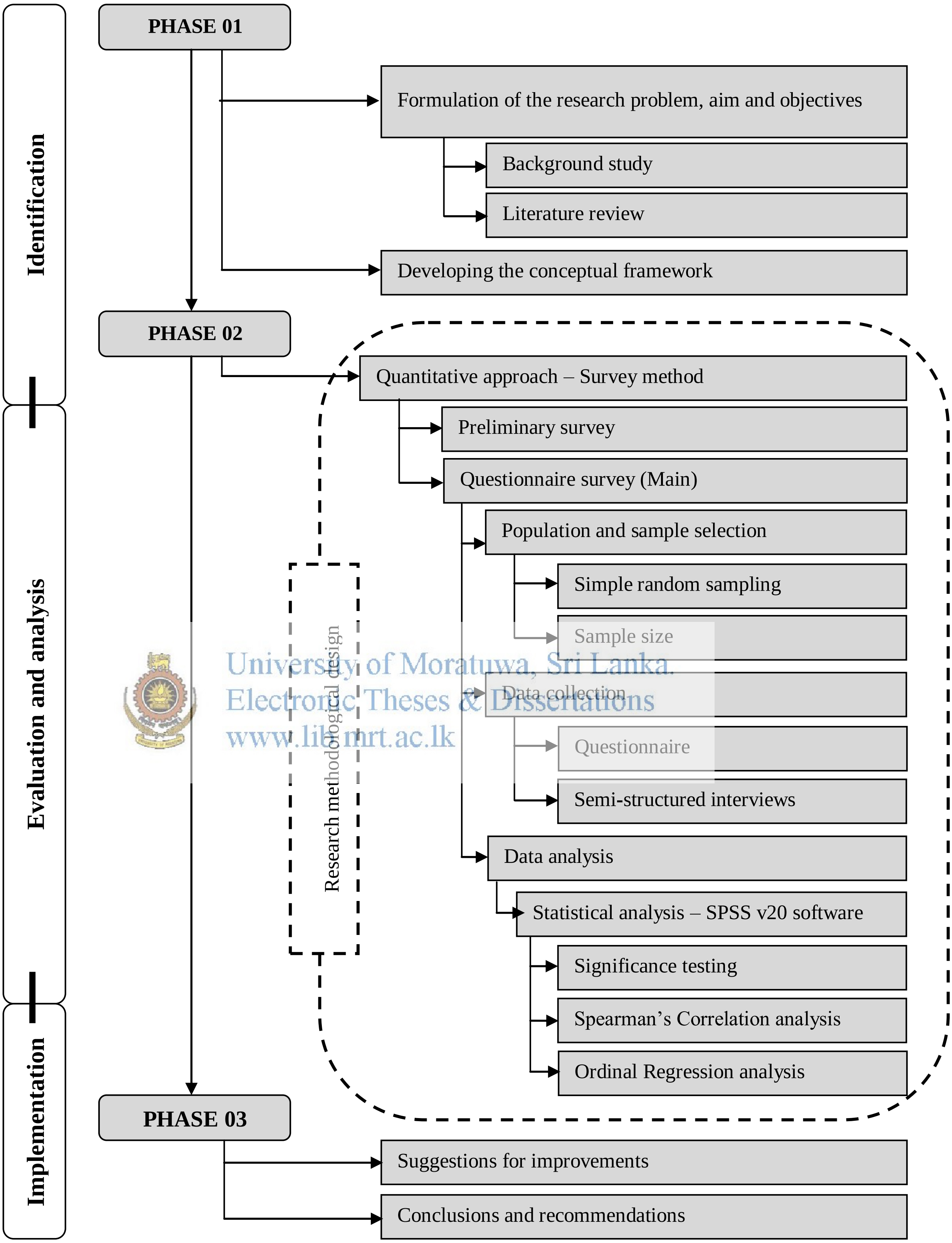


Figure 5.1: Research design framework

5.3 Phase One

The phase one deals with the identification of the main concepts, specifically focusing on the research area. It further verifies the research question by justifying the importance, significance and the value of conducting this research. Therefore, it consists with the discussion of related key research terms, including green buildings, expectations of green buildings, green certification, occupants' productivity and measurement, and built environment factors influencing occupants' productivity. Hence, as the first phase of the research process conducted, research question, aim and objectives are formulated as mentioned in Section 5.3.1.

5.3.1 Formulation of the research problem

5.3.1.1 Background study

A background study was carried out through books, journals, articles, publications and opinions gathered from professional staffs, which were useful in gaining an early understanding and to clearly define the research problem (refer Section 1.1). Further, the aim and objectives were established with regards to this research problem and the scope and limitations of the study were also defined in the primary stage.

5.3.1.2 Literature review

The literature synthesis was done through books, journals, articles, publications, and government reports to emend the research problem. The literature was reviewed specifically focusing on the research area. It further verifies the research gap and research question by justifying the importance, significance and the value of conducting the current research. Therefore, it consists of discussion of the research domains, paradigms and theories as well as definitions of the related key research terms such as green buildings, expectations of green buildings, green certification, occupants' productivity and measurement and, the built environment factors influencing occupants' productivity in Chapter 2 and Chapter 3 respectively. Accordingly, it was applied to formulating a conceptual framework which formed a way forward the study. Further, literature synthesis was extended to gain a broader knowledge on research methodology to design the research process in line with research aim and objectives.

5.3.2 Research problem

According to Yin (2009), defining the research question is probably the most important step to be taken in a research study. Thus, the research problem could be ascertained as: "What are the built environment factors critical for green buildings and their degree of influence on occupants' productivity?" The aim of this research was established based on the main research question while it further divides into sub four sub questions to developing research objectives (refer Table 5.1).

5.3.3 Research aim and objectives

The aim of this research is to investigate the built environment factors critical for green buildings and its degree of influence on occupants' productivity in green certified office buildings in Sri Lanka.

In order to achieve the aim, the objectives have been formulated as follows;

1. To identify the occupants' expectations of the green building environment.
2. To identify built environment factors influencing occupants' productivity and develop a conceptual framework of occupants' productivity based on the identified factors.
3. To determine built environment factors critical for occupants' productivity in green buildings and its degree of influence on occupants' productivity.
4. To propose probable suggestions to enhance the evaluation criteria of Indoor Environmental Quality in national green rating system.

The research questions were used to achieve the objectives of this study. Hence, sub questions were prepared for each objective in order to facilitate an inclusive way to achieve the objectives and the aim of the research. The sub research questions phrased are shown in Table 5.1.

Table 5.1: Phrasing research questions as research objectives

Research questions	Research objectives
1) What is a green building? 2) Is there any link between occupants' productivity and green buildings?	Identify the occupants' expectations of green buildings.
3) What are the built environment's related factors influencing occupants' productivity in buildings?	Identify built environment factors influencing occupants' productivity and develop a conceptual framework of occupants' productivity based on the identified factors.
4) What are the occupants' productivity influencing factors critical for green buildings? 5) What is the relationship between critical factors and occupants' productivity? 6) How much the degree of influence of critical factors on occupant's productivity?	Determine built environment factors critical for green buildings and its degree of influence on occupants' productivity.
7) What are the existing attributes of built environment considered in green certification? 8) What are the new attributes to be considered in the GREEN$^{SL®}$ rating system?	Propose probable suggestions to enhance the evaluation criteria of Indoor Environmental Quality in national green rating system.

5.3.4 The research hypothesis and conceptual framework for evaluation

The conceptual framework (refer Figure 4.1) and research hypotheses (refer Section 4.2) were developed as a guide for this study. It provides a basis for future evaluations to achieve research aim and objectives. According to the framework, identified factors are evaluated to identify factors critical for green buildings and their degree of influence on occupants' productivity.

As the first phase, background study and literature survey were conducted with the discussion on the key research terms and finally the conceptual framework was developed (refer Figure 4.1). Further, the researcher identified related literature in order to fulfill first two objectives of the research by answering related sub research questions. Whilst this section describes the initial procedures conducted in phase one, the next phase to discuss the methods applied in data collection, evaluation and data analysis of the research.

5.4 Phase Two

Whilst phase one recognizes theoretical explanations and discussions of key research terms by further verifying the research question, the phase two of the research design framework deals with research methodology design. Creswell (2009) states that "the research design acts as the plan or proposal to conduct research involves the intersection of philosophy, strategies of inquiry, and specific methods" (p.5).

"Knowing the purpose of research helped researcher to formulate correct research question and to identify clear direction for research. The classification of research purpose most often used in the research methods' literature is the threefold one of exploratory, descriptive and explanatory. However, in the same way as your research question can be both descriptive and explanatory" (Saunders, Lewis & Thornhil, 2009, p.139). An exploratory study is 'a valuable means of finding out 'what is happening; to seek new insights; to ask questions and to assess phenomena in a new light' (Robson 2002, p.59). In the exploratory research, the researcher can change the direction as a result of new data that appeared and new insights that occurred. Descriptive research portrays an accurate profile of persons, events or situation (Robson, 2002). In explanatory research, a situation or a problem is studied in order to explain the relationships between variables. The purpose of this research is to explore the built environment factors critical for green buildings and their degree of influence on occupants' productivity. Further, this research evaluates the existing situation by testing hypothesis constructed through literature in order to explore new insight between occupants' productivity and built environment of green buildings.

Hence, this research can be considered as an 'explorative' research which helped to develop the research question in a very prominent manner.

As Johnson and Clark (2006) note, it is important to be aware of the philosophical commitments made within the research to select the most appropriate research methodological design. There are research methodological models have been developed that discuss the philosophical aspects of a research (Kagioglu, Cooper, Aouad & Sexton, 2000; Creswell, 2009; Saunders et al., 2009). In the hierarchical model proposed by Kagioglu et al. (2000), the research philosophy, research approach and research techniques are nested together (refer Figure 5.2).

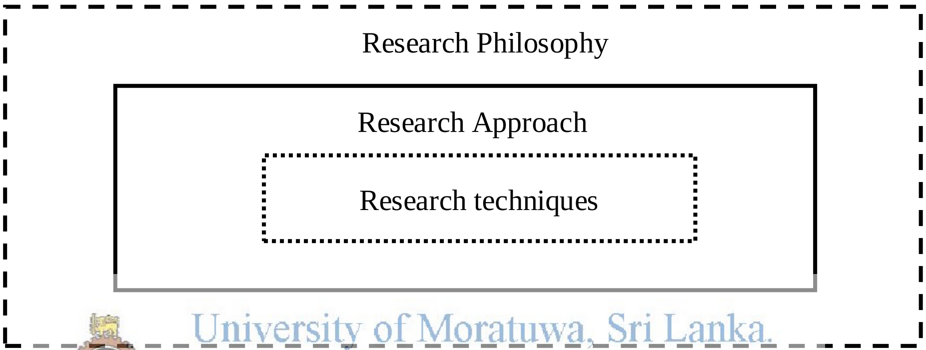


Figure 5.2: Nested approach

Source: Kagioglu et al. (2000)

Within this "nested" model, research philosophy which is at the outer ring "guides and energises the inner research approaches and research techniques" while ensuring that the chosen research philosophy, approach, and techniques are compatible with each other.

A framework proposed by Creswell (2009) consists of three elements of research design which can be considered in selecting an appropriate research methodology. As the Figure 5.3 illustrates, the research design should address the three main elements as follows,

- The philosophical worldview (research philosophy)
- Strategies of inquiry (research approach)
- Research methods (research techniques)

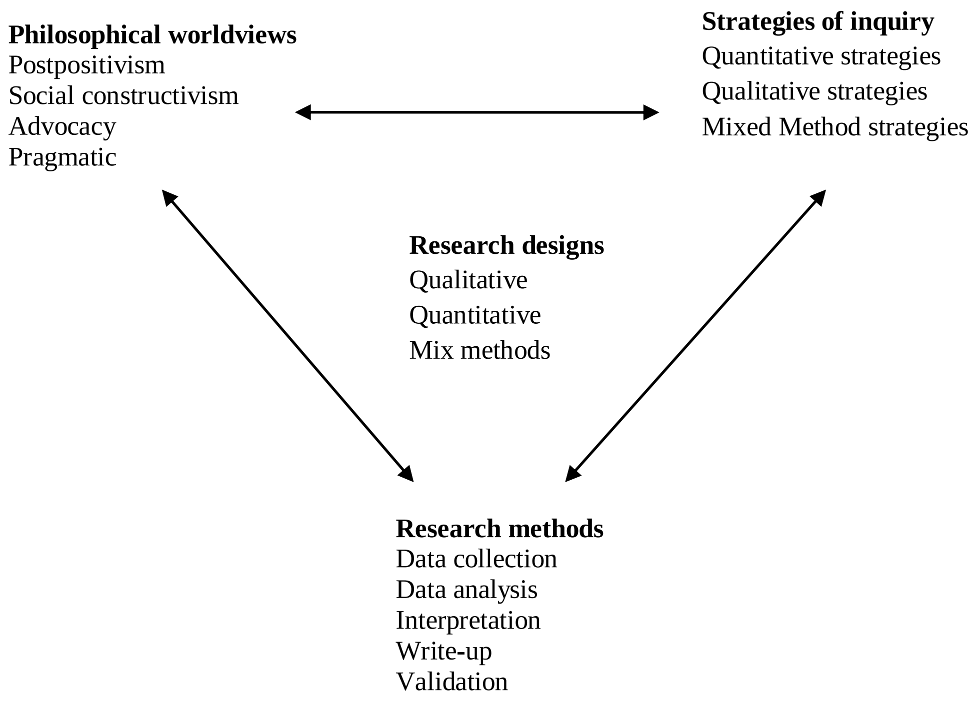


Figure 5.3: A framework for research design

Source: Creswell (2009)

Further, it shows many similarities with the nested model proposed by Kagioglu et al (2000), as it discusses three stages such as research philosophy, research approach and research techniques. Thus, the researcher adopted the nested model proposed by the Kagioglu et al. (2000) to discuss research methodological design of this study. In the following sections, the stages of this nested model are reviewed in relation to this research.

5.4.1 Research philosophy

Although philosophical ideas remain largely hidden in research, they still influence the practice of research and need to be identified (Slife & Williams, 1995 cited Creswell, 2009). Creswell (2009) uses the term, “philosophical worldview” for paradigm while others have called them paradigms (Lincoln & Guba, 2000; Mertens, 1998 cited Creswell, 2009). As Guba (1990 cited Creswell, 2009) states research paradigm or philosophical worldview means a basic set of beliefs that guide action.

Four different worldviews can be identified as, postpositivism, constructivism, advocacy, and pragmatism where two prominent research philosophies are in use, namely positivism/postpositivism and interpretivism/social constructivism (Bailey, 1987; Fellows & Liu, 2008 cited Manu, 2012; Creswell, 2009). According to a study by Burrell and Morgan (1979 as cited Holden & Lynch, n.d.), the other dimension involves either a subjective or an objective approach to research. These two major philosophical approaches are delineated by three major assumptions such as, ontology (reality), epistemology (knowledge) and axiology (Sexton, 2003 cited Kulatunga, Amaratunga & Haigh, n.d.; Saunders et al., 2009).

The first assumption, epistemology deals with the general set of assumptions about how the researcher acquires and accepts knowledge about the world (Sexton 2003 cited Kulatunga et al., n.d.). Further, it concerns what constitutes acceptable knowledge in a field of study (Saunders et al., 2009). Easterby-Smith et al. (2002 cited Holden & Lynch, n.d.) stated two traditions of philosophies; "positivism," and "social constructionism/interpretivism.

Positivist assumptions have presented the traditional form of research, and these assumptions hold true more for quantitative research than qualitative research. It holds a deterministic philosophy in which causes probably determine the effects or outcomes (Saunders et al., 2009). Social constructivism is typically seen as an approach to qualitative research. It holds assumptions that individuals seek understanding of the world in which they live and work. Individuals develop subjective meanings of their experiences. Hence, such meanings are constructed by human beings as they engage with the world they are interpreting (Creswell, 2009).

As Easterby-Smith et al (2002 cited Holden & Lynch, n.d.) further verifies that there are many features of positivism can be identified compared to interpretivism, as mentioned in Table 5.2.

Table 5.2: Implications between positivism and interpretivism

Feature	Positivism	Interpretivism
The observer	Must be independent	Part of what is being observed
Human interest	Should be irrelevant	Main drivers of science
Explanations	Must demonstrate causality	Aim to increase general understanding of a situation
Research progresses through	Hypotheses and deduction	Gathering rich data from which ideas are induced
Concepts	Need to be operationalised so that they can be measured	Should incorporate stakeholder perspectives
Units of analysis	Should be in simple terms	May include complexities of a 'whole' situation
Generalisation through	Statistical probability	Theoretical abstraction
Sampling requires	Large numbers selected randomly	Small numbers of cases chosen for specific reasons

Source: Easterby-Smith et al. (2002 cited Holden & Lynch, n.d.)

In relation to this research, the researcher identified many concepts, and factors influencing occupants' productivity through a comprehensive literature survey. The identified factors will be evaluated and measured to identify relationships and influences. The researcher works as a neutral recorder without being a part of the research environment.

The conceptual model has been developed incorporating measurable variables identified which need to be included in research instruments. It is evident that the research questions and hypotheses (refer Section 4.2) were developed laden with measurements. Further, respondents have to deal with objective criteria in the questionnaire survey when assessing the level of influence of built environment factors on their productivity. Thus, the collected data on occupants' experience and performance in green buildings were statistically evaluated by using statistical analysis techniques. A large number of sample (100 occupants of green office buildings) was selected randomly for data collection to generalize research conclusions. By considering the above reasons, this research was laden more towards positivism.

As the second assumption, ontology is concerned with the nature of reality (Saunders et al., 2009). "The researcher's view of reality is the corner stone to all other assumptions, that is, what is assumed here predicates the researcher's other assumptions" (Holden & Lynch, n. d., p.5). Furthermore, ontological assumptions require the researcher to decide whether to consider the world as external to the researcher, or whether the world is socially constructed, by examining human perceptions (Karunasena, 2012). It represents two major dimensions, namely objectivism (realism) and subjectivism (idealism) (Saunders et al., 2009). Objectivism represents the position that social entities exist in reality external to social actors and methodologies focusing on testing hypotheses, while idealism is based on analysis of subjective matters.

Table 5.3: Comparison between objectivism and subjectivism

Objectivism (Realism)	**Subjectivism (Idealism)**
Deduction	**Induction**
▪ Explanation via analysis of causal relationships	▪ Explanation of subject meanings and by understanding
▪ Generation and use of quantitative data	▪ Generation and use of qualitative data
▪ Use of various controls, physical or statistical, to test hypotheses	▪ Commitment to research in everyday settings, allowing access to and minimizing reactivity among subjects of research
▪ Highly structured research methodology to ensure reliability	▪ Minimised structure to ensure the above aspects

Source: Gill and Johnson (2002)

There are many aspects of objectivism (realism) can be identified compared to subjectivism (idealism) as presented by Gill and Johnson (2002). As presented by the Table 5.3, there many unique aspects of objectivism and subjectivism research can be identified. According to a study by Adams et al. (2007), deductivism and inductivism are two major aspects to be considered. As Adams et al. (2007) further verified that the inductive research relies on the empirical verification of a general conclusion derivable from a finite number of observations while deductive research operates from 'the general to the specific'.

This research takes the realism (objectivism) as it analyses casual relationships between variables by using quantitative data. The researcher identified the occupants' productivity influencing factors from prior studies and literature and which were tested by narrowing down to a specific set of testable hypotheses and research objectives (deductivism). Then the casual relationship and influences between dependent and independent factors (variables) were examined by holding the rest of the environment constant, statistically or experimentally. Further, this study claims an objective reality, that can be observed and measured without bias using standardized instruments and by selecting a large sample (refer Section 5.4.4). The research is intended to use control on research environment and statistical methods with the highly structured research methodology. Henceforth, this research favour realism/ objectivism than idealism/subjectivism.

Axiology is the third assumption made by previous researches, which is a branch of philosophy that studies judgments about value. Further, it is the researcher's view of the role of values in research (Saunders et al., 2009). Axiology is classified based on whether the reality is value free or value laden (Saunders et al., 2009). In value neutral research, the choice of what to study and how to study can be determined by objective criteria, whilst in value laden research choice is determined by human beliefs and experience (Easterby-Smith et al., 2002 cited Pathirage, Amarathunga & Haigh, 2008). As states by Silverman (2006 cited Karunasena, 2012), interpretivism supports a value laden system, while positivism supports a value free system. In case of this research, it takes value free approach as the way of doing the research has been determined by the objective criteria. Further, the researcher is not putting own value during the research as the research is undertaken in a value-free way where the researcher is independent of the data and maintains an objective stance. Accordingly, it is logical to adopt positivism epistemologically, as this research is continuing with measurements laden on the research questions made. Further, it favour realism/objectivism under ontological undertaking. It is because the degree of influence of identified factors on occupants' productivity in green buildings views as a 'single reality' in this study which can be observed and assessed by testing the hypotheses developed. Finally, this research takes value free stance in terms of axiological undertaking.

5.4.2 Research Strategies

The research strategy provides specific direction for procedures in a research design (Creswell, 2009). Others have called them as research approaches (Creswell, 2007; Yin, 2009) or research methodologies (Mertens 1998 cited Creswell, 2009), while Creswell (2009) identified them as strategies of inquiry. According to the onion research methodology model introduced by Saunders et al. (2009), there are two main research approaches namely deductive and inductive research approaches. In the deductive approach, the theory will deduct into hypothesis or research questions and the hypothesis will tested to examine causal relationships between variables. Research using an inductive approach is likely to be particularly concerned with the context. However, according to previous research studies (Creswell, 2009; Yin, 2003) qualitative and quantitative research approaches are two main schools of research design whilst mixed method approach has come up by incorporating qualitative and quantitative methods together.

Table 5.4: Alternative research strategies

Quantitative	Qualitative	Mixed Method
Experiments Survey	Narrative research Ethnography Grounded theory Action research Case study	Sequential Concurrent Transformative

Sources: Yin, 2003; Creswell, 2009

As the above Table 5.4 illustrates, surveys and experiments are basically coming under quantitative approaches while case study research, ethnography, action research and grounded theory can be taken under qualitative approaches. Further, both qualitative and quantitative methods can be applied together as sequential, concurrent or transformative mixed method approach.

The purpose of an experiment is to study causal links; whether a change in one independent variable produces a change in another dependent variable (Hakim 2000 cited Saunders et al., 2009). Kraemer (2002 cited Priyadarshani, 2010) states that, the experiments involve in an examination of the phenomenon in a control setting where case study does not require such control on behavioral events in research. "Survey research provides a quantitative or a numeric description of trends, attitudes, or opinions of population by studying a sample of that population" (Creswell, 2009, p. 12). Saunders et al. (2009) have identified it as the deductive research approach where the survey deals with testing of a theory by collecting a large sample of quantitative data and analyzed them in an objective manner to examine casual relationships between predetermined variables.

Narrative research is a form of qualitative inquiry in which the researcher studies the lives of individuals and asks one or more individuals to provide stories about their lives (Creswell, 2009). In ethnography research under qualitative research approach, the researcher studies an intact cultural group in a natural setting over a prolong period of time by collecting observational and interviewed data (Creswell, 2007 cited Creswell, 2009). Grounded theory is an inductive research approach (Saunders et al., 2009), where the researcher derives a general, abstract theory of a process, action or interaction grounded in the view of the participants. Grounded theory involves multiple stages of data collection and the refinement and interrelationship of data categories (Creswell, 2009).

According to Yin (2009), case study approach is more appropriate to bring an understanding of a complex issue or object and can extend experience or add strength to what is already known through previous research. Further, the researcher explores in depth a program, event, activity, process or one or more individuals (Creswell, 2009). As Creswell (2009) further verifies that, both qualitative and quantitative research methods can be incorporated together as mixed research methods. The researcher elaborates on or expands on the findings of one method with on the method called 'Sequential mixed method' while in 'concurrent mixed method, the researcher collect both qualitative and quantitative data at the same time and integrate into interpretation of overall results to analyse different type of questions. Tashakkori and Teddlie (1998 cited Manu, 2012) term this approach as the parallel/simultaneous mixed design. Unlike sequential strategies where the researcher begins with one strategy (quantitative or qualitative) and follows with another (quantitative or qualitative). In the transformative mixed research method, the researcher uses a theoretical lens containing both qualitative and quantitative data. According to the previous researches of research methodologies reviewed above, there are many research approaches can be identified as case study, grounded theory, narrative research, ethnography (qualitative approaches), experiment, survey (quantitative approaches) and sequential, concurrent, transformative method (mixed approaches).

5.4.2.1 Research strategy used in this research

Among the other strategies, survey was selected as suitable research strategy for this research as per the following reasons.

- The survey strategy under quantitative research phenomenon was adopted as the primary method in this research, as it is usually applicable when the research is derivative in the positivist paradigm (Creswell, 2009).
- Since this research takes the positivism and objectivism with regards to the philosophical stances, the use of qualitative strategies such as case studies etc are unjustifiable.
- As Yin (2009) verifies the first and most important condition for identifying suitable approach for any research is differentiating various research approaches by type of research questions being asked. As this research aims to identify the built environment factors influencing occupants' productivity in green buildings, and its degree of influence, the research question was formulated as;
  "What are the built environment factors critical for green buildings, and its degree of influence on occupants' productivity?"

- Further, Yin (2003) and Kraemer (2002) suggested that the survey design should be considered when the focus of the study is to answer "who", "what", "where", "how many" and "how much' questions whereas a case study would not be an advantageous strategy in this situation. It is because of the case study research focused on "how" and "why" questions. This research has also focused on 'what' question, this justifies the selection of survey strategy.
- Further, this research is studied under quantitative phenomenon as it requires quantitative outcome. As Patton and Applbaum (2003) verify the case studies were more suitable for the studies in qualitative data phenomenon.
- Further, the survey approach is utmost relevant where it involves in analysing numerical data to analyse in an objective manner and construct statistical models in an attempt to identify casual relationships between variables abstracted through hypothesis or research questions developed (Yin, 2009). As Gable Guy (1994) reveal, surveys can accurately document the norm, identify extreme outcomes, and delineate associations between variables in a sample.
- In this study, it is clearly defined in the objectives that the final outcome is to determine critical built environment factors influencing occupants' productivity in green buildings and its degree of influence.

- Further, the conceptual framework and relevant research hypotheses were developed based on previous literature by identifying the dependent and independent variables, which should be measured to answer the research questions and hypotheses formed (refer Table 4.1). It implies that the study needs a quantitative approach rather than qualitative.
- Further, this study will not apply experimental strategy even though it is quantitative. As this research studies a selected sample of the population through cross-sectional studies using questionnaires and semi-structured interviews for data collection rather using true experiments. Furthermore, the survey approach refers to a group of methods which emphasize quantitative analysis, where data for a large number of organizations are collected.

The survey approach seeks to discover relationships that are common across organizations and hence to provide generalisable statements about the object of study

(Gable Guy, 1994). Further, surveys are useful in describing the characteristics of a large population. There is no other method of observation which could provide the generalising capability (Saunders et al., 2004). By considering all above reasons, the survey approach under the quantitative phenomenon was selected as the most appropriate research strategy to conduct this study. Accordingly, the Section 5.4.3 describes the survey design adopted in this research.

5.4.3 Survey design

After selecting an appropriate research approach, the survey design was correctly set-up. The survey was designed to conduct in two stages as preliminary survey and the main questionnaire survey.

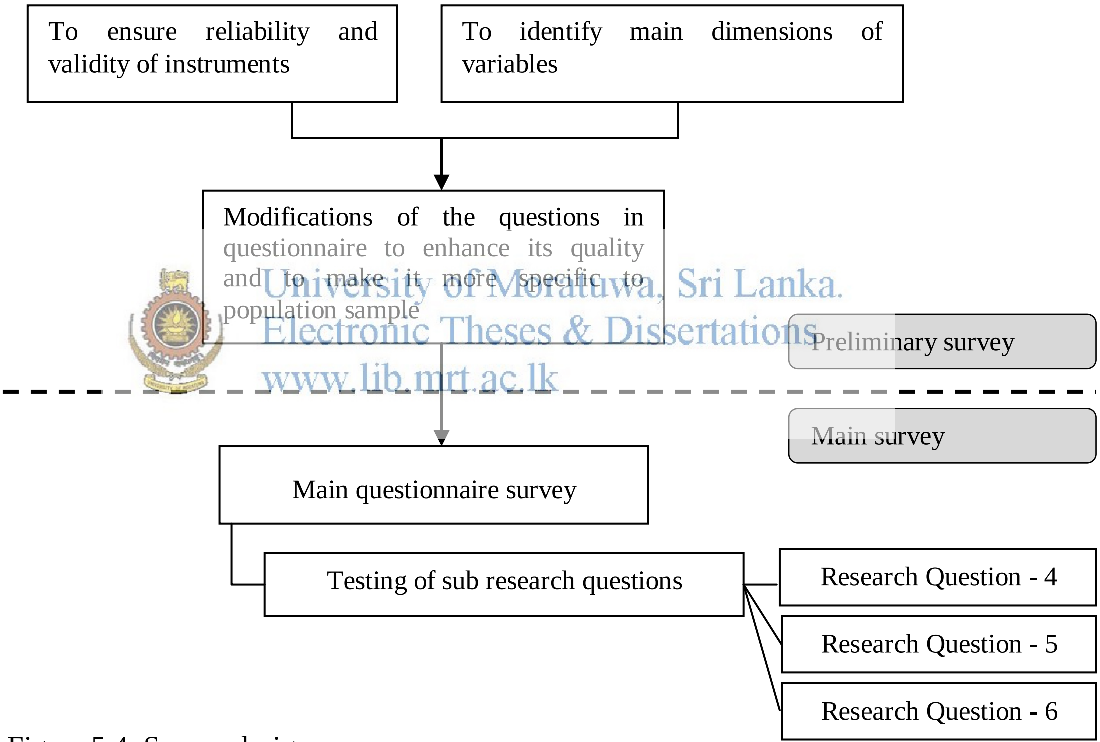


Figure 5.4: Survey design

The preliminary survey was conducted among the selected sample of occupants' in green buildings in order to ensure the reliability and validity of data collection instruments. The main questionnaire survey was conducted as the second stage after possible changes are made in data collection instruments. As illustrated by above Figure 5.4, the survey was designed to conduct as preliminary survey and the main survey. As the main purpose of this study, research hypotheses (refer Section 4.2) are tested in the main questionnaire survey. Following Sections describe data collection instruments used, population and sample selected for conducting the main survey.

5.4.3.1 Questionnaire Survey

There are various data collection techniques available in doing research. According to Saunders et al. (2009), participant observations, interviews, questionnaires and document surveys can be applied as data collection techniques in research. The questionnaire was selected as the suitable data collection technique for this research, as it requires determining the relationship between the identified dependent and independent variables by evaluating the degree of influence.

Development of the Questionnaire

The questionnaire was selected as the suitable instrument to collect the data. The development of the questionnaire is not a simple task where it needs to assure the validity and reliability of data collected. It has clearly described by Saunders et al. (2009, p.371) as "the internal validity and reliability of the data you collect and the response rate you achieve depend, to a large extent, on the design of your questions, the structure of your questionnaire, and the rigour of your pilot testing. A valid questionnaire will enable accurate data to be collected, and one that is reliable will mean that these data are collected consistently." Considering above, the questionnaire was developed mainly including closed ended questions relating to the quantitative outcome of the research. The questionnaire consists of two main sections as follows,

Section A: Self assessed perceived productivity by building occupants

Section B: Evaluation of built environment factors on occupants' productivity

The developed questions were structured in a logical manner and it was modified through the pilot survey before starting the main survey (refer Section 5.4.3.1 for implications on questionnaire given for the main survey). The five point Likert-style rating scale was used in which the respondent is asked to rate the given factors considering the change in their perceived productivity by moving from non green to green built environment. Accordingly, the questionnaire was developed considering its validity and the reliability to gather all required data to answer research questions established (refer Appendix 5.1 for the questionnaire developed for preliminary survey).

Results of preliminary survey and implications to main survey

Pilot survey is necessary to show the methodological rigor of a survey (Munn & Drever, 1995). As the first stage of the survey process, the pilot survey was conducted to assess the clarity and comprehensiveness of the questionnaire. As previously mentioned, the pilot survey targeted the occupants in green rated office buildings which have been obtained the green certification. The survey was thus conducted on the sample of ten (10) building occupants randomly assorted from the selected green office buildings.

The questionnaire was handed over to the selected sample of green building occupants and 6 responses were able to yield through the survey giving a response rate of 60%. All the respondents showed willingness to participate in the main survey with the interest for this study as they consider it as important. Further, there was no indication from respondents that the questions given in the questionnaire were difficult to understand. However, when they asked about some built environmental factors, there were some similar and repetitive factors in different terms. As the one improvement which was identified through pilot survey, the built environment factors were rearranged by identifying twelve main factors. Overall, the pilot survey indicated that the questionnaire was suitable to be administered in a larger survey (refer Appendix 5.2 for the main survey questionnaire developed). The Section 5.4.3.2 describes the main survey process.

5.4.3.2 Main survey

Population and sample selection

Sampling is a means of selecting a subset of units from a population for the purpose of collecting information for those units to draw inferences about the population as a whole. There are two types of sampling: probability or representative sampling and non-probability or judgmental sampling (Saunders et al., 2009). As Saunders et al

(2009) further revealed, with probability samples the chance, or probability, of each case being selected from the population is known and is usually equal for all cases. However, according to a study by the Ministry of Industry (2010), probability sampling is a method of sampling that allows inferences to be made about the population based on observations from a sample. Consequently, probability sampling is often associated with the survey and experimental research strategies. Non-probability sampling is a method of selecting units from a population using a subjective (non random) method (Ministry of Industry, 2010). For non-probability samples, the probability of each case being selected from the total population is not known and it is impossible to answer research questions or to address the objectives. Hence, the probability sampling technique was adopted in this study.

Building end users of green certified office buildings were selected as the suitable sample frame. Office employees were considered as building users when selecting a suitable sample for the main survey. The Figure 5.5 shows the building profile which was considered in the selection of organisations for data collection.

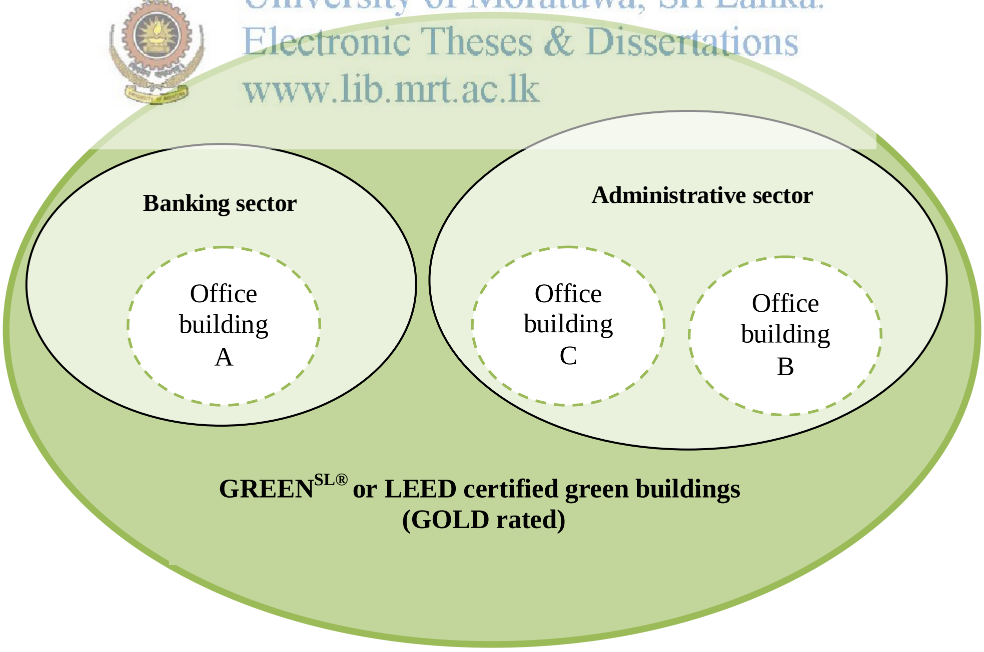


Figure 5.5: Building profile

As Figure 5.5 illustrates, the organisations were selected based on green certification considering the similar green features adopted. Three Green certified office buildings were selected from administrative and banking sectors in Sri Lanka by considering the accessibility and the limited time. Office buildings which have obtained the green 'GOLD' certification by following the criteria of GREEN$^{SL®}$ rating system and LEED green certification system (considering the similarities of both rating systems) were selected.

As the purpose of this study is to determine the built environment factors critical for green buildings and their degree of influence on occupants' productivity, the occupants of green certified office buildings in Sri Lanka were selected as the population sample to collect the data. Under the probability sampling, the suitable sample size was selected. The simple random sampling technique was used to select the suitable sample for distributing questionnaires. Simple random sampling involves the selecting of sample at random from the sampling frame (Saunders et al., 2009). Further, the sample size is also an important factor that affects the accuracy of the survey. As Chan, Yung, Lam, Tam and Chueng (2001) states that, the sample size should be of anywhere from 10 to 50 participants. Further, as stated by the Saunders et al. (2009), statisticians have also shown that a sample size of 30 or more will usually result in a sampling distribution for the mean that is very close to a normal distribution. Stutely (2003 cited Saunders et al., 2009) further advised that a minimum number of 30 for statistical analyses provides a useful rule of thumb for the smallest number in each category within the overall sample. However, the larger sample's size the lower the likely error in generalizing to the population (Saunders et al., 2009). Considering the minimum sample of 30 and the importance of having a large sample to generalize the survey findings to the whole selected population, '100' was selected as suitable sample size for this study. Accordingly, 100 occupants of green certified office buildings in Sri Lanka were selected randomly to distribute questionnaires.

5.4.3.3 Distribution of questionnaires

The main survey was conducted as two rounds among 100 building occupants of green certified office buildings who worked as office employees. The questionnaires were distributed electronically via email and directly delivered (manually) to the participants considering the easy response of respondents. However, the researcher was involved in the collection of questionnaires by giving a possible date for respondents. It would be a great opportunity obtained by the researcher to gather some validated responses from survey participants and to conduct semi-structured interviews. Furthermore, it helped researcher to maintain the response rate to a highest and acceptable level as it is most important for the validity of the research.

The response rate

As planned, questionnaires were distributed among 100 building occupants of green certified office buildings in Sri Lanka by targeting to receive minimum sample of 30.

Table 5.5: Response rate

Questionnaires	Number of questionnaires distributed	Number of questionnaires returned	Response rate
Distributed manually	40	30	75%
Distributed via email	60	35	58%
Total	100	65	65%

As the Table 5.5 indicates, 65 questionnaires were returned from the distributed 100 questionnaires as 30 from manually distributed and 35 from electronically distributed questionnaires. Hence, the main survey yielded a better response from participants with the rate of 65%. According to a study by Takim, Akintoye and Kelly (2004), the response rate norm for questionnaire survey is 20-30%. However, as verified by Richardson (2005 cited Nulty, 2008), 50% is regarded as an acceptable response rate in social research surveys. Baruch (1999 cited Nulty, 2008) researched the response rates reported by 141 published studies and 175 surveys in five top management journals published in 1975, 1985 and 1995 and the response rate of 60% or more are both desirable and achievable. Further, it is widely recognised and accepted that for inferential statistical analysis to be undertaken, a large sample is required. It is also generally accepted that as a rule of thumb, any sample with size greater than the threshold of 30 (n > 30) should be considered as a large sample (Sutrisna, 2004). Therefore, the sample size of 65 obtained in this survey was considered adequate for the purpose of inferential statistical analysis.

5.4.4 Multiple choice of data collection techniques

With more than one data collection technique, the reliability and validity of data can be increased. Further, it may also help for data triangulation to construct internal and external validity (Harris & Brown, 2010). As Harris & Brown further mentioned, structured questionnaires and semi-structured interviews are often used methods especially in social science studies to generate confirmatory results despite differences in methods of data collection, analysis, and interpretation. Different approaches are available for mixing the qualitative and quantitative data such as, concurrent and sequential mix methods (Creswell, 2009). The choice of multiple data collection techniques over single method generates benefits to research, especially for data validation purposes. Although questionnaires may be used as the only data collection method, it may be better to link them with other methods in a multiple-methods research design (Saunders et al., 2009). Further, it can be especially useful when unexpected results arise from a quantitative study (Morse, 1991 cited Creswell, 2009). Considering the above, both questionnaire and semi-structured interview techniques were used in this research. As this research focused on positivism paradigm, questionnaire survey was selected as primary data collection technique while it linked to semi-structured interviews, which were conducted among selected respondents in the main survey. However, the interview data were not analysed separately. Interview data were only used to validate the survey results by identifying similarities and differences through comprehensive discussion.

Altogether, twenty five (25) semi-structured interviews were conducted with selected building occupants and professionals who had experienced green buildings since its early stages, to obtain opinions to validate the quantitative findings of the research. The interview profile is illustrated in the following Table 5.6.

Table 5.6: Interview profile

Building Category	Agency	Designation
Green building - A	A1	Branch Manager
	A2	Assistant Manager
	A3	Banking Assistant
	A4	Banking Assistant
	A5	Junior Executive
Green Building - B	B1	Intern-Engineer
	B2	Facilities Engineer
	B3	Intern-Engineer
	B4	Manager Engineering
	B5	Engineer Research and Development
	B6	Manager Human Resource
Green Building - C	C1	Senior Quantity Surveyor
	C2	Engineer
	C3	Trainee Quantity Surveyor
	C4	Assistant Quantity Surveyor
	C5	Quantity Surveyor
	C6	Civil Engineer
	C7	Technical Assistant
	C8	Electrical Engineer
	C9	Technical Assistant
	C10	Civil Engineer
	C11	Architect
	C12	Architect
	C13	Civil Engineer
	C14	Architect

A guideline was prepared to get the opinions of the building occupants. The interview guideline was designed to capture data around the research problem and interview questions were developed based on the literature synthesis and theoretical framework of the study. The guideline was prepared by mainly focusing on obtaining the opinions on the influence of built environment factors on their work productivity and to get suggestions for improving the green certification system to enhance occupants' productivity (refer Appendix 5.3 for the interview guideline prepared). Interview transcripts were filled and developed with the facts discussed to generate a sensible adaptation of interview data (Refer Appendix 5.4 for example of completed transcript). However, the actual names of the organisations and the interviewees were not revealed in this report or any other document relating to the study to maintain confidentiality. Accordingly, the quantitative research findings were analysed along with the qualitative data which were obtained from the interviews conducted.

5.4.5 Data analysis

The data collected through questionnaire survey were subjected to statistical data analysis. Data analysis phase consists of two stages as illustrated in Figure 5.6.

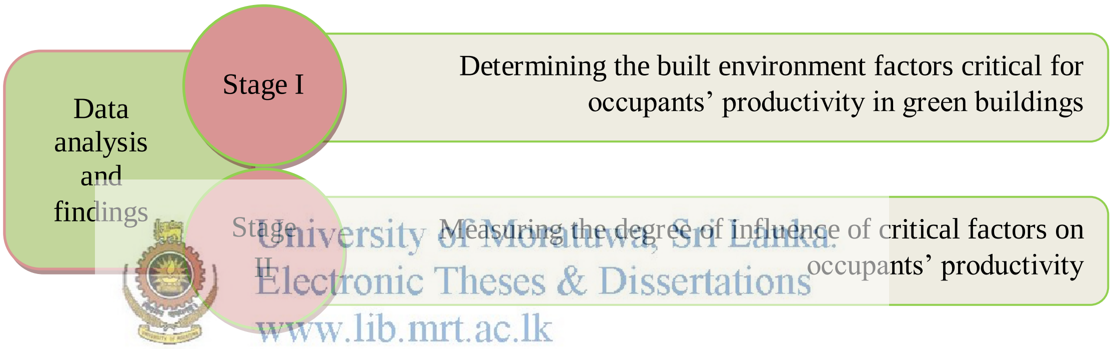


Figure 5.6: Data analysis stages

5.4.5.1 Stage One

Occupants' productivity is a function of several factors, one of which is built environment. One of the main objectives of this research is to identify the built environment factors influencing occupants' productivity and to determine the factors critical for green buildings. The researcher identified 12 main built environment factors and 54 sub factors influencing occupants' productivity (refer Table 3.1). All the factors were evaluated to identify significance and level of influence on occupants' productivity. The overall ratings given by respondents for main factors (ordinal data) were considered in identifying the factors critical for green buildings.

5.4.5.2 Stage Two

Twelve main factors identified through literature were evaluated in the first stage by using correlation analysis and most critical factors were identified. As the next stage of data analysis, the influence of critical built environment factors (independent variables) on occupants' productivity (dependent variable) in green buildings were evaluated. The significant sub factors of critical main factors were considered in evaluating relation and degree of influence on occupants' productivity. Accordingly, relevant hypothesis were tested to show the relation and the degree of influence of built environment factors and occupants' productivity in green buildings. Finally a statistical model was developed to show the strength of the relationship between dependent and independent factors. The net effect on occupants' productivity would be the total sum of the partial effects of all relevant built environment factors. Following statistical analysis techniques were used in determining the factors critical for green buildings and degree of influence on occupants' productivity. Statistical analysis was done by using Statistical Package for the Social Science (SPSS) v20 software.

5.4.6 Data analysis techniques

The data collected through questionnaires were analysed by using the techniques of significance testing, correlation and regression analysis.

5.4.6.1 Statistical significance testing

As this research requires testing the relationship between built environment factors and occupants' productivity in green buildings, Significance or hypothesis testing was used. It is useful technique to test the likelihood of the relationship (or one more extreme) occurring by chance alone, if there really was no difference in the population from which the sample was drawn (Robson 2002). There are two main groups of statistical significance tests. "Non-parametric statistics are designed to be used when your data are not normally distributed. Not surprisingly, this most often means they are used with categorical data where parametric statistics are used with numerical data" (Saunders et al., 2009, p. 449). In this research, non-parametric statistics was used to analyse the data, as the research contains not normally distributed, categorical (rank) data.

Testing the probability of a pattern such as a relationship between variables occurring by chance alone is known as significance testing (Berman Brown & Saunders 2008 cited Saunders et al., 2009). If the probability of the test statistics or one more extreme having occurred by chance alone is very low (usually $p<0.05$ or lower), there is a statistically significant relationship. This refers to rejecting the Null hypothesis whilst accepting the hypothesis.

Where,

H_0 : $p = 0$ (Null hypothesis)

H_1 : $p \neq 0$

The relationship is not statistically significant when the probability (p- value) is higher than 0.05 (Gardner, 2007).

In the testing of statistical significance, the significance level was set to 0.05 to reduce the occurrence of Type I errors in the analysis. This means an error made by wrongly coming to a decision that something is true when in reality it is not, is reduced. When the probability which is higher the 5% ($P>0.05$) making Type I error. Type II error involves the opposite occurring, which means something is not true, when in reality it is, and accept the null hypothesis. Statistical significance refers to the probability of making a Type I error. Accordingly, statistical significance was tested by setting the significant level to 0.05 to reduce the occurrence of Type I errors. The level of significance of each factor was considered when determining the critical built environment factors, which showed probability less than 0.05.

5.4.6.2 Correlation

There are several methods of determining the relationship among variables. Correlation analysis is used where a change in one variable is accompanied by a change in another variable, but it is not clear which variable caused the other to change (Saunders et al., 2009). A correlation coefficient enables the researcher to quantify the strength of the relationship between two ranked or numerical variables.

in the testing of the relationship between two ranked variables, two techniques under correlation are used most widely in research such as, Spearman's (Rank) Correlation coefficient (Spearman's rho) and Kendall's Rank Correlation coefficient (Kendall's tau). "Where data is being used from a sample, both these rank correlation coefficients assume that the sample is selected at random and the data are ranked (ordinal)" (Saunders et al., 2009, p.461). Considering all the above, Charles Spearman's coefficient of correlation was selected in this research to analyze the survey data.

Charles Spearman's Coefficient of Correlation (Rank Correlation)

Charles Spearman's coefficient of correlation also known as 'Rank Correlation' is the technique of determining the degree of correlation between two variables in case of ordinal data where ranks are given to the different values of the variables. Further, this is applicable to assess the strength of the relationship and the direction of association between two variables which could be positively related, not related at all or negatively related (Field, 2000; Saunders et al., 2009). As the survey of this research was designed with five point Likert scale (ordinal scale), Rank Correlation was selected as an appropriate method to analyze the data.

Hypothesis testing

In attempting to reach decisions, it is useful to make assumptions or guesses. Such assumptions, which may or may not be true, are called ***Statistical Hypothesis.*** In many instances researchers formulate a statistical hypothesis for the sole purpose of rejecting it or nullifying it. Such hypotheses are often called ***Null Hypothesis*** and are normally denoted by H_0. Any hypothesis which differs from a given hypothesis is called an alternative hypothesis.

So, in this research the ***Null Hypothesis*** was,

H0 - There is no correlation between the green built environment and occupants' productivity in green buildings.

H1 - There is a correlation between the green built environment and occupants' productivity in green buildings.

Test Statistics to Test Rank Correlation Coefficient

$$\text{Spearman's coefficient of correlation} = 1 - \left[\frac{6\sum d_i^2}{n(n^2-1)}\right]$$

where, d_i = difference between ranks of *i*th pair of the two variables

n = number of pairs of observations

$$t_{cal} = r_s \frac{\sqrt{n-2}}{\sqrt{1-r_s^{\,2}}}$$ Distributed "t" with "n-2" degree of freedom

r_s - Rank Correlation Coefficient

d_i - Difference between each rankings

n - Number of objectives

Null Hypothesis H_0 : $\rho = 0$ (There is no correlation between rankings)

Alternative Hypothesis H_1 : $\rho \neq 0$ (There is a correlation between rankings)

"ρ" is the standard symbol of Correlation Coefficient. In this hypothesis "ρ" is the Rank Correlation coefficient (Crawshaw & Chambers, 2001). Further, by testing the significance together with the correlation coefficient in the statistical data analysis, the probability (p-value) of correlation coefficient having occurred by chance alone was also tested.

5.4.6.3 Strength of Correlation

The selection of the critical factors was performed considering the strength of the correlation between variables. The strength of the correlation could be determined by considering its monotonic relationship. A monotonic function is one that either never increases or never decreases as its independent variable increases. It can be, monotonic increasing, monotonic decreasing or non monotonic relationship. In the monotonically increasing, as the x variable increases the y variable never decreases in monotonically decreasing, as the x variable increases the y variable never increases. In non monotonic relationship, as the x variable increases the y variable sometimes decreases and sometimes increases.

Spearman's correlation coefficient is a statistical measure of the strength of monotonic relationship between paired data (-1; +1). It is presented between -1 to +1. This coefficient of correlation can take on any value between -1 and +1. A value of +1 represents a perfect positive correlation. This means that the two variables are precisely related and that, as values of one variable increase, values of the other variable will increase. By contrast, a value of -1 represents a perfect negative correlation. Again, this means that the two variables are precisely related; however, as the values of one variable increase those of the other decrease. Correlation coefficients between -1 and +1 represent weaker positive and negative correlations, a value of 0 meaning the variables are perfectly independent. However, the closer r_s is to +1 the stronger monotonic relationship. A value of $r_s = 0$ does not imply there is no relationship between variables, which implies there is no monotonic correlation however; there is a perfect quadratic relationship (Saunders et al., 2009).

The strength of the correlation has determined and interpreted by the several studies using rule of thumb. As Saunders et al. (2009) mentioned that, the correlation coefficient could take on any value between -1 and +1. A value of +1 represents a perfect positive correlation. The value of -1 represents a perfect negative correlation. Correlation coefficients between -1 and +1 represent weaker positive and negative correlations, a value of 0 meaning the variables are perfectly independent as illustrated in Figure 5.7.

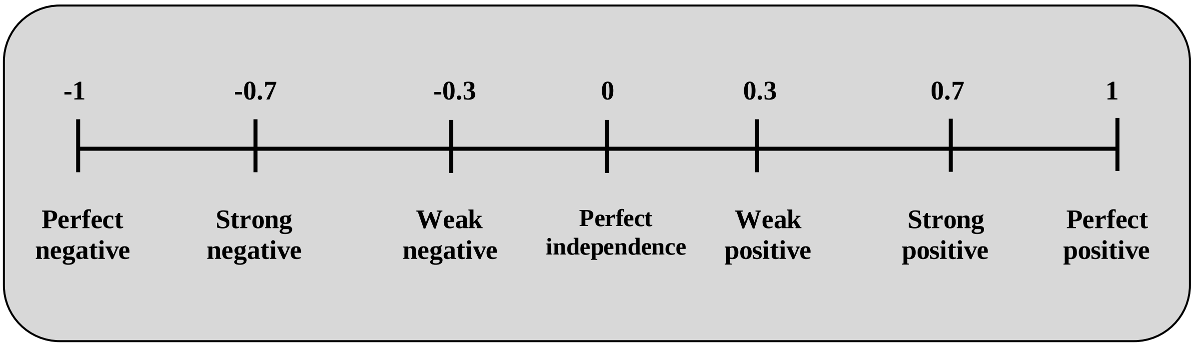


Figure 5.7: Values of the correlation coefficient

Source: Saunders et al. (2009)

Hinkle, Wiersma and Jurs (1998) have presented a rule of thumb for interpreting the size of the correlation coefficient in social science research where, a very high monotonic correlation exists when rho is closer to 1 (refer Table 5.7).

Table 5.7: Rule of thumb for interpreting the size of a correlation coefficient

Size of Correlation	Interpretation
0.90 to 1.00 (-0.90 to -1.00)	Very high correlation
0.70 to 0.90 (-0.70 to -0.90)	High correlation
0.50 to 0.70 (-0.50 to -0.70)	Moderate correlation
0.30 to 0.50 (-0.30 to -0.50)	Low correlation
0.00 to 0.30 (0.00 to -0.30)	Little if any correlation

Source: Hinkle, Wiersma and Jurs (1998)

Dancey and Reidy's (2004) has introduced another guide to interpret the correlation of variables (refer Table 5.8).

Table 5.8: Guide to interpret correlation coefficient

Value of the Correlation Coefficient	Strength of Correlation
1	Perfect
0.7 - 0.9	Strong
0.4 - 0.6	Moderate
0.1 - 0.3	Weak
0	Zero

Source: Dancey and Reidy's (2004)

As Hinkle et al., (1998) further verifies that, a small correlation coefficient is just as good as a high correlation, because most biological relationships are a long way from perfect. That is, the relationships are complex, so one should not expect a single variable to be a good predictor for another variable. Knoke, Bohrnstedt and Mee (2002) stated a similar statement about correlations in social science research as “Typically, a single independent variable in social research seldom accounts for more than 25% to 30% of the variance in a dependent variable, and often for as little as 2% to 5%.” (p.132). As Knoke et al. (2002) further mentioned, correlations are just as small or smaller, since biological phenomena are just as complex as social phenomena, where it is rare that a single variable explains much of the variation in another variable. Further, within business research it is extremely unusual to obtain perfect correlations (Saunders et al., 2009). The Table 5.9 illustrates the frequency to obtain strong and weak correlation values in social science research.

Table 5.9: Frequency occurs in social science research

r_s	**Frequency occurs in social science research**
0.50	seldom
0.55	seldom
0.14	often
0.22	often

Source: Knoke, Bohrnstedt and Mee (2002)

The criteria introduced by Saunders et al. (2009) were selected as widely used method, to interpret the correlation test results of variables (refer Table 5.10).

Table 5.10: Interpretation of correlation in this study

Size of Correlation	**Interpretation**
0.70 to 1.00 (-0.70 to -1.00)	Perfect correlation
0.30 to 0.70 (-0.30 to -0.70)	Strong correlation
0.00 to 0.30 (0.00 to -0.30)	Weak correlation
0.00	Perfect independence

Based on the strength of correlation between dependent and independent variables and the statistical significance which is less than 0.05 ($p<0.05$), the critical built environment factors were determined.

5.4.6.4 Ordinal logistic regression analysis

Logit models are used to solve regressions with a single dependent variable and various independent variables. Dependent variables which are analyzed in the majority of researches and applied studies are generally in categorical and ordinal structure. Ordinal Logit Models that consider the ordinal structure of the dependent variable are used in case where the dependent variable has at least 3 categories with these categories ordinally arranged (Ari & Yildiz, 2014). Ordinal logistic regression or ordinal regression is used to predict an ordinal dependent variable given one or more independent variables (Statistics Solutions, 2013). Further, it enables to determine which of independent variables have a statistically significant effect on dependent variable. There are various approaches, such as the use of mixed models or another class of models, probit for example, but the ordinal logistic regression models have been widely used in most of the previous research works (McCullagh, 1980; Anderson, 1984; Das & Rahman, 2011). The most common ordinal logistic model is the proportional odds model.

Ordinal logistic regression was selected as the most appropriate method for this study based on the following assumptions.

- Assumption 1: Dependent variable should be measured at the ordinal level

Occupants' productivity; the dependent variable was measured using an ordinal scale in this research (refer Section 2.5.4).

- Assumption 2: One or more independent variables, which are continuous, categorical or ordinal

Five critical built environment factors were identified as independent variables in this research which were significantly and positively correlated to occupants' productivity (refer Table 6.16). The independent variables were also measured in ordinal scale ranging from much lower to much higher (1-Much Lower; 2- Slightly Lower; 3- Normal, 4- Slightly Higher; 5-Much Higher).

- Assumption 3: There is no Multi-collinearity

Multi-collinearity occurs when there are two or more independent variables, which are highly correlated with each other. This leads to problems with understanding which variable contributes to the explanation of the dependent variable and technical issues in calculating an ordinal regression. The independent variables are not correlated to each other (refer Table 6.15). It shows that there is no multi-collinearity where it could occur when there are two or more independent variables, which are highly correlated with each other.

- Assumption 4: Proportional odds

The assumption of proportional odds means that each independent variable has an identical effect at each cumulative split of the ordinal dependent variable. According to previous studies, proportionality assumption is more often violated in practice, however; the violation does not really matter (Long & Freese, 2006). The research assumed that the distance between each category is equivalent and tested (refer Table 7.5). However, in the use of ordinal logistic regression, the implications of violating this assumption are minimal. Accordingly, the Polytomous Universal model (PLUM) of ordinal regression procedure in the SPSS v20 software was used in the analysis.

5.5 Phase Three

5.5.1 Draw conclusions and recommendations

Based on data analysis, the built environment factors critical for green buildings and their degree of influence on occupants' productivity were determined. Finally, improvements were suggested to enhance the IEQ evaluation criteria of the GREEN$^{SL®}$ rating system, based on the research outcomes. It fulfills the final objective of the research by giving a considerable outcome to the knowledge and industry.

5.6 Research Validity

As the measures that were taken to validate this research study, content validation, replication, internal and external validation were addressed in this research. To ensure the content validation, the survey questionnaire was tested by conducting a preliminary survey and relevant implications were identified. Further, the questionnaire was tested to ensure the data collected was reliable (replication). The selection of large sample and high response rate also improved the validity of research findings. Two research hypotheses and a conceptual framework were developed for internal validation. In the research analysis, the developed models were tested by using various parameters to ensure construct validity.

5.7 Summary

This chapter intended to describe the research methodology adopted. The research design framework was developed containing three phases. The first phase intended to formulate the research problem, aim and objectives and to develop a conceptual framework. Phase two consists of research methodological design. Nested model was adopted in this research. Positivism was identified as the suitable philosophical background with the assumptions of positivism under epistemology, objectivism under ontology and value free stance in terms of axiological undertaking. The survey method under quantitative research approach was identified as the suitable approach because this research is studied under quantitative phenomenon and further it gives quantitative outcome. The survey was designed to undertake as pilot and main surveys, and the occupants' in green office buildings was selected as population sample for this study. Questionnaire and semi-structured interviews were used to collect the data whilst significance testing, rank (Spearman) correlation and ordinal logistic regression were used in the data analysis. SPSS v20 software was used to conduct the data analysis. Accordingly, the research methodology which is more appropriate to conduct this research was identified corresponding to the research problem, aim and objectives.

6. DATA ANALYSIS AND FINDINGS 1: CRITICAL BUILT ENVIRONMENT FACTORS INFLUENCING OCCUPANTS' PRODUCTIVITY IN GREEN BUILDINGS

6.1 Introduction

The survey elicited the perception of green building occupants regarding the influence of built environment factors to enable an assessment of their degree of influence on occupants' productivity. Based on the adopted research paradigm, the relationship of built environment factors is viewed as a single reality implying the need to aggregate the individual assessment of the respondents. As the first stage, critical built environment factors influencing occupants' productivity were tested whilst the related hypothesized relationship is subsequently presented. This chapter thus addresses the part of the third objective by presenting the results of data analysis in relation to the assessment of critical built environment factors. Therefore, this explicates the potential relationships between the built environment factors and the occupants' productivity in green buildings.

6.2 Research Hypothesis - 01

The aim of this research is to investigate the built environment factors critical for green buildings and, its degree of influence on occupants' productivity in green certified office buildings in Sri Lanka. In order to achieve the aim, third objective was addressed in the first stage of data analysis. The developed H_1 hypothesis was tested by answering the developed sub research questions.

Hypothesis (H_1):

There is a significant relationship between the built environment and occupants' productivity in green buildings.

Sub research questions:

- What are the occupants' productivity influencing factors critical for green buildings?

In order to test the hypothesis, the identified built environment factors were categorized under twelve (12) major dimensions. The task of testing the hypothesis is thus simplified to an examination of the data to evidence the significant associations between the dimensions of the built environment and occupants' productivity. To facilitate the analysis, a widely used statistical technique was employed; Spearman's Correlation.

6.3 Demographic Information

The Figure 6.1 presents the respondents' demographic information. The purpose of which is to provide an overview of the expertise and experience of the respondents so as to generate confidence and credibility in the research findings. The respondents who engaged in this research represent the occupants of green certified office buildings. The respondents were selected randomly from managerial level, executive and clerical levels of green office buildings, which have obtained green 'gold' certification. Altogether, 65 employees responded to the main survey (refer Table 5.5). In this profile of respondents, 43.08% represented executive level office employees, 32.31% worked as clerical level employees and 24.62% were engaged as managerial level office employees.

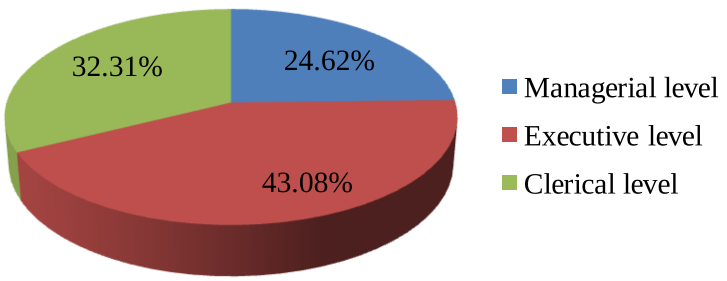


Figure 6.1: Respondents profile

The positions reported by respondents include office workers such as, Branch Managers, General Managers, Operations Managers, Office Executives, Assistant Managers, Secretariats, Maintenance Managers, Accountants, Quantity Surveyors, Project Managers, Engineers and Book Keepers. Further, all the selected occupants have occupied the green building since it was changed to green from their traditional work setting. It was evident that most of the respondents were in a position to provide the information requested in the questionnaire. The Section 6.4 describes the variables used in statistical analysis.

6.4 Variables in Research Analysis

In order to conduct the data analysis, dependent and independent variables were identified. Occupants' productivity was considered as the 'dependent variable' whilst the built environment factors were selected as 'independent variables.' Hence, 54 independent variables were considered in correlation analysis. The data analysis was performed among such dependent and independent variables of the research to explore the potential relationships between built environment factors and occupants' productivity in green buildings. Both statistical significance and correlation were tested to identify variables which showed a statistically significant association, and a strengthen relationship. Based on the strength of the correlation and its probability (p-value) of having occurred by chance alone, critical built environment factors were determined. Accordingly, as the first stage of data analysis, built environment factors in each cluster were evaluated to identify critical built environment factors, as described in Section 6.5.

6.5 Significant Built Environment Factors

6.5.1 Assessment of significant built environment factors

The identified 54 built environment factors were categorized under 12 major dimensions. As the first step, the correlation and its statistical significance of built environment factors to the major dimension were evaluated. Significant factors in each category were determined with the data reduction intension, based on the strength of the relationship and the level of significance. The bivariate correlation procedure in SPSS v20 software was used to compute the Spearman's Correlation coefficient and the level of significance.

The developed clusters are as follows;

Cluster A : Thermal quality

Cluster B : Visual quality

Cluster C : Indoor Air Quality

Cluster D : Ventilation

Cluster E : Acoustic quality

Cluster F : Spatial quality

Cluster G : Appearance of workplace

Cluster H : Building maintenance and cleanliness

Cluster I : Office type

Cluster J : Building materials used

Cluster K : Office layout

Cluster L : Social engagement

In the Spearman's Correlation analysis, the factors which showed statistically significant relationship (p-value), which is below the 0.05 and, the high coefficient of correlation, were considered as 'significant factors'. In the analysis, strength of the relationship between variables was assessed and interpreted by considering the value of correlation coefficient. This coefficient of correlation could take on any value between -1 and +1. A value of +1 represents a perfect positive correlation. Correlation coefficients between -1 and +1 represent weaker positive and negative correlations, a value of 0 meaning the variables are perfectly independent. The criteria introduced by Saundars et al. (2009) was considered to interpret the strength of monotonic correlation of variables (refer Table 6.1).

Table 6.1: Interpretation of Correlation

Size of Correlation	Interpretation
0.70 to 1.00 (-0.70 to -1.00)	Perfect correlation
0.30 to 0.70 (-0.30 to -0.70)	Strong correlation
0.00 to 0.30 (0.00 to -0.30)	Weak correlation
0.00	Perfect independence

Source: Saunders et al. (2009)

The correlation test results of built environment factors and its interpretations are presented subsequently.

6.5.1.1 Thermal quality

This includes built environment factors relating to thermal quality such as, personal control on ambient conditions, temperature, opening windows and personal thermal system control (refer Figure 6.2).

Thermal quality
Personal control on ambient conditions
Opening windows
Personal thermal system control
Temperature

Figure 6.2: Thermal quality Factors

Spearman's Correlation test was carried out to test the relationship between identified variables to determine the significant thermal quality factors. The Table 6.2 shows the SPSS Spearman's Correlation test results of significant thermal quality factors.

Table 6.2: Spearman correlation test results of significant thermal quality factors

		Thermal quality
Opening windows	Spearman's Correlation	**.285***
	Sig. (2-tailed)	**.022**
	N	65
*. Correlation is significant at the 0.05 level (2-tailed).		

Among the other factors, opening window is significantly associated to the thermal quality. However, it shows weak positive monotonic correlation (Spearman's rho=.285, p=.022), which implies the slightly increase of the number of opening windows would increase the thermal quality (monotonically increasing). Hence, opening windows was identified as a significant factor among the others. The remaining factors, such as, personal control on ambient conditions (Spearman's rho=.105, p=.407), temperature (Spearman's rho=-.111, p=.311) and personal thermal system control (Spearman's rho=-.079, p=.531) were rejected as they were not shown statistically significant correlation (refer Appendix 6.1 for Spearman's correlation matrix of thermal quality).

6.5.1.2 Visual quality

This includes the built environment factors related to visual quality. Provisions of daylighting, radiation and electromagnetic fields, electric lighting quality, glare, controllable task-lighting, illuminance, controllable lighting installations, lighting intensity, colour, personal/task lighting, proximity to a window and view to outdoor environment are the visual quality factors, which were identified by reviewing key literature (refer Figure 6.3).

Visual quality
Provisions of daylighting
Radiation and electromagnetic field
Electric lighting quality
Glare
Controllable task-lighting
Illuminance
Controllable lighting installation
Lighting intensity
Colour
Personal/task lighting
Proximity to a window
View to outdoor environment

Figure 6.3: Visual quality factors

Of those factors, controllable lighting installations (Spearman's rho=.260, p=.037), personal lighting (Spearman's rho=.248, p=.047) and view to outdoor environment (Spearman's rho=.388, p=.001) factors showed a statistically significant correlation to the visual quality. However, controllable lighting installations and personal lighting factors showed a weak positive monotonic correlation, whilst view to outdoor environment showed a strong positive monotonic correlation. As it is implied in test results, the increase of the provisions of personal lighting, view to outdoor environment and controllable lighting installations would slightly increase the visual quality. Therefore, those three factors were identified as the significant visual quality related factors. The results of Spearman's Correlation test carried out in SPSS are illustrated in Table 6.3.

Table 6.3: Spearman correlation test results of significant visual quality factors

		Visual quality
Controllable lighting installations	Spearman's Correlation	**.260***
	Sig. (2-tailed)	**0.037**
	N	65
Personal lighting	Spearman's Correlation	**.248***
	Sig. (2-tailed)	**0.047**
	N	65
View to outdoor environment	Spearman's Correlation	**.388****
	Sig. (2-tailed)	**0.001**
	N	65

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Accordingly, the factors which were not in a position of statistically significant relationship to the visual quality, such as, provisions of day lighting (Spearman's rho=.135, p=.282), radiation and electromagnetic fields (Spearman's rho=.045, p=.724), electric lighting quality (Spearman's rho=.074, p=.558), glare (Spearman's rho=.037, p=.773), controllable task-lighting (Spearman's rho=.139, p=.270), illuminance (Spearman's rho=.047, p=.713), lighting intensity (Spearman's rho=.021, p=.870), colour (Spearman's rho=.102, p=.419) and proximity to a window (Spearman's rho=.119, p=.345) were rejected (refer Appendix 6.2 for Spearman correlation matrix of visual quality).

6.5.1.3 Indoor Air Quality (IAQ)

The Figure 6.4 illustrates the IAQ related built environment factors.

Indoor Air Quality (IAQ)
Indoor air temperature
Air quality
Dust
Odour
Air freshness
Air movement

Figure 6.4: Indoor Air Quality factors

As the above Figure 6.4, IAQ consists of six sub factors, such as, indoor air temperature, air quality, dust, odour, air freshness and air movement. The significant IAQ factors were determined by testing statistically significant Spearman's Correlations in between variables. The output of SPSS showed a significant association between air quality and IAQ as illustrated in Table 6.4.

Table 6.4: Spearman correlation test results of significant IAQ factors

		Indoor Air Quality
Air quality	Spearman's Correlation	**.253***
	Sig. (2-tailed)	**.042**
	N	65
*. Correlation is significant at the 0.05 level (2-tailed).		

According to the Table 6.4, air quality shows a statistically significant, weak positive monotonic correlation to IAQ (Spearman's rho=.253, p=.042). As per the positive monotonic correlation, IAQ will slightly increase when air quality is increasing (refer Appendix 6.3 for Spearman correlation matrix of IAQ). Accordingly, indoor air temperature (Spearman's rho=.059, p=.639), dust (Spearman's rho=.042, p=.740), odour (Spearman's rho=.062, p=.625), air freshness (Spearman's rho=.045, p=.723) and air movement (Spearman's rho=-.021, p=.866) factors were rejected as they were not shown a statistically significant relationship.

6.5.1.4 Ventilation

According to Figure 6.5, natural ventilation, mechanical ventilation and amount of ventilation were identified as the factors relating to ventilation.

Ventilation
Amount of ventilation
Natural ventilation
Mechanical ventilation

Figure 6.5: Ventilation factors

The identified factors were evaluated by performing a Spearman's Correlation test in SPSS. The Table 6.5 illustrates the correlation test results of the significant factors selected. As the test results show, amount of ventilation has a weak positive monotonic correlation to ventilation. Further, the relationship is statistically significant where the probability of the test statistics or one more extreme having occurred by chance alone is low (Spearman's rho=.254, p=.041).

Table 6.5: Spearman correlation test results of significant ventilation factors

		Ventilation
Amount of ventilation	Spearman's Correlation	**.254***
	Sig. (2-tailed)	**.041**
	N	65
*. Correlation is significant at the 0.05 level (2-tailed).		

As such weak positive monotonic correlation implies, the slightly increase of the amount of ventilation could effect to slightly increase the ventilation in buildings. Accordingly, the amount of ventilation is considered as a significant factor whilst the other factors, such as, natural ventilation (Spearman's rho=.143, p=.257) and mechanical ventilation (Spearman's rho=.134, p=.246) were rejected as statistically insignificant (refer Appendix 6.4 for Spearman correlation matrix of ventilation).

6.5.1.5 Acoustic quality

This includes the built environment factors relating to acoustic quality, such as, background sound level, acoustical partitioning, sound privacy, system controls and sound absorption materials (refer Figure 6.6).

Acoustic quality
Background noise level
Acoustical partitioning
Sound privacy
System controls
Sound absorption materials

Figure 6.6: Acoustic quality factors

The Spearman's Correlation test was carried out and, the significant factors were identified. According to Table 6.6, system control showed a statistically significant, weak positive monotonic correlation to acoustic quality (Spearman's rho=.281, p=.023). Further, acoustic partitioning is also significantly correlated (Spearman's rho=.248, p=.047). As these monotonic correlations showed, the slightly increase of the provisions of system control and acoustical partitioning could increase the acoustic quality in buildings. Hence, system control and acoustical partitioning factors were selected as significant acoustic quality factors.

Table 6.6: Spearman correlation test results of significant acoustic quality factors

		Acoustic quality
System controls	Spearman's Correlation	**.281***
	Sig. (2-tailed)	**.023**
	N	65
Acoustical partitioning	Spearman's Correlation	**.248***
	Sig. (2-tailed)	**.047**
	N	65
*. Correlation is significant at the 0.05 level (2-tailed).		

The remaining factors, such as, background noise level (Spearman's rho=.193, p=.124), sound privacy (Spearman's rho=.-189, p=.132) and sound absorption materials (Spearman's rho=.048, p=.702), which were not significantly associated with acoustic quality were rejected (refer Appendix 6.5 for Spearman correlation matrix of acoustic quality).

6.5.1.6 Spatial quality

As the Figure 6.7 shows, spatial quality factors, such as, distractions, personal control workstations, privacy, work instruments and aids, office instrumentality, space arrangement, orientation of office and space flexibility are identified.

Spatial quality
Distractions
Personal control workstations
Privacy
Office instrumentality
Space arrangement
Orientation of office
Space flexibility

Figure 6.7: Spatial quality factors

The Table 6.7 illustrates the test results of Spearman's Correlation. According to the test statistics, personal control workstation showed a statistically significant correlation to the spatial quality. Further, it was a weak positive monotonic correlation (Spearman's rho=.249, p=.045). This implies when the provisions of personal control workstations increase slightly, spatial quality is also increased. Even though distractions showed a statistically significant association to the spatial quality, it was a weak negative correlation (r=-.250, p=.045).

Thus, it is necessary to take actions to reduce the distractions in order to improve the spatial quality in buildings.

Table 6.7: Spearman correlation test results of significant spatial quality factors

		Spatial quality
Distractions	Spearman's Correlation	**-.250***
	Sig. (2-tailed)	**.045**
	N	65
Personal control workstations	Spearman's Correlation	**.249***
	Sig. (2-tailed)	**.045**
	N	65
*. Correlation is significant at the 0.05 level (2-tailed).		

Considering the statistically significant monotonic correlation, distractions and personal control workstations were selected as significant factors. Accordingly, the remaining factors, such as, privacy (Spearman's rho=.192, p=.125), office instrumentality (Spearman's rho=.066, p=.603), space arrangement (Spearman's rho=-.100, p=.428), orientation of office (Spearman's rho=-.127, p=.315) and space flexibility (Spearman's rho=.160, p=.202) were rejected (refer Appendix 6.6 for Spearman correlation matrix of spatial quality).

6.5.1.7: Appearance of workplace

This consists of the built environment factors relating to appearance of workplace, such as, art and aesthetic, contact with nature and views, symbolism, floor coverings and wall hangings and the architectural arrangement of workplace (refer Figure 6.8).

Appearance of workplace
Art and aesthetic
Contact with nature and views
Symbolism
Floor coverings and wall hangings
Architectural arrangement of workplace

Figure 6.8: Appearance of workplace related factors

According to the test results of Spearman's Correlation, art and aesthetic showed a statistically significant, weak positive monotonic correlation to appearance of workplace (Spearman's rho=.295, p=.017). As it means, the slightly increase of the provisions of art and aesthetic may increase the workplace appearance (Table 6.8).

Table 6.8: Spearman correlation test results of significant workplace appearance related factors

		Appearance of workplace
Art and aesthetic	Spearman's Correlation	**.295***
	Sig. (2-tailed)	**.017**
	N	65
*. Correlation is significant at the 0.05 level (2-tailed).		

Thus, art and aesthetic of workplace was selected as significant factor whilst remaining factors, such as, contact with nature and views (Spearman's rho=.115, p=.364), symbolism (Spearman's rho=.040, p=.752), floor coverings and wall hangings (Spearman's rho=-.154, p=.221), and architectural arrangement of workplace (Spearman's rho=.050, p=.694) were rejected as statistically insignificant factors (refer Appendix 6.7 for Spearman correlation matrix of workplace appearance).

6.5.1.8 *Building maintenance and cleanliness*

Building maintenance and cleanliness is another major dimension demonstrated in the existing literature. This cluster includes two built environment factors, such as, building maintenance and general cleanliness (Figure 6.9).

Building maintenance and cleanliness
Building maintenance
Cleanliness

Figure 6.9: Building maintenance and cleanliness related factors

The Spearmen's Correlation test results are shown in Table 6.9. According to the test results, there is a statistically significant monotonic correlation between those two factors and the building maintenance. The test results of building maintenance showed a weak positive monotonic correlation to the major factor (Spearman's rho=.276), with high statistical significance (p=.026). Cleanliness also showed a statistically significant and strong positive monotonic correlation (Spearman's rho=.552, p=.000).

Table 6.9: Spearman correlation test results of significant building maintenance related factors

		Building maintenance and cleanliness
Building maintenance	Spearman's Correlation	**.276***
	Sig. (2-tailed)	**.026**
	N	65
Cleanliness	Spearman's Correlation	**.552****
	Sig. (2-tailed)	**.000**
	N	65

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The overall quality of the building maintenance and general cleanliness could increase monotonically by increasing the quality of those two factors. Hence, both factors were considered as significant factors (refer Appendix 6.8 for Spearman correlation matrix of building maintenance and cleanliness).

6.5.1.9 Office type

In this cluster, two factors, such as, open plan and cellular type office designs were identified as illustrated in Figure 6.10.

Office type
Open plan
Cellular

Figure 6.10: Office type related factors

The output of SPSS is shown in Table 6.10. According to the test results of Spearman's Correlation, there is a strong positive monotonic correlation between open plan design and the office type (Spearman's rho=.518). Further, it was identified as statistically significant correlation (p=.004).

Table 6.10: Spearman correlation test results of significant office type related factors

		Office type
Open plan office design	Spearman's Correlation	**.518***
	Sig. (2-tailed)	**.004**
	N	65
*. Correlation is significant at the 0.05 level (2-tailed).		

Considering both statistical significance and the strength of correlation, open plan design was selected as the significant factor, whist rejecting cellular office design as insignificant (Spearman's rho=.178, p=.156) (refer Appendix 6.9 for Spearman correlation matrix of office type).

6.5.1.10 Building materials used

According to the literature, building materials used in buildings have a great influence on occupants' productivity, thus have been considered in the evaluation. Thereby, use of low toxic emitting materials was identified as the related factor.

Building materials used
Use of low toxic emitting materials

Figure 6.11: Building materials related factors

The Spearman's Correlation test results are shown in Table 6.11.

Table 6.11: Spearman correlation test results of significant building materials related factors

		Building materials
Use of low toxic emitting materials	Spearman's Correlation	**.559****
	Sig. (2-tailed)	**.015**
	N	65
*. Correlation is significant at the 0.05 level (2-tailed).		

The test results of Spearman's Correlation showed that there is a statistically significant, strong positive monotonic correlation to building materials used (Spearman's rho=.559, p=.015). Thus, the use of low toxic emitting materials was considered as the significant factor (refer Appendix 6.10 for Spearman's correlation matrix of building materials).

6.5.1.11 Office layout

The factors identified in key literature were evaluated and tested to identify significant factors relating to the office layout.

Office layout
Ergonomics
Screen position of workstation
Adjustability of furniture
Amount of space

Figure 6.12: Office layout related factors

As existing literature demonstrated, ergonomics, screen position of workstation, adjustability of furniture, amount of space were identified as built environment factors relating to the office layout (refer Figure 6.12). The test results of Spearman's Correlation showed that, the factors, such as, amount of space and adjustability of furniture confirm a statistically significant association (Table 6.12). According to the criteria adopted, adjustability of furniture shows a strong positive monotonic correlation to the office layout with a strong correlation coefficient and high statistical significance (Spearman's rho=.389, p=.001). Amount of space is also showed a weak positive monotonic correlation (Spearman's rho=.261, p=.036). Accordingly, those factors were selected as significant factors, whilst, remaining factors, such as, ergonomics (Spearman's rho=.210, p=.093) and screen position of workstation (Spearman's rho=.046, p=.716) were rejected (refer Appendix 6.11 for Spearman correlation matrix of office layout).

Table 6.12: Spearman correlation test results of significant office layout related factors

		Office layout
Adjustability of furniture	Spearman's Correlation	**.389****
	Sig. (2-tailed)	**.001**
	N	65
Amount of space	Spearman's Correlation	**.261***
	Sig. (2-tailed)	**.036**
	N	65
*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).		

6.5.1.12 Social engagement

As one of main dimensions influencing occupants' productivity, social engagement was considered in the evaluation. Space for informal meetings, access to documents and psychological restoration and relaxation are the built environment factors related to social engagement as illustrated in Figure 6.13.

Social engagement
Space for informal meetings
Access to documents
Psychological restoration and relaxation

Figure 6.13: Social engagement related factors

As the above Figure 6.13 exemplifies, all three factors were evaluated by testing the Spearman's Correlation. Test results mentioned in Table 6.13 showed that all three factors prove a statistically significant association to the social engagement. The correlation coefficient values of space for informal meetings and psychological restoration and relaxation factors showed a strong positive monotonic correlation (Spearman's rho=.512) with high statistical significance (p=.000). Access to documents is also showed a statistically significant, strong positive monotonic correlation to the social engagement (Spearman's rho=.449, p=.000).

Table 6.13: Spearman correlation test results of significant social engagement related factors

		Social engagement
Space for informal meetings	Spearman's Correlation	**.512****
	Sig. (2-tailed)	**.000**
	N	65
Access to documents	Spearman's Correlation	**.449****
	Sig. (2-tailed)	**.000**
	N	65
Psychological restoration and relaxation	Spearman's Correlation	**.512****
	Sig. (2-tailed)	**.000**
	N	65
**. Correlation is significant at the 0.01 level (2-tailed).		

Hence, all three factors were selected as significant factors by considering the high statistical significance and the strong positive monotonic correlation as per the criteria adopted (refer Appendix 6.12 for Spearman's Correlation matrix of social engagement). Accordingly, 54 built environment factors were evaluated and, 35 insignificant factors were rejected based on the test results of Spearman's Correlation. The Figure 6.14 differentiates the significant and insignificant built environment factors based on its statistically significant monotonic correlation to each major dimension.

Statistically significant factors (Selected)

Thermal quality:
- Opening windows

Visual quality:
- Controllable lighting installation
- Personal/task lighting
- View to outdoor environment

Indoor Air Quality:
- Air quality

Ventilation:
- Amount of ventilation

Acoustic quality:
- System controls
- Acoustical partitioning

Spatial quality:
- Distractions
- Personal control workstations

Appearance of workplace:
- Art and aesthetic

Building maintenance and cleanliness:
- Building maintenance
- Cleanliness

Building materials:
- Use of low toxic emitting materials

Office type:
- Open plan office design

Office layout:
- Amount of space
- Adjustability of furniture

Social engagement:
- Space for informal meetings
- Access to documents
- Psychological restoration and relaxation

Statistically insignificant factors (Rejected)

Thermal quality:
- Personal control on ambient conditions
- Temperature
- Personal thermal system control

Visual quality:
- Provisions of day lighting
- Radiation and electromagnetic field
- Electric lighting quality
- Controllable task lighting
- Colour, illuminance and glare
- Lighting intensity
- Proximity to window

Indoor Air Quality:
- Indoor air temperature
- Dust and odour
- Air freshness
- air movement

Ventilation:
- Natural ventilation
- Mechanical ventilation

Acoustic quality:
- Background noise level
- Sound privacy
- Sound absorptive materials

Spatial quality:
- Privacy
- Office instrumentality
- Space arrangement
- Orientation of office
- Space flexibility

Appearance of workplace:
- Contact with nature
- Symbolism
- Floor coverings and wall hangings,
- Architectural arrangement

Office type:
- Cellular design

Office layout:
- Ergonomics
- Screen position of workstations

Figure 6.14: Statistically significant and insignificant factors

Accordingly, significant factors were selected for subsequent analysis, as they have shown a statistically significant monotonic correlation to each major dimension.

6.5.2 Validation of survey results

From the overall assessment, significant built environment factors were selected. According to the test statistics, twenty (20) factors were selected which have showed a statistically significant weak or strong monotonic correlation to the major dimensions. However, none of the factors were generally perceived as perfectly correlated factors. Further, this fact is in confirming with the extant literature and the findings of the qualitative inquiry that indeed the potential of selected built environment factors. Therefore, the factors which showed statistically significant correlation to the major dimension were selected for the subsequent analysis even though the strength of the relationship of some factors was at moderate and weak levels.

As Hinkle et al. (1998) further verified that, a small correlation coefficient is just as good as a high correlation, because such most relationships are a long way from perfect.

"Typically, a single independent variable in social research seldom accounts for more than 25% to 30% of the variance in a dependent variable, and often for as little as 2% to 5%" (Knoke et al., 2002, p.132)

The overall assessment showed the weak and strong correlation of factors influencing occupants' productivity. Further, it also confirmed that indeed a varying significance may influence occupants' productivity.

The Table 6.14 indicates the overall assessment of the significant built environment factors.

Table 6.14: Significant factors selected

Significant Built Environment Factors	Statistical Significance (p-value)	Coefficient of Correlation (Spearman's rho)	Strength of Correlation			
			Perfect strong	Strong	Weak	Perfect Independence
Thermal quality						
Opening windows	**.022**	**.285***			√	
Visual quality						
Controllable lighting installation	**.037**	**.260***			√	
Personal/task lighting	**.047**	**.248***			√	
View to outdoor environment	**.001**	**.388****		√		
Indoor Air quality						
Air quality	**.042**	**.253***			√	
Ventilation						
Amount of ventilation	**.041**	**.254***			√	
Acoustic quality						
System controls	**.023**	**.281***			√	
Acoustical partitioning	**.047**	**.248***			√	
Spatial quality						
Distractions	**.045**	**-.250***			√	
Personal control workstations	**.045**	**.249***			√	
Appearance of workplace						
Art and aesthetic	**.017**	**.295***			√	
Building maintenance and cleanliness						
Building maintenance	**.026**	**.276***			√	
Cleanliness	**.000**	**.552****		√		
Building materials used						
Use of low toxic emitting materials	**.015**	**.559****		√		
Office type						
Open plan office design	**.004**	**.518***		√		

Office layout						
Amount of space	**.036**	**.261***			√	
Adjustability of furniture	**.001**	**.389****		√		
Social engagement						
Space for informal meetings	**.000**	**.512****		√		
Access to documents	**.000**	**.449****		√		
Psychological restoration and relaxation	**.000**	**.512****		√		

Generally, the overall assessment given in Table 6.14 is consisting with existing literature, in terms of the significance of selected factors in each cluster. The factor called 'opening windows' is selected as a significant built environment factor to measure the influence of thermal quality in subsequent analysis. The selection is further proved in existing literature. According to the study by Muhi & Butala (2003), buildings occupants had faced for several building related symptoms such as, dry skins, headache etc due to the lack of air inside the building as it may decrease the thermal comfort in the building. As Muhi and Butala (2003) further mentioned, facilitating more provisions to naturally ventilate the building, such as, more opening windows would help to increase the thermal quality. By further proving the selection of opening windows under thermal quality, Madavi and Unzeitig (2004) have also selected the opening windows as one of major parameters of thermal quality in buildings.

In this research, controllable lighting installations, personal/task lighting and view to outdoor environment factors showed statistically significant relationship to the visual quality. As the selection is further confirmed, most of studies have selected those factors to evaluate the influence of visual quality on occupants' satisfaction and productivity (Madavi & Unzeitig, 2004; Juslen et al., 2006; Lee & Guerin, 2009). According to the study by Juslen et al. (2006), controllable lighting installations and task lighting have considered as the significant factors to test the effect on occupants' productivity and wellbeing. In the evaluation of IAQ in buildings, air quality has considered as the major parameter in many of previous studies (Bartlett & Howard, 2000; Clements-Croome, 2002; Mahdavi & Unzeitig, 2004 & Kim & Dear, 2011).

In the study by Kim and Dear (2011), air quality has selected as the parameter for IAQ in occupants' satisfaction survey. Hence, the selection of air quality as a significant factor in this evaluation can be further confirmed with regards to the extant literature.

According to the Table 6.14, amount of ventilation showed a statistically significant weak positive correlation to the ventilation in building. In some of the studies, the relationship between ventilation and occupants' satisfaction and productivity has evaluated. However, no evaluation has made on such sub indicators of built environment to measure the influence. Even though, none of studies have merely focusing on sub ventilation factors, a previous environmental study conducted by Muhi and Butala in the year of 2003 identified that the ventilation can have a high influence on occupants' productivity, as the amount of ventilation flowing into a building is the amount which would satisfy the majority of occupants. Thus, the selection of the 'amount of ventilation' as a significant factor in this research was further validated.

Acoustic quality is one of important areas that need to be considered in productivity research. As most studies confirmed, there is a significant impact of internal and external background noises on occupants' productivity. System control and acoustical partitioning were identified as significant factors in this research by considering the statistical significance of their monotonic correlation. Most of previous studies have conducted their evaluations on those factors to measure the occupants' satisfaction and its effect on productivity (Heerwagen, 2000; Mahdavi & Unzeitig, 2004; Clements-Croome, 2002; Kim & Dear, 2011). Further, a study by Frontczak and Wargocki (2010) proved that noise is distracting the concentration on work or study and provides less than ideal working and learning environments, which could be mainly due to uncovered building systems and less design concerns. Among the other significant factors, spatial quality related factors take important position as most of previous studies have focused on the evaluation of spatial quality and occupants' productivity. Mainly, facilitating personal control workstations and reduce the background distractions are most common considerations in extant literature (Saari et al., 2005; Codinhoto et al., 2009). Similarly, this research has selected those factors to evaluate their potential links and influences on occupants' productivity in green buildings.

Art and aesthetic, building maintenance and cleanliness, use of low toxic emitting materials are other significant factors selected in this research (refer Table 6.14). According to the test statistics, all those factors showed a statistically significant correlation to the major parameters. As Muhi and Buthala (2003) identified that, art and aesthetic gives occupants' a pleasure to work whilst building maintenance situations and cleanliness of the workplace could also affect the productivity. Mostly, occupants may always expect to work in pleasant and cleanly environment and it should not generate toxicity too. Thus, in the productivity research conducted, those factors have considered as significant factors similar as selected in this study. Further, the arrangement of office space is another main aspect considered in designing office buildings. Among the other sub parameters, the amount of space given for occupants and, the adjustability of their furniture are two major aspects that need to be considered most (Kim & Dear, 2011). The test results of correlation analysis in this research also confirmed that the use of those factors with the high statistical significance and the strength of correlation (refer Table 6.14). Nevertheless, office type came to the top level in designing workplace environment, as most of studies believed that the type of office could have greater influence on occupants' productivity. As Kim and Dear (2011) mentioned, open plan and cellular designs were the major types of office designs, however, most of studies had focused on the open plan office space and productivity. According to a study by Lee (2010), open plan office without partitions, presented significantly higher association to the noise level in indoor environment, even though it has given an opportunity to interact with other workers. Similarly, the correlation test results in this research also showed the statistical significance of open plan office design in relation to the office type. As the last three significant factors, social space for informal meetings, access to documents and psychological restoration and relaxation were selected with high statistically significant strong monotonic correlation (refer Table 6.14). According to the extant literature, especially in a study by Mahdavi and Unzeitig, (2004), the productivity evaluation has focused on the impact of social engagement in an office environment. As the author mentioned that the social space for informal meetings, access to documents and psychological restoration and relaxation have identified as significant parameters that need to be importantly evaluated. Accordingly, the correlation test results were further discussed in order to validate the first stage of research analysis. With the data reduction intention of the research, twenty (20) significant built environment factors from fifty four (54) factors were selected to use in subsequent analysis to test the relationship and, the effect on occupants' productivity in green certified office buildings. The Section 6.6 presents the test results of Spearman's Correlation analysis conducted among significant built environment factors and occupants' productivity.

6.6 Critical Built Environment Factors for Green Buildings

6.6.1 Assessment of critical built environment factors

Survey data collected on significant built environment factors influencing occupants' productivity were evaluated and tested to identify built environment factors critical for green buildings. Occupants' productivity was considered as the 'dependent variable' whilst the significant built environment factors were deemed as 'independent variables' (refer Figure 6.15).

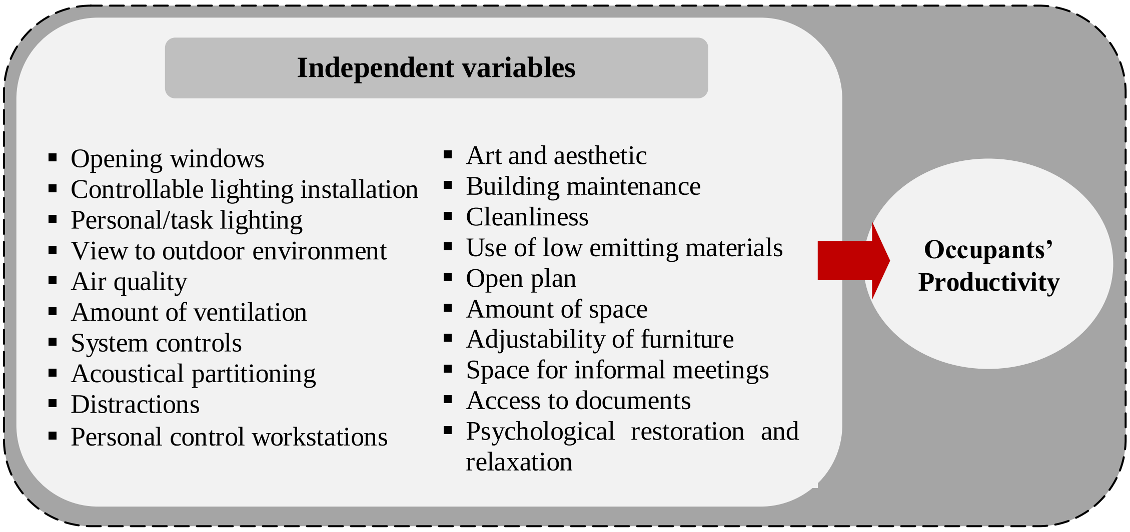


Figure 6.15: Variables in correlation analysis

The test results of Spearman's Correlation are shown in Table 6.15.

Table 6.15: Spearman's Correlation matrix of significant built environment factors

The Spearman's Correlation analysis was performed as the bivariate procedure in SPSS v20 statistical analysis software. The test results were interpreted based on the statistical significance (p-value), which is below the 0.05, and the strength of the correlation in relation to the criteria adopted (refer Table 6.15). The correlation test results of critical built environment factors influencing occupants' productivity in green buildings are shown in Table 6.16.

Table 6.16: Spearman correlation matrix of critical built environment factors

		Occupants productivity	Air quality	Acoustical partitioning	System control	Open plan	Amount of space
Occupants productivity	Correlation Coefficient	1.000	**.258***	**.257***	**.347****	**-.262***	**.252***
	Sig. (2-tailed)		**.038**	**.039**	**.005**	**.035**	**.043**
	N	65	65	65	65	65	65
Air quality	Correlation Coefficient	**.258***	1.000	.093	-.049	-.137	-.129
	Sig. (2-tailed)	**.038**		.462	.697	.277	.305
	N	65	65	65	65	65	65
Acoustical partitioning	Correlation Coefficient	.257*	.093	1.000	-.169	-.086	.110
	Sig. (2-tailed)	.039	.462		.179	.494	.385
	N	65	65	65	65	65	65
System control	Correlation Coefficient	.347**	-.049	-.169	1.000	.141	-.141
	Sig. (2-tailed)	**.005**	.697	.179		.261	.262
	N	65	65	65	65	65	65
Open plan office type	Correlation Coefficient	**-.262***	-.137	-.086	.141	1.000	.136
	Sig. (2-tailed)	**.035**	.277	.494	.261		.280
	N	65	65	65	65	65	65
Amount of space	Correlation Coefficient	**.252***	-.129	.110	-.141	.136	1.000
	Sig. (2-tailed)	**.043**	.305	.385	.262	.280	
	N	65	65	65	65	65	65

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

According to the SPSS test results of Spearman's Correlation, air quality, acoustical partitioning, system control, open plan office type and amount of space were identified as the critical built environment factors.

As SPSS output shows, there is a statistically significant weak positive correlation between air quality and occupants' productivity in green buildings, with the .258 of correlation coefficient (Spearman's rho) and the .038 of statistical significance (p-value). As this monotonic correlation implies, the slight improvement of air quality in green buildings would link to improve the occupants' productivity. Acoustical partitioning was another factor which could critically influence occupants' productivity in green buildings. Acoustical partitioning showed a statistically significant, weak positive monotonic correlation to occupants' productivity (Spearman's rho= 257, p= .039). Further, system control was determined as another critical factor, as it showed a strong positive monotonic correlation (Spearman's rho= .347), with high statistical significance (p= .005). Hence, those two factors were identified as critical acoustic quality factors influencing occupants' productivity in green certified office buildings. Amount of space was identified as an important parameter which could critically influence the occupants' productivity in green buildings. According to the test statistics of Spearman's Correlation analysis, there is a weak positive monotonic correlation between amount of space and occupants' productivity (Spearman's rho= .252) at the .043 of statistical significance. Even though other factors showed statistically significant positive correlation to occupant's productivity, open plan office type showed a negative association towards occupants' productivity improvements. According to the test statistics, open plan office type showed a statistically significant, weak negative monotonic correlation (Spearman's rho= -.262, p= .035). Accordingly, the potential link between critical built environment factors, such as, air quality, acoustical partitioning, system controls, open plan office type and amount of space (independent variables) and occupants' productivity (dependent variable) was determined based on the Spearman's Correlation. All those five factors were selected as critical built environment factors influencing occupants' productivity, as they showed a statistically significant monotonic correlation to the dependent variable.

Based on the strength of correlation, all those factors were ranked in order to identify most and least critical built environment factors influencing occupants' productivity. Accordingly, the factors which have high correlation coefficient value to lower correlation coefficient value were recognized. According to the Table 6.17, system control was determined as the highly critical factor as it has showed highest coefficient value compared to the other factors. Open plan office design has obtained the send place in ranking, whilst, air quality, acoustical partitioning and amount of space gained the third, fourth and fifth places respectively.

Table 6.17: Ranking of critical factors

Built environment factors	Correlation coefficient	Rank
System controls	.347**	1
Open plan office type	-.262*	2
Air quality	.258*	3
Acoustical partitioning	.257*	4
Amount of space	.252*	5

As per the research hypothesis developed, the significant relationship between built environment and occupants' productivity in green buildings was tested. The questionnaire survey data was evaluated by using statistical analysis techniques of probability testing and Spearman's Correlation. According to the analysis of survey data, five built environment factors were selected as critical factors influencing occupants' productivity in green certified office buildings. The survey results were further verified by conducting interviews with green building occupants. The Section 6.6.3 describes the overall assessment of critical built environment factors along with the analysis of interview data and extant literature for further verification.

6.6.2 Validation of survey results

The test results of Spearman's Correlation confirmed the link between built environment and occupants' productivity in green buildings. Twenty significant factors were evaluated in the analysis and five factors were determined as critical factors, which have showed a statistically significant relationship to occupants' productivity.

The overall assessment of critical built environment factors is exemplified in Table 6.18. As Table illustrates, the strength of correlation and the level of significance of system control, open plan office design, air quality, acoustical partitioning and amount of space were further reviewed.

Table 6.18: Overall assessment of critical built environment factors

Significant Built Environment Factors	**Statistical Significance (p-value)**	**Coefficient of Correlation (Spearman's rho)**	**Strength of Correlation**				**Ranking order**
			Perfect strong	**Strong**	**Weak**	**Perfectly Independent**	
Occupants' productivity influencing factors							
System controls	.005	.347**		√			**1**
Open plan office type	.035	-.262*			√		**2**
Air quality	.038	.258*			√		**3**
Acoustical partitioning	.039	.257*			√		**4**
Amount of space	.043	.252*			√		**5**

Among the other acoustic quality related factors, system control and acoustical partitioning were identified as the significant factors, which showed a statistically significant monotonic correlation to the acoustic quality in green buildings. In the correlation analysis, system control and acoustical partitioning factors (independent variables) were evaluated with the occupants' productivity (dependent variable). As SPSS output showed, both of them proved a significant association to the occupants' productivity. System control showed a strong positive monotonic correlation (Spearman's rho=.347, p=.005), whilst acoustical partitioning showed a weak positive monotonic correlation (Spearman's rho=.347, p=.005) at high statistical significance level ($p<0.05$). The monotonic correlation of both factors confirms the improvement of occupants' productivity in green buildings with respect to the acoustic quality provisions provided in green buildings. Hence, the provisions of system control and acoustical partitioning can increase to ensure occupants' productivity improvements. The test results of Correlation were further verified by the opinions of interviewees.

A Quantity Surveyor in Green Building C stated that,

> *"we are working here very happily as the environment is comfortable with this natural environment than our previous building. However, it would be beneficial to further concern on controlling the noise generated inside and outside the building."*

It is further proved by Branch Manager in Green Building A as,

> *"Green building is a new concept and we have introduced to this new building. Environment is really comfortable to work and, it increases our productivity as well. But, I would like to highlight one area that needs to be improved further. The noise generated inside the building is really disturbing to our day to day works."*

Furthermore, according to the previous productivity related studies, acoustic quality has a potential link to occupants' productivity (Mahdavi & Unzeitig, 2004; Clements-Croome, 2002; Kim & Dear, 2011). A study by Frontczak and Wargocki (2010) proved that noise is distracting the concentration on work or study and provides less than ideal working and learning environments. Further, it could be from internal sources such as, building systems, office works and workers etc. and from background noise generating sources. According to the test results and interview data, the potential relationship between system control and acoustical partitioning factors and occupants' productivity was determined. As SPSS test statistics showed, open plan office type indicated a statistically significant weak negative monotonic correlation to occupants' productivity in green buildings (Spearman's rho= -.262, p= .035). It was identified as a surprised finding, as most of buildings tend to design their office spaces as open plans. Thus, the test results of correlation analysis were further verified by comparing with the interview data and extant literature.

The opinions given by interviewees are stated below.

> *"It is good to have this type of office areas, as it helps to interact with our junior staff and other co-workers"*

(Facilities Engineer – Green Building B)

There is a potential link between open plan and worker productivity. Open plan designs give workers a comfortable environment, as it facilitates interaction and team work with other employees. It enhances productivity. However, organization can decide which type is suitable for their office space based on the nature of work. So… I think this office space has facilitated high interaction with our staff."

(Architect – Green Building C)

"This type of office is good to interact with others but, sometimes, mind set is changing due to the distractions in open plan office environment. It reduces our productivity."

(Assistant Manager – Green Building A)

"As I think, this is not always suited for office buildings. It has different influences relating to the nature of the work. Mainly, open plan offices without any partitions generate disturbances on our work. And, it takes our attention away from the works. Such disturbances affect to get rid of the uniformity of office work which reduces our productivity."

(Civil Engineer - Green Building C)

"Changing and the rearranging of the workplace to a large open plan office area affect to delay the work carried out and it sometimes adversely affect the meeting of deadlines due to distractions, disturbances and less concentration of work."

(Research and Development Engineer - Green Building B)

As interview data represents, the design of open plan helps to enhance the interaction among the workers. However, from the perspective of their personal productivity, it shows a considerable effect to decline the work performance and productivity. Accordingly, the survey findings were further verified with reference to the existing literature. According to a study by Pejtersen, Allermann, Kristensen and Poulsen (2006), open-plan offices were originally designed to mainly reduce the costs of work environment and promote communications between co-workers by eliminating physical walls between workers. Further, many organisations have pushed their employees to get out of individual and private working environments, and to interact with each other for the informal flow of information by reducing the size of individual workspaces and creating open-plan offices (Rashid, Kampschroer, Wineman & Zimring, 2006). This shows a difference between survey results and extant literature, as there was a weak negative correlation between open plan office design and occupants' productivity.

However, some of previous studies also argued that, negative effects could be occurred by open plan office designs. Hence, the success of open plan offices in terms of better communication is not as obvious as proponents of open plan offices explained. Moreover, research shows mixed-results between positive and negative effects of open plan offices on employee behaviours, attitudes and perceived productivity (Allen & Gerstberger, 1973; Maher & Hippel, 2005 cited Lee, 2010). Accordingly, negative aspects regarding the employee attitude and perception when compared to traditional enclosed private offices could be found, even though there is an increase in communication between co-workers in open-plan offices (Maher & Hippel, 2005 cited Lee, 2010).

As stated by Banbury and Berry (2005), the increased distractions negatively affecting employee job performance in open plan offices were a big problem. Further, in the literature of open plan offices, noise issue is one of the subjects extensively examined along with the privacy issue (Pejtersen et al., 2006). Additionally, open plan offices has showed significantly lower satisfaction and perceived job performance than the other office types in a study by Lee (2010). As Lee further verifies, open plan layouts tend to offer workers a less individual control over their work environment and visual privacy which could decrease the level of work performance and personal productivity. Accordingly, the similarities and differences between, survey data, interview data and extant literature relating to open plan design were identified. According to the analysis, survey findings were further validated, as most of studies had come up with similar or mixed-results in productivity research. According to the test statistics of probability and Spearman's Correlation (refer Table 6.16), air quality was identified as the critical built environment factor influencing occupants' productivity. It has been verified by the significant and weak positive monotonic correlation between air quality and occupants' productivity (Spearman's rho=.258, p=.038). As it further demonstrates, the slightly improvement of air quality in green buildings would slightly increase the occupants' productivity. The results are further proved by two interviewees as follows,

As stated by Human Resource Manager in Green Building B,

> *"it is really comfortable to work in green buildings with the high quality indoor air provided. We are maintaining required air quality standards to provide workers a comfortable environment. And, the complaints from our workers were considerably less and they also work very efficiently."*

It is further proved by an Engineer in Green Building C as,

> *"there is an optimum use of natural air inside the building with the less use of air conditioning. However, our workers have changed themselves suited to work in this green environment. I also work very happily thus; personal productivity is at highest level."*

Further, a study of Heerwagen (2000) also confirmed the link between air quality and occupants' productivity. As Heerwagen (2000) further stated, the improved air quality is likely to have a greatest impact on wellbeing and personal productivity. Further, the studies which used self-assessments of productivity have found strong relationship of air quality factors to occupants' productivity. Among those, air quality was identified as a critical factor influencing occupants' productivity in green buildings by testing the literature existed on the relationship between air quality and occupants' productivity. Among the other factors, amount of space given for office workers was identified as another critical built environment factor influencing occupants' productivity in green buildings. Further, it showed a weak positive monotonic correlation to occupants' productivity in the analysis of Spearman's

Correlation (Spearman's rho= .252, p= .043). As this relationship implies, the slight increase of space given for individual workers would increase their perceived productivity. The survey data were further analyzed with reference to the interview data and extant literature. The arrangement of office space, which provides an enough space for workers, has a significant effect to enhance their productivity. It is further proved by many of interviewees as mentioned below.

An Architect in Green Building C stated,

> *"Quality of the space directly effects on productivity. If management can give enough space for the workers; for their works and storages, it would enhance their perception and attitude to work effectively thus, it enhances productivity."*

It further proved by an Electrical Engineer in Green building C as;

> *"The space given for workers is an important fact to increase productivity, because…Sometimes office workers, especially in this type of office buildings have to deal with large drawings. They should have enough individual space to carry out their works."*

Branch Manager in Green Building A also verified;

> *"Enough space always gives comfortable environment to work with high concentration. In Green buildings, the space needs to have a further concern to give quality and enough spaces for occupants, as it directly affects their productivity."*

As most of the interviewees held that, a considerable relationship between amount space given for building occupants and their perceived productivity could be identified. Similarly, most of the previous studies have also mentioned the importance of amount of space to enhance occupants' productivity. As Frontczak et al. (2012) stated, the satisfaction with the amount of space was ranked to be the most important factor for workspace satisfaction and ultimately for occupants' productivity. A study by Hameed and Amjad (2009) also confirmed that there was a significant positive relationship between the space allocated for office workers and, their work productivity. Further, a higher area available per person for work and storage increases satisfaction to work (Monika et al., 2012). Thus, a high concern should be paid to the arrangement of individual work spaces in modern office designs (Hameed & Amjad, 2009). Accordingly, H_1 hypothesis was tested and, the third objective of the research was partially fulfilled by determining the built environment factors critical for occupants' productivity in green certified office buildings.

6.7 Summary

This chapter presented the research analysis and findings related to the potential relationships between green built environment and occupants' productivity. As the third objective, significant built environment factors were determined. The Spearman's Correlation analysis was conducted in SPSS to identify significant built environment factors. According to the test statistics, twenty factors were identified as significant factors, which showed significant monotonic correlation to the each main dimension. Opening windows, controllable lighting installation, personal/task lighting, view to outdoor environment, air quality, amount of ventilation, system controls, acoustical partitioning, distractions, personal control workstations, art and aesthetic, building maintenance and cleanliness, use of low emitting materials, open plan design, amount of space, adjustability of furniture, space for informal meetings, access to documents, psychological restoration and relaxation were determined as significant built environment factors. Then, the correlation between significant built environment factors and occupants' productivity was tested. As test statistics showed, air quality, system controls, acoustical partitioning, open plan design and amount of space were significantly correlated to the occupants' productivity in green buildings. Further, critical factors were ranked based on the strength of correlation. System control was determined as most critical factor whist open plan design, air quality, acoustical partitioning and amount of space obtained the second, third, fourth and fifth places respectively. The survey results were further validated through interview results and key literature. Accordingly, H_1 hypothesis was tested and third objective was partially fulfilled.

7. DATA ANALYSIS AND FINDINGS 02: DEGREE OF INFLUENCE OF CRITICAL BUILT ENVIRONMENT FACTORS ON OCCUPANTS' PRODUCTIVITY IN GREEN BUILDINGS

7.1 Introduction

This chapter intends to present the data analysis and findings of critical built environment factors influencing occupants' productivity. Hence, the identified critical factors are evaluated and tested by using ordinal logistic regression, in order to model the relationship between built environment and occupants' productivity. Further, the effect of the critical factors on occupants' productivity is also tested (Section 7.4). The test statistics of ordinal regression, related findings and models developed are described in Section 7.4.3 and Section 7.4.4 subsequently.

7.2 Research Hypothesis for Testing

In order to achieve the research aim, the following hypothesis and sub research questions were addressed in this stage.

Hypothesis (H_1):

Green built environment has a significant influence on occupants' productivity.

Sub research questions:

- What is the relationship between critical factors and occupants' productivity?
- How much the degree of influence of critical factors on occupant's productivity?

7.3 Critical Built Environment Factors

The identified critical built environment factors in green buildings were tested by using ordinal logistic regression analysis. The identified critical factors are considered as the 'independent variables' whist occupants' productivity is considered as the 'dependent variable' (refer Figure 7.1).

Occupants' productivity
Air quality
System controls
Acoustical partitioning
Open plan office type
Amount of space

Figure 7.1: Variables in ordinal logistic regression analysis

7.4 Ordinal Logistic Regression Analysis

The identified critical built environment factors were evaluated and tested in order to estimate the effect of each identified independent factor on occupants' productivity. Ordinal logistic regression analysis technique was used to test the effect.

7.4.1 Occupant distribution on the scale of occupants' productivity

There is a significant ordinal outcome in the dataset regarding the influence of critical built environment factors on occupants' productivity in green buildings. The level of influence of the critical factors was ranked and recorded in terms of occupants' productivity. Five influence levels were considered (5 point Likert scale) as Much Lower, Slightly Lower, Normal, Slightly Higher and Much Higher. The Figure 7.2 shows the proportion of occupant distribution regarding their perceived productivity level in green built environment.

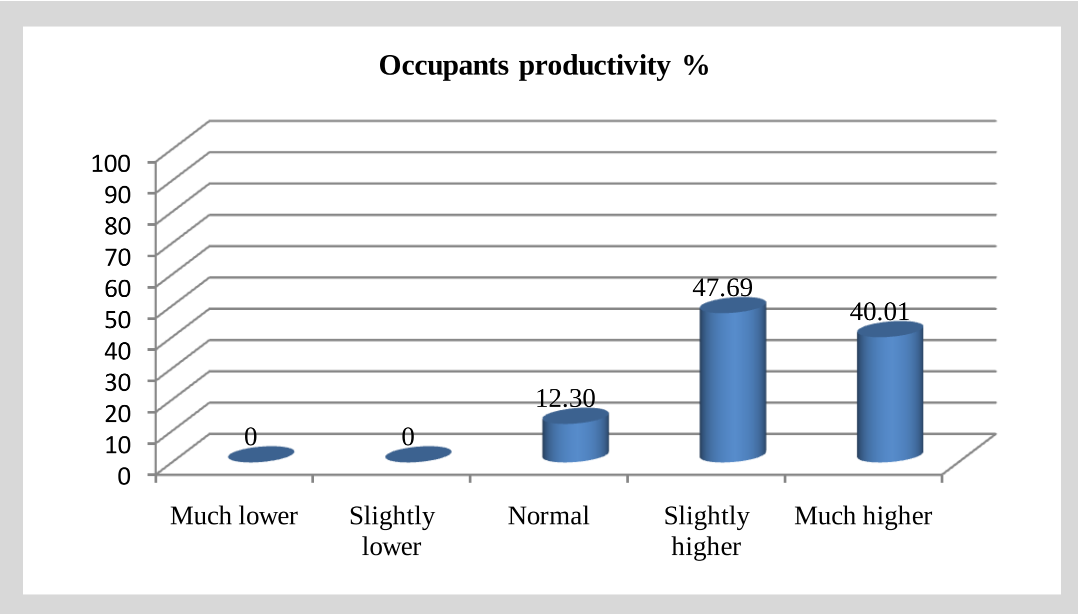


Figure 7.2: Proportions of occupants responded on level of productivity

According to the Figure 7.2, a high proportion of occupants have responded at the Slightly Higher influence level on occupants' productivity in green buildings. Further, 40.01% of occupants have responded that their productivity level was much higher in the green built environment. The proportions of occupants' responses at each level for critical factors are shown in Figure 7.3.

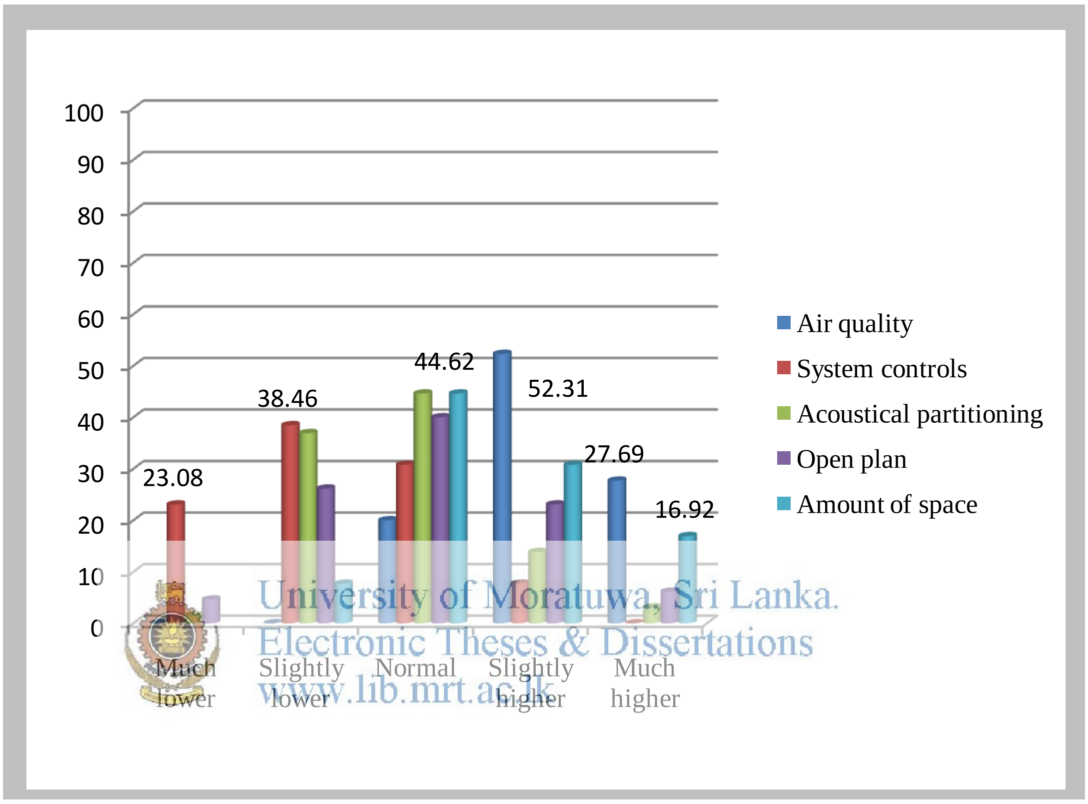


Figure 7.3: Proportions of occupants responded at each influence level

As the Figure 7.3 shows, most of the occupants were responded at the "Slightly Lower", "Normal" and "Slightly Higher" influence levels. In the distribution, air quality has a large proportion at Slightly Higher level (52.31%). The next highest proportion goes to "Normal" influence level (44.62%), equal for both amount of space and acoustical partitioning. The highest proportion for slightly lower level has obtained by the system controls (38.46%), where 23.18% and 16.92% proportions obtained by system controls and the amount of space respectively at the much lower level. The Figure 7.4 shows the proportion of occupants' distribution for each individual factor.

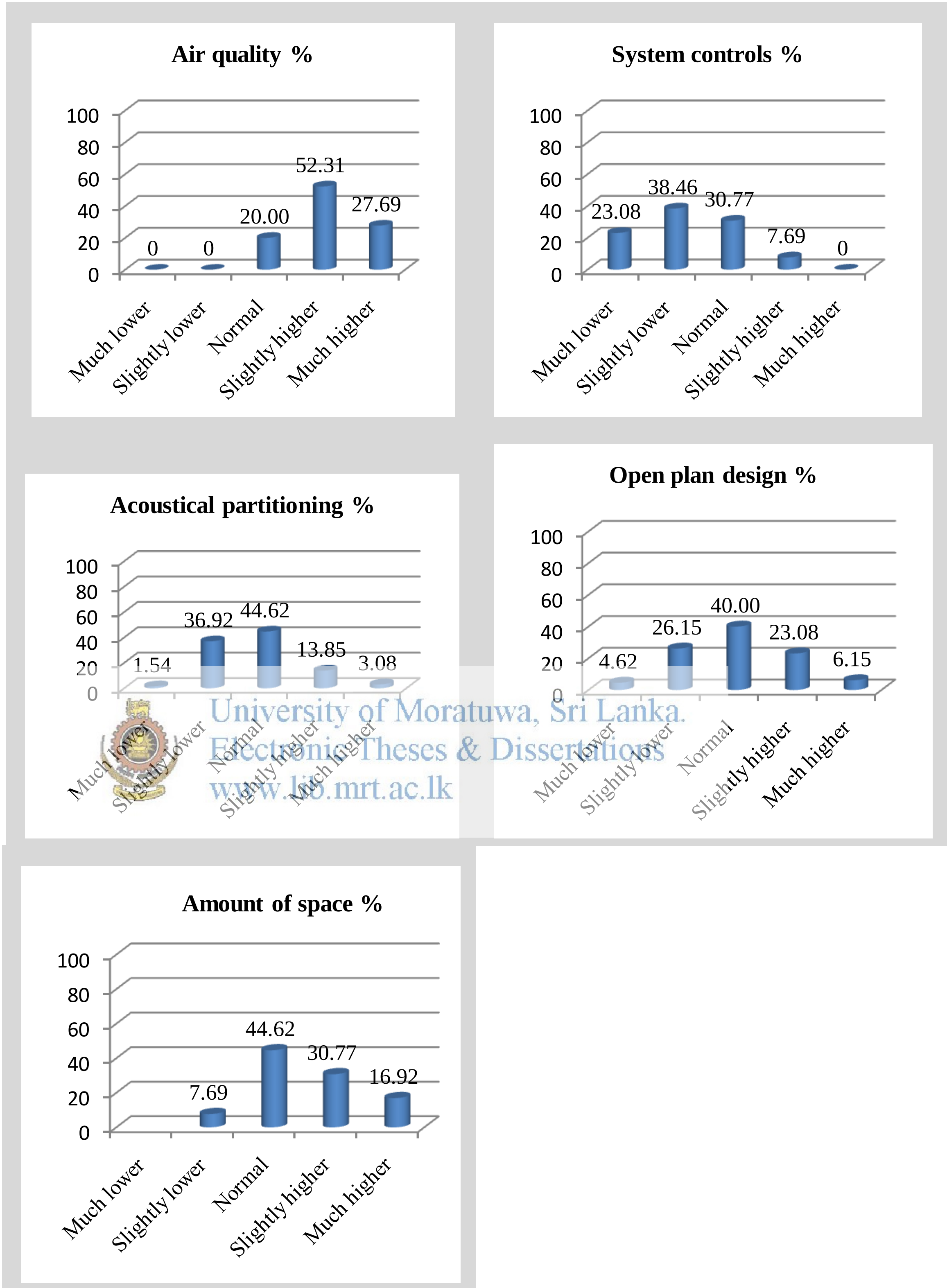


Figure 7.4: Proportion of occupant distribution for individual critical factors

Air quality has a proportion of 20% at the normal level, 52.31% at the slightly higher level and 27.69% at the much higher influence level. System control has a proportion of 23.08% at the much lower influence level, 38.46% at the slightly lower level, 30.77% at the normal level and 7.69% at the slightly higher influence level. Acoustical partitioning shows the occupant distribution at each influence level where, 1.54% at the much lower level, 36.92% at the slightly lower level, 44.62% at the normal level, 13.85% at the slightly higher level and 3.08% at the much higher influence level. Similarly, for open plan design, occupants have responded at each level as, the proportion of 4.62% at the much lower level, 26.15% at the slightly lower level, 40% at the normal level, 23.08% at the slightly higher level and 6.15% at the much higher influence level. Further, the amount of space has a 7.69% proportion of occupants at the slightly lower level, 44.62% at the normal level, 30.77% at the slightly higher level and 16.92% at the much higher influence level.

Accordingly, the ordinal outcome obtained from the dataset was considered in the analysis of the data to test the effect of critical factors on occupants' productivity in green buildings.

7.4.2 Modeling the relationship between built environment factors and occupants' productivity

In ordinal regression instead of modeling the probability of an individual event, the probability of that event and all influencing factors are considered in the ordinal ranking. The cumulative probabilities rather than probabilities for discrete categories were considered in this study. According to study by Brant (1990), "if a single model could be used to estimate the odds of being at or above a given threshold across all cumulative splits, the model would offer far greater parsimony compared to fitting multiple." Further, estimating four separate binary logistic regression equations is wasting of the information on ordiality in the research outcome and may lead to estimate more parameters than which are necessary to account for the relationships between explanatory variables and the outcome. Hence, the cumulative odds model is used to consider the effect of a set of explanatory variables (critical built environment factors) across the possible consecutive cumulative splits in the outcome. The assumption of proportional odds was established where the effects of explanatory variables are the same across the different thresholds (refer Table 7.5 for testing of proportional odds assumption). The critical built environment factors such as air quality, system controls, acoustical partitioning, open plan design and amount of space were evaluated in ordinal regression to test the effect of each factor on occupants' productivity. Accordingly, the ordinal regression was conducted and regression models were developed as described in the subsequent Sections of 7.4.3 and 7.4.4.

7.4.3 Evaluation of the model and assumption of proportional odds

The case processing summary table extracted from the SPSS output of the ordinal regression procedure (refer Table 7.1) has clearly labeled the variables and their values in the analysis.

Table 7.1: Case processing summary

Case Processing Summary			
		N	Marginal Percentage
Occupants_productivity	Normal	8	12.3%
	Slightly_higher	31	47.7%
	Much_higher	26	40.0%
System_controls	Much_lower	15	23.1%
	Slightly_lower	25	38.5%
	Normal	20	30.8%
	Slightly_higher	5	7.7%
Air_quality	Normal	13	20.0%
	Slightly_higher	34	52.3%
	Much_higher	18	27.7%
Acoustical_partitioning	Much_lower	1	1.5%
	Slightly_lower	24	36.9%
	Normal	29	44.6%
	Slightly_higher	9	13.8%
	Much_higher	2	3.1%
Open_plan	Much_lower	3	4.6%
	Slightly_lower	17	26.2%
	Normal	26	40.0%
	Slightly_higher	15	23.1%
	Much_higher	4	6.2%
Amount_of_space	Slightly_lower	5	7.7%
	Normal	29	44.6%
	Slightly_higher	20	30.8%
	Much_higher	11	16.9%
Valid		65	100.0%
Missing		0	
Total		65	

The Table 7.1 shows the variables entered in the analysis, which were evaluated, and modeled in relation to the occupants' productivity. According to the outcome variable of this analysis, occupants' productivity includes three levels such as normal, slightly higher or much higher influence. In the case processing summary, N provides the number of observations fitting the description in the first column. In this analysis, the first three values (N = 8; N = 31; N = 26) give the number of observations for which the level of occupants' productivity is normal, slightly higher or much higher respectively. Similarly, it gives number of observations for each independent variable as mentioned in Table 7.1. Marginal percentage lists the proportion of valid observations found in each of the outcome variable's groups (i.e. marginal percentage for normal level of occupants' productivity is (8/65)*100 = 12.3% etc). Further, according to the above summary, the number of observations of all outcome and predictor variables in the dataset is not missing (valid = 65).

The Table 7.2 indicates the model fitting data. The adequacy of the model and model fit through proportional odds assumption were tested.

Table 7.2: Model fitting information

Model Fitting Information				
Model	**-2 Log Likelihood**	**Chi-Square**	**df**	**Sig.**
Intercept Only	119.329			
Final	67.603	51.726	16	.000
Link function: Logit.				

In the test statistics, -2 log likelihood is the product of -2 and the log likelihoods of the null model and fitted "final" model. The likelihood of the model is used to test of whether all predictors' regression coefficients in the model are simultaneously zero and in tests of nested models. As test statistic indicates there is 51.726 of chi-square value with 16 degree of freedom (df) which is defined by the number of predictors in the model. As the SPSS outcome showed, there is a highly significant reduction in the chi-square statistics ($p<0.05$ or below) as .000 ($p=.000$), so the model is clearly showed a significant improvement over the baseline or intercept only model. Also, the significant p value is the probability of obtaining the chi-square statistic of

51.726 if there is no effect of the predictor variables. Accordingly, the null hypothesis that all independent variables are equal to zero was rejected.

The significant chi-square statistics in Table 7.3 indicates that the final model gives a significant improvement over the baseline intercept-only model. This states that the model gives better predictions than a value guessed based on the marginal probabilities for the outcome categories. Further, the Pseudo R^2 values (Cox and Snell=.546, Nagelkerke=.6398 and McFadden=.407) indicate that the data in model are performed well.

Table 7.3: Pseudo R-Square results

Pseudo R-Square	
Cox and Snell	.549
Nagelkerke	.639
McFadden	.407
Link function: Logit.	

According to the R^2 test results, air quality, system controls, acoustical partitioning, open plan design and amount of space have statistically significant and relatively large proportion of the variance between the productivity levels of the occupants. The Table 7.4 contains the Pearson's chi-square statistic of the model and, the deviance statistical test results. These statistics are intended to test whether the observed data are consisting with the fitted model. Hence, the null hypothesis (H_0) was developed as 'the model fit is good' (when p value is large: p>0.05).

Table 7.4: Goodness-of-fit for model

Goodness-of-Fit			
	Chi-Square	**df**	**Sig.**
Pearson	138.846	100	.006
Deviance	60.436	100	.999
Link function: Logit.			

The hypothesis was tested and was not rejected as p value is large. Since p value is large (P>.05) in deviance goodness of test results (p=.999), goodness-of-fit statistics suggest that the model fits the data well. Thus, the model predictions are similar and have a good model. Proportional odds assumption is an important assumption which belongs to the ordinal odds. According to this assumption, parameters should not change for different categories. Hence, correlation between independent variables (critical built environment factors) and dependent variable (occupants' productivity) does not change for dependent variable's categories and parameter estimations do not change for cut-off points. The assumption of proportional odds was tested by using SPSS procedure of the test of parallel lines (refer Table 7.5).

Table 7.5: Test of parallel lines

Test of Parallel Lines[c]

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	67.603			
General	46.696[a]	20.907[b]	16	.182

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.

a. Maximum number of iterations was exceeded, and the log-likelihood value and/or the parameter estimates cannot converge.

b. The Chi-Square statistic is computed based on the log-likelihood value of the last iteration of the general model. Validity of the test is uncertain.

c. Link function: Logit.

These statistics also showed that the model fits the data well. The estimated chi-square statistics show the PO assumption is statistically significant in this study. Hence, the proportional odds assumption might not be rejected since the p value is greater than 0.05 (p=.182). The model fitting information table gives the -2 log-likelihood (-2LL) values for the baseline and the final model, and SPSS performs a chi-square to test the difference between the -2LL for the two models. Accordingly, the major assumptions of ordinal regression, such as, model fit, goodness-of-fit and the PO assumption (test of parallel lines) were tested. Altogether these findings signified that the regression model created is a precise and valid representation of the survey data and can be applied to the whole population. The Section 7.4.4 intends to describe the ordinal regression model developed to test the behaviour of occupants' productivity in accordance with the effect of critical built environment factors.

7.4.4 Ordinal regression model developed

As the final step of regression analysis, the relationship between critical built environment factors and occupants' productivity in green buildings was modeled. A mathematical equation is developed for the line of best fit representing the data. From this regression equation, prediction becomes possible where either variable (occupants' productivity) can be predicted based on a value of the other variable (critical built environment factors). As the core output of the regression analysis procedure conducted in SPSS, the parameter estimate table was extracted. It specifically describes the relationship between explanatory variables and the outcome (refer Table 7.6). According to the parameter estimate of the model, occupants' productivity is the response variable (threshold), it was estimated for the levels of normal and slightly higher influence level. Estimate values show the ordered log-odds regression coefficients. In this value, for a one unit increase in the predictor (critical factor), the response variable (occupants' productivity) level is expected to change by its respective regression coefficient in the ordered log-odds scale while the other variables in the model are held constant. Accordingly, the system controls at the much lower influence level, air quality at normal and slightly higher influence level, acoustical partitioning at slightly higher influence level, open plan design and amount of space at the normal influence level were identified as statistically significant coefficient factors ($p<0.05$). The occupants' productivity as the response variable in ordinal regression has ordered log-odds regression coefficients of -5.521 at the normal influence level compared to the reference level of slightly higher. Respectively, the regression coefficient of system controls is -.600 at level 1 (much lower influence level) reference to the slightly higher level. This means, at the much lower influence level, a one unit increase in system control of green buildings expects a 0.6 increase in the ordered log odds of being in a higher level of occupants' productivity. The regression coefficient of air quality is -2.154 at level 3 (normal influence level), of acoustical partitioning is -2.799 at level 4 (slightly higher influence level), of open plan is 3.278 at level 3 (normal influence level) and the regression coefficient of amount of space is -4.150 at level 3 (normal influence level) compared to the reference level in the model (much higher influence level). As it is expected, when one unit in air quality, acoustical partitioning and amount of space increase, it would also effect to increase in the ordered log-odds of being in a higher level of occupants' productivity. However, as open plan design shows a negative relationship with occupants' productivity, a one unit increase in open plan expects the decrease in the ordered log odds of being in the higher level of occupants' productivity.

Table 7.6: Parameter estimates of the model

Parameter Estimates							95% Confidence Interval	
		Estimate	Std. Error	Wald	df	Sig.	Lower Bound	Upper Bound
Threshold	[Occupants_productivity = 3]	-5.521	2.737	4.068	1	.044	-10.886	-.156
	[Occupants_productivity = 4]	-1.170	2.654	.194	1	.659	-6.373	4.032
Location	[System_controls=1]	-.600	1.488	.162	1	.037	-3.516	2.317
	[System_controls=2]	.479	1.451	.109	1	.741	-2.365	3.323
	[System_controls=3]	-.692	1.397	.245	1	.620	-3.430	2.046
	[System_controls=4]	0[a]	.	.	0	.	.	.
	[Air_quality=3]	-2.154	1.089	3.913	1	.048	-4.287	-.020
	[Air_quality=4]	-1.755	.846	4.306	1	.038	-3.412	-.097
	[Air_quality=5]	0[a]	.	.	0	.	.	.
	[Acoustical_partitioning=1]	17.590	.000	.	1	.	17.590	17.590
	[Acoustical_partitioning=2]	.919	2.070	.197	1	.657	-3.138	4.977
	[Acoustical_partitioning=3]	-.077	2.107	.001	1	.971	-4.206	4.053
	[Acoustical_partitioning=4]	-2.799	2.339	1.432	1	.023	-7.383	1.785
	[Acoustical_partitioning=5]	0[a]	.	.	0	.	.	.
	[Open_plan=1]	-.390	1.937	.041	1	.840	-4.186	3.407
	[Open_plan=2]	2.891	1.591	3.300	1	.069	-.228	6.010
	[Open_plan=3]	3.278	1.562	4.402	1	.036	.216	6.340
	[Open_plan=4]	.935	1.479	.400	1	.527	-1.963	3.833
	[Open_plan=5]	0[a]	.	.	0	.	.	.
	[Amount_of_space=2]	.742	1.929	.148	1	.701	-3.039	4.523
	[Amount_of_space=3]	-4.150	1.310	10.03	1	.002	-6.717	-1.582
	[Amount_of_space=4]	-2.392	1.276	3.515	1	.061	-4.892	.109
	[Amount_of_space=5]	0[a]	.	.	0	.	.	.
Link function: Logit.								
a. This parameter is set to zero because it is redundant.								

According to the test results, the model equations were developed as mentioned below.

When, Occupants' Productivity is at level 3 or normal influence level (OP=3);

$$\log\left(\frac{\Pr(Occupants\_Productivity = 3)}{1-\Pr(Occupants\_Productivity = 3)}\right)$$ = -5.521 – [0.60*(System_Controls=1)

- 0.479*(Sytem_Controls=2)-0.692*(System_Controls=3)-2.154*(Air_Quality=3)

-1.755*(Air_Quality=4)+17.59*(Acoustical_Partitioning=1)

+0.919*(Acoustical_Partitioning=2)-0,077*(Acoustical_Partitioning=3)

-2.799*(Acoustical_Partitioning=4)-0.39*(Open_Plan=1)+2.891*(Open_Plan=2)

+3.218*(Open_Plan=3)+0.935*(Open_Plan=4)+0.742*(Amount_of_Space=2)

-4.150*(Amount_of_Space=3)-2.342*(Amount_of_Space=4)]

Occupants' Productivity is below or equal to the slightly higher influence level (OP≤ 4);

$$\log\left(\frac{\Pr(Occupants\_Productivity \leq 4)}{1-\Pr(Occupants\_Productivity \leq 4)}\right)$$ = -5.521 – [0.60*(System_Controls=1)

- 0.479*(Sytem_Controls=2)-0.692*(System_Controls=3)-2.154*(Air_Quality=3)

-1.755*(Air_Quality=4)+17.59*(Acoustical_Partitioning=1)

+0.919*(Acoustical_Partitioning=2)-0,077*(Acoustical_Partitioning=3)

-2.799*(Acoustical_Partitioning=4)-0.39*(Open_Plan=1)+2.891*(Open_Plan=2)

+3.218*(Open_Plan=3)+0.935*(Open_Plan=4)+0.742*(Amount_of_Space=2)

-4.150*(Amount_of_Space=3)-2.342*(Amount_of_Space=4)]

In the given model, system controls, air quality, acoustical partitioning, open plan design and amount of space are found to be significantly associated with occupants' productivity. As the test results verify, an improvement of the system controls, air quality, acoustical partitioning amount of space in green buildings may increase the perceived productivity of occupants.

7.4.5 The behaviour of occupants' productivity

The built environment factors which showed a highly significant correlation to occupants' productivity ($p<.05$) were considered to evaluate the behaviour of occupants' productivity. The parameter estimates (regression coefficients) were extracted from parameter estimate table by considering the positive and negative relationship between the critical built environment factors and occupants' productivity. The Table 7.7 illustrates the regression coefficients selected to calculate the odds ratios.

Table 7.7: Regression coefficients converted to odds ratios

Built environment factors (independent variables)	Regression coefficient	Statistical relationship to dependent variable (occupants' productivity)	Level of significance ($p<0.05$)
Air quality	1.755	Positive	.038
System controls	0.600	Positive	.037
Acoustical partitioning	2.799	Positive	.023
Open plan design	(3.278)	Negative	.036
Amount of space	4.150	Positive	.002

According to the Table 7.7, air quality was selected with the regression coefficient of 1.755 by considering its significant positive relationship to occupants' productivity. Further, the system controls, acoustical partitioning and amount of space were also selected, which showed a significant positive association. Open plan office design was considered in the interpretation of odds ratios with the significant negative regression coefficient of 3.278 (p=.036). Accordingly, those regression coefficients of the model were interpreted as odds ratios (exponential value of log-odds).

The odds ratios were calculated by considering the reference level of each factor as mentioned in Table 7.8.

Table 7.8: Odds ratios of regression coefficients

Built environment factor	Odds ratio (e^x)
Air quality	5.783
System controls	1.822
Acoustical partitioning	16.428
Open plan design	0.038
Amount of space	63.434

According to the Table 7.8, the effect of each critical factor (e^x) resulting much higher occupants' productivity level in green certified office buildings were determined. In accordance with the test statistics, the regression coefficient of air quality was interpreted as the odds ratio (exponential value) of 5.783. As it verifies, air quality is 5.783 times more likely effect to result in much higher occupants' productivity in green certified office buildings. Further, system controls may result in much higher occupants' productivity, which is 1.822 times more likely than the much lower influence level. The behaviour of occupants' productivity was also determined by the acoustical partitioning in green certified office buildings. According to the calculation of exponential values of log-odds in the model, acoustical partitioning is 16.428 times more likely effect to enhance the occupants' productivity. The amount of space and open plan design factors were also interpreted as the odds ratios to determine the behavior of occupants' productivity. As test results showed, amount of space is 63.434 times and open plan design is 0.038 times more likely effect than the normal influence level considered. Accordingly, the amount of space showed a much more likely effect to result in much higher occupants' productivity, whilst, open plan was identified as the least factor, which is less likely resulted in much higher occupants' productivity.

7.5 Summary

As the second stage of data analysis, the relation between critical built environment factors such as, air quality, system controls, acoustical partitioning, open plan design, amount of space (independent variables) and occupants' productivity (dependent variables) was modeled and tested. Ordinal logistic regression analysis was conducted as PLUM procedure in SPSS v20 to find the relation and the effect of each factor on occupants' productivity improvements in green office buildings. As the first step, the distribution of the proportion of occupants' responses was evaluated. The model parameters such as goodness of fit, chi-square test, -2 Log Likelihood, Pseudo R^2 values and the proportional odds assumption were tested and identified that the model is good and the data are performed well. According to the regression coefficients of critical built environment factors in model developed, air quality, system controls, acoustical partitioning and amount of space factors have showed positive association to occupants' productivity in green certified office buildings. Further regression coefficient has demonstrated the influence of each critical factor on occupants' productivity. When one unit in air quality, system controls, acoustical partitioning and amount of space increase, it would also increase in the ordered log-odds of being in a higher level of occupants' productivity. Among the other factors, open plan office design has showed a negative relationship to the dependent variable (occupants' productivity) according to the parameter estimate values of the model developed. As the final step, the odds ratio of each factor coefficient was calculated in order to test the behaviour of the occupants' productivity in green certified office buildings. This verified the degree of the effect of each critical factor, which would be resulted in much higher occupants' productivity level. Accordingly, H_2 hypothesis was tested and the third of objective of the research was fulfilled by determining the relationship between critical built environment factors and occupants' productivity in green certified office buildings and their degree of influence.

8. DISCUSSION OF RESEARCH FINDINGS

8.1 Introduction

The main objective of this chapter is to discuss and compare the findings of this research with previous key literature findings to confirm its validity. Further, this chapter highlights the test results of research hypotheses to present the results of knowledge tested in this study. The research findings relating to the built environment factors influencing occupants' productivity in green buildings were discussed by achieving the main aim of the research. Accordingly, the key research findings and literature were conversed by ensuring the testing of research hypotheses and research questions developed.

8.2 Research Hypotheses Tested

The purpose of this research was to determine the critical built environment factors influencing occupants' productivity in green buildings and their degree of influence. As this research had been conducted in the positivism and objectivism stances, research hypotheses were developed to test the extant literature. Accordingly, two hypotheses were formed together with three sub research questions in order to achieve the third objective of the research (refer Figure 8.2).

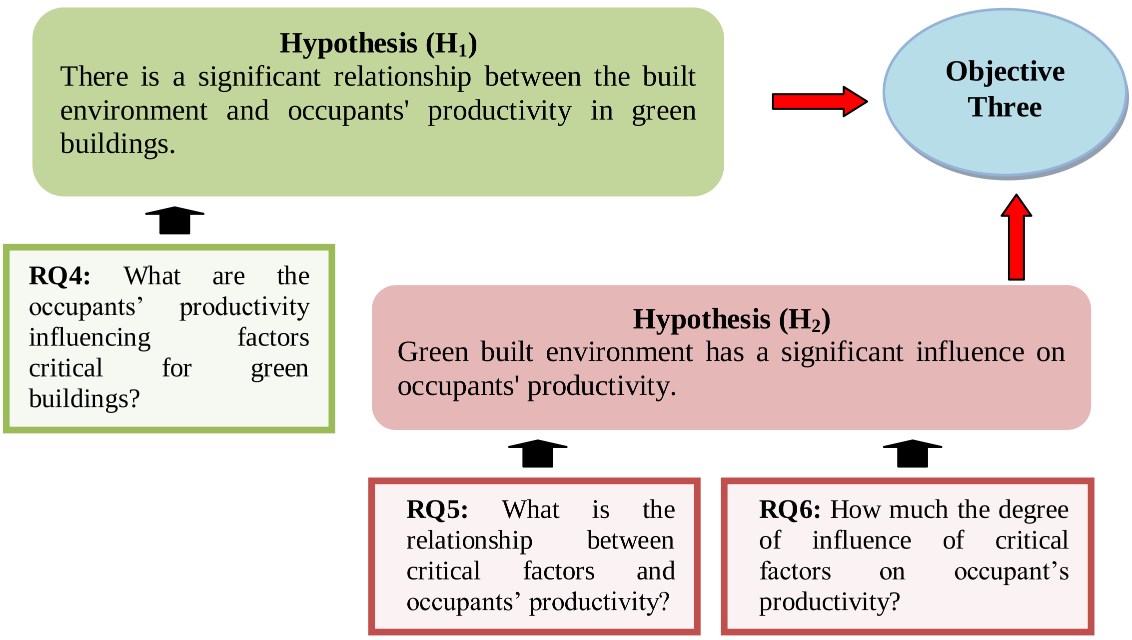


Figure 8.1: Research hypotheses tested

As the Figure 8.1 illustrates, the related research questions were answered to test the hypotheses developed. The researcher tested the hypotheses through correlation and regression analysis conducted. The next section intends to converse the key research findings on the following headings, which were developed by focusing on the research hypotheses and sub research questions.

- Significant built environment factors influencing occupants' productivity
- Air quality and occupants' productivity
- Acoustic quality and occupants' productivity
- Open plan office design and occupants' productivity
- Amount of space and occupants' productivity

8.3 Discussion of Research Findings

8.3.1 Significant built environment factors influencing occupants' productivity

According to the study by Clements-Croom and Kaluarachchi (2000), physical environment is one of the major factors influencing occupants' productivity. Since majority of people spent most of their time indoors, there is a continuous and dynamic interaction between the occupants and their surrounded working environment especially in an office environment. It can produce both physiological and psychological effects on occupants (Lan & Lian, 2009). Numerous studies have shown that indoor environment impacts both health and performance of occupants, which in turn affect productivity (Mahdavi & Unzeitig, 2004). The previous studies which are conducted in similar research settings stated that occupants' productivity can be affected by many built environment related factors, however; most studies have been focused only on Indoor Environmental Quality (Augenbroe & Park, 2005; Ries et al., 2006; Lai & Yik, 2008; Lan & Lian, 2009; Bluyssen, 2009; Hui, Wong & Mui, 2009).

In this research, first two steps of data analysis - stage one were subjected to identify the significant and most critical built environment factors influencing occupants' productivity. The Spearman Correlation was tested and the statistical correlation between independent variables (critical built environment factors) and occupants' productivity was recognized. As the first step, 20 built environment factors were selected as significant factors influencing occupants' productivity in green buildings which showed significant monotonic association to the major built environment dimensions, while rejecting the 35 factors which were not shown statistically significant monotonic correlation. Accordingly, opening windows (Spearman's rho=.285, p=.022), controllable lighting installations (Spearman's rho=.260, p=.037), personal lighting (Spearman's rho=.248, p=.047), view to outdoor environment (Spearman's rho=.388, p=.001), air quality (Spearman's rho=.253, p=.042), amount of ventilation (Spearman's rho=.254, p=.041), system control (Spearman's rho=.281, p=.023), acoustic partitioning (Spearman's rho=.248, p=.047), personal control workstations (Spearman's rho=.249, p=.045), distractions (Spearman's rho= -.250, p=.045), art and aesthetic (Spearman's rho=.295, p=.017), building maintenance (Spearman's rho=.276, p=.026), cleanliness (Spearman's rho=.552, p=.000), open plan office type (Spearman's rho=.518, p=.004), low toxic emitting materials (Spearman's rho=.559, p=.015), amount of space (Spearman's rho=.261, p=.036), adjustability of furniture (Spearman's rho=.389, p=.001), space for informal meetings (Spearman's rho=.512, p=.000), psychological restoration (Spearman's rho=.512, p=.000) and access to documents (Spearman's rho=.449, p =.000) were selected as significant built environment factors which have shown statistically significant monotonic correlation to each major dimension. The significant factors were considered as the independent variables and occupants' productivity was considered as the dependent variable in data analysis to determine the relationship and, the degree of influence of critical built environment factors on occupants' productivity.

8.3.2 Air quality and occupants' productivity

According to the test statistics of probability and Spearman's Correlation, air quality was identified as critical IAQ factor influencing occupants' productivity. Air quality showed a significant weakly positive monotonic correlation to the occupants' productivity (Spearman's rho=.258, p=.038). As it confirms, the slight improvement of air quality in green buildings would slightly increase the occupants' productivity. The results were further verified by both perceptions of the interviewees and key literature findings. Most of interviewees had positive observations towards the air quality in green certified office buildings. As they further proved, air quality has highly influenced to enhance their personal productivity as it created a comfortable environment to work.

From the 23 interviews conducted among building occupants of green certified office buildings selected in this research, 83% of interviewees agreed with the survey results, which were found towards the influence of air quality on their perceived productivity. However, 13% showed no idea whilst, 04% were not agreed (refer Figure 8.2).

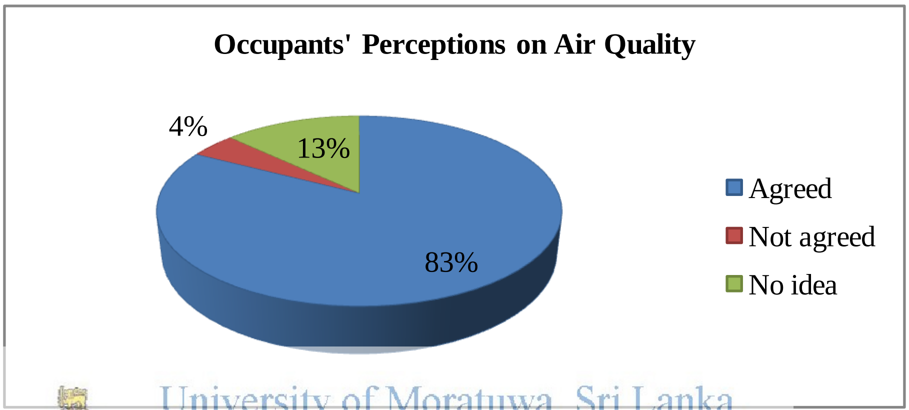


Figure 8.2: Occupants' perceptions on air quality

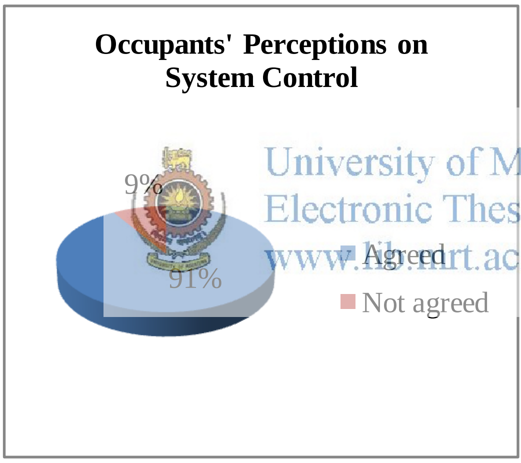
The key literature also confirmed the relationship between air quality and occupants' productivity. For an example, a study by Heerwagen (2000) stated that the improved air quality was likely to have a greatest impact on wellbeing and personal productivity. Accordingly, air quality was identified as a critical factor influencing occupants' productivity in green certified office buildings by testing the key literature existed on the relationship between air quality and occupants' productivity. As per the next stage of data analysis, the influence and the degree of influence of air quality on occupants' productivity were tested through Ordinal Logistic Regression.

According to the regression model developed (refer Table 7.6), the regression coefficient of air quality showed positive association to occupant's productivity at the slightly higher influence level (1.755). In this value, for a one unit increase in the air quality, the response variable (occupants' productivity) level is expected to increase by its respective regression coefficient in the ordered log-odds scale while the other variables in the model are held constant. As the final evaluation, the degree of influence was determined by calculating the odds ratio of air quality in the regression model developed. According to the test statistics, the regression coefficient of air quality was interpreted as the odds ratio (exponential value) of 5.783. As it verifies, air quality is 5.783 times more likely effected to result in much higher occupants' productivity in green certified office buildings. As per the research findings, air quality showed a statistically significant weakly positive monotonic correlation to occupants' productivity, where, the one unit increase in air quality is expected to increase the occupants' productivity by its log odds of 1.755. Further, it is 5.783 times more likely effect to enhance the perceived productivity of green occupants. Consequently, it creates an importance to introduce further provisions on IAQ, which will enhance the occupants' productivity, as they work with comfort and greater satisfaction in green working environment. Hence, air quality requires a further consideration, as it showed significant relationship to occupants' productivity in green office buildings. Hence, the existing provisions of air quality in GREEN$^{SL®}$ National Rating System need to be revised by adopting new strategies to enhance the air quality as described in Chapter 9: The Review on GREEN$^{SL®}$ and Enhancements Proposed.

8.3.3 Acoustic quality and occupants' productivity

Noise is distracting the concentration on work or study and provides less than ideal working and learning environments, thus influencing occupants' productivity. Among the other acoustic quality related factors, system control and acoustical partitioning were identified as the significant factors which showed statistically significant correlation to the acoustic quality in green buildings. In the correlation analysis, system control and acoustical partitioning factors (independent variables) were evaluated with the occupants' productivity (dependent variable). As SPSS output showed, both factors proved a significant association to the occupants' productivity, where, system control showed a strongly positive monotonic correlation (Spearman's rho=.347, p=.005), whilst acoustical partitioning showed a weakly positive monotonic correlation (Spearman's rho=.347, p=.005).

The evaluation was further tested through semi-structured interviews conducted among 23 building occupants, who were selected from the sample population. Hence, the opinions and perceptions of occupants' were gathered for the verification of the relationship between system control, acoustic quality factors and occupants' productivity. As most of the interviewees stated that, acoustic quality has created a considerable influence on their productivity. Similar to the survey results, both system control and acoustical partitioning were identified as critical factors influencing their work performance and productivity. However, most of them were not satisfied with the existing provisions, which were facilitated to control the internal and external noises specially for controlling the noise generated from building systems. Hence, most of them were agreed with the survey results found in this research. Further they proposed to enhance the acoustic quality in green buildings to facilitate acoustically comfortable environment to work effectively.



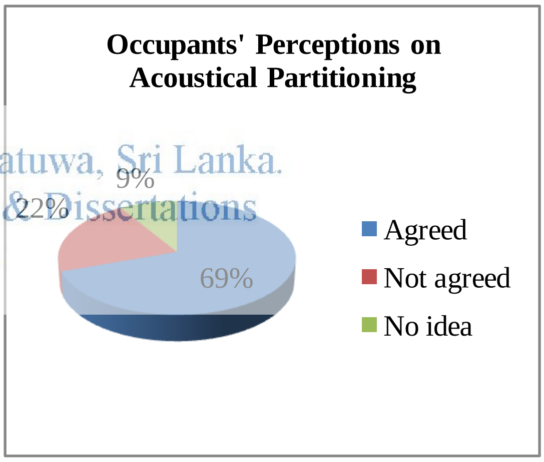


Figure 8.3: Occupants' perceptions on system control and acoustical partitioning

The Figure 8.3 shows the different perception of interviewees towards the influence of system control and acoustical partitioning on occupants' productivity. As the Figure shows, 91% of interviewees were agreed with the survey results as they have personally experienced the influence of the system control on occupants' productivity. Furthermore, 69% were also agreed with the relationship found between acoustical partitioning and occupants' productivity. However, 09% and 22% were not agreed with the survey results, as they had not experienced any disturbance on their work performance due to internal and external noise generated due to systems and less partitioning. As they further verified, most of them were working in cellular and enclose office area, thus; there was not a considerable effect of noises generated by the systems on their productivity.

In addition to that the research findings could be further verified in accordance with the key literature. As an example, most of previous studies stated that there is a potential link of acoustic quality to occupants' productivity (Mahdavi & Unzeitig, 2004; Clements-Croome, 2002; Kim & Dear, 2011). A study by Frontczak and Wargocki (2010) further proved that noise was distracting the concentration on work or study and provided less than ideal working and learning environments. Further, it could be from internal sources such as, building systems, office works and workers etc. and from background noise generating sources. One of main reasons is that the design techniques that are utilized in green buildings to improve energy efficiency, sustainability, and other IEQ aspects of buildings tend to worsen acoustic defects. Accordingly, the potential relationship between system control and acoustical partitioning factors and the occupants' productivity could be determined.

Furthermore, the relationship between system control, acoustical partitioning and occupants' productivity was further verified through Ordinal Logistic Regression. According to the regression model developed (refer Table 7.6), both system control and acoustical partitioning showed a positive influence on occupants' productivity. As it confirms, a one unit increase in those two factors is expected to increase the occupants' productivity by its respective regression coefficient in the ordered log-odds scale with the regression coefficient values of 0.600 and 2.799 respectively. Whilst the relationship and influence were determined through correlation and regression analysis, the exponential values, which were calculated on system control and acoustical partitioning, determined the degree of influence of each factor on occupants' productivity. According to the results obtained, system control is 1.822 times and acoustical partitioning is 16.428 times more likely effect to result in much higher level of occupants' productivity.

The summary of research findings, which were obtained through the testing of hypothesis developed on extant literature, system control shows a statistically significant strongly positive monotonic correlation to occupants' productivity, where, one unit increase is expected to increase the occupant's productivity by the log odds scale of 0.600. The degree of such influence of system control was also determined as 1.822 times more likely effect. Moreover, acoustical partitioning shows a statistically significant weakly positive monotonic correlation. It shows 2.799 of log-odds of being in high level of productivity with the 16.428 times more likely effect. Hence, it creates an urgency to introduce new provisions to ensure acoustic quality in green certified office buildings to enhance occupants' productivity. As most of the interviewees proposed, new provisions and strategies are required to enhance the controllability of systems to reduce the noise generated. Further, office spaces could also design with acoustical partitioning to reduce both internal and external noises. (Refer Chapter 9 for new provisions proposed).

8.3.4 Open plan office design and occupants' productivity

To enhance the interaction among workers, open plan design has become a great necessity in most of buildings. Furthermore, it is one of the major built environment factor influencing occupants' wellbeing and work performance. However in the consideration of an office environment, it was identified as a surprised finding, as the correlation test results showed a statistically significant weakly negative correlation to occupants' productivity in green buildings (Spearman's rho= -.262, p= .035). Hence, several arguments could be made on this result, as both occupants' perceptions and key literature gave similar and different overviews.

The Figure 8.4 exemplifies the occupants' perception towards the survey results on the relationship between open plan office design and occupants' productivity. According to the Figure 8.3, whilst 35% were not agreed, most of occupants (61%) were agreed with the finding of the research, as they felt uncomfortable to work in open plan type office areas. As the major reason they mainly stated was there is a disturbance on their concentration in open plan office, as it takes their attention away from the works most of the time. However, some of the employees who bear the managerial positions preferred to have open plan type office environment, as it creates close supervision and interaction with junior staff.

As they further mentioned, it enhances the opportunity to work collaboratively and will also enhance the worker efficiency and productivity.

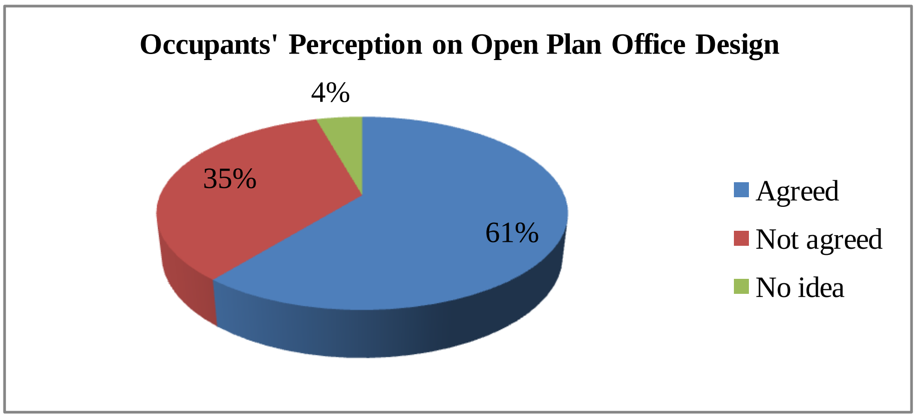


Figure 8.4: Occupants' perceptions on open plan office design

Even though it enhances the team work and interaction among the workers, a major question arisen was "is it suitable to design large open plan type working environments, where the workers need much attention and concentration on their work, like offices?" The question was further reviewed through extant literature. Many similar and different research overviews were identified. Moreover, research shows mixed results between positive and negative effects of open plan offices on employee behaviours, attitudes and perceived productivity (Allen & Gerstberger, 1973; Maher & Hippel, 2005 cited Lee, 2010).

Open plan offices were originally designed mainly to reduce cost of work environment and to promote communication and informal flow of information among co-workers by interacting with each other (Pejtersen, et al., 2006; Rashid et al., 2006). Even though, it differentiates the results of this research, some of previous studies argued that the negative effects could be occurred in open plan office designs. As stated by Banbury and Berry (2005), the increased distractions negatively affecting employee job performance in open plan offices were a big problem. By supporting the results obtained in this research, Pejtersen et al. (2006) affirmed that the noise issue is one of the subjects extensively examined along with the privacy issue in open plan office environments. Additionally, open plan offices have showed a significantly lower perceived job performance than the other office types (Lee, 2010). Further, Clements-Croome (2000) has strongly supported this negative relationship between open plan office design and occupants' productivity. As Clements-Croome (2000) further verified in her productivity research conducted, the floor area designed as open plan office had shown a greater dissatisfaction of occupants, where the self-rated productivity reported low level due to the crowding and lack of privacy. As Lee further confirmed, open plan layouts tend to offer workers less individual control over their work environment and visual privacy which could decrease the level of work performance and productivity. Hence, the negative relationship between open plan office design and occupants' productivity in green buildings was further derived through occupants' perceptions and extant literature.

Accordingly, the correlation test results were further evaluated by using the Ordinal Logistic Regression, in order to determine the influence and the degree of influence of open plan office design on occupants' productivity in green certified office buildings. According to the regression model developed (refer Table 7.6), open plan design showed a negative influence on occupants' productivity. As it confirms, a one unit increase is expected to decrease the occupants' productivity by its respective regression coefficient in the ordered log-odds scale, with the negative regression coefficient value of 3.278.

However, the degree of effect of open plan office design on occupants' productivity was identified as relatively less compared to other factors. In the calculation of exponential values (e^x), open plan office design showed an odds ratio of 0.038 at the reference level considered. Accordingly, the relationship between open plan office design and occupants' productivity in green certified office buildings as well as its degree of influence were derived through this research. While most of previous researches showed mixed results on the relationship between those two factors as both negative and positive influence, this research showed a statistically significant weakly negative monotonic correlation to occupants' productivity with the relatively less degree of influence, by supporting the extant literature results. Hence, it has conveyed a key important point to building designers and other professionals involved in green office building designs, to make more consideration on the behaviours and perceptions of building occupants, when selecting a suitable type of office design. Or else, it would be beneficial to go for a balance between open plan and cellular designs by considering the expectations of occupants. It will enhance the occupants' satisfaction towards working in green office environment with high work performance and productivity. With the above consideration, the opinions of occupants' were further reviewed on existing green certification criteria, in order to propose probable improvements to facilitate quality working environment to enhance their productivity (Refer Chapter 9 for new provisions proposed).

8.3.5 Amount of space and occupants' productivity

The occupants' who facilitated with a sufficient or large individual work space seem to be more productive. It is has been confirmed by a productivity study conducted by Clements-Croome (2000) as, "occupants showed high level of self-rated productivity when they satisfied with the amount of individual space provided." Further, a study by Hameed and Amjad (2009) also confirmed that there is a significant positive relationship between the space allocated for office workers and their work productivity. Further, an enough space provided for a person to work and for his storage has increased his satisfaction to work, which could effect to enhance the perceived productivity (Monika et al., 2012).

By strengthening the extant literature findings, the amount of space has showed a statistically significant positive relationship to occupants' productivity in this research. According to the individual responses, amount of space has reported as a significant factor influencing their perceived productivity. In the Spearman's Correlation analysis conducted in the SPSS statistical analysis software, amount of space showed a statistically significant weak positive monotonic correlation to occupants' productivity in green certified office buildings (Spearman's rho= .252) at the level of significance of 0.043. Similarly, the research findings on amount of space were further strengthened by the different perceptions of occupants obtained through semi-structured interviews conducted. Hence, the survey results were further evaluated through occupants' perceptions as illustrated in Figure 8.5.

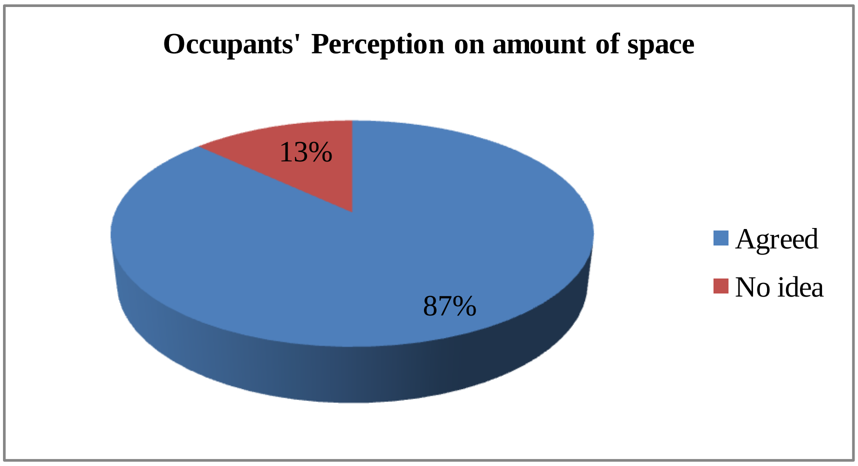


Figure 8.5: Occupants' perceptions on amount of space

According to the perceptions evaluated, most of the occupants (87%) were strongly agreed with the positive relationship existed between the amount of space provided and productivity. As they further mentioned, sufficient space provided to work has enhanced their satisfaction towards working more efficiently. Furthermore, it also enhanced the mental wellbeing which could also be resulted in high level of productivity, as it reduces the sickness and negative minds of workers. In addition, the self-rated productivity level was high in most of occupants' due to the influence of amount of individual space provided. Additionally, the influence and, the degree of influence of amount of space for occupants' productivity were further tested through Ordinal Logistic Regression. According to the regression model developed (refer Table 7.6), the regression coefficient of air quality showed positive association to occupant's productivity. As it further verified, a one unit increase in amount of space is expected to increase the occupants' productivity by its respective regression coefficient in the ordered log-odds scale, with the positive regression coefficient of 4.150. Further, odds ratio (exponential value) calculated on the log-odds value of amount of space showed a 63.434 of more likely effect, which could be resulted in much higher level of productivity. Consequently, the positive relationship between amount of space and occupants' productivity in green certified office buildings were determined by strengthening the extant literature on similar setting. Further, it showed a more likely effect on productivity compared to the other critical factors; thus, facilitating sufficient individual space for office workers was identified as critical factor to enhance occupants' productivity. Hence, a further consideration is required on green office building designs to manage office space effectively, not only to reduce the cost of space but also to enhance occupants' health, wellbeing and productivity. As a result, the existing green certification criteria was reviewed and probable enhancements were suggested (Refer Chapter 9 for new provisions proposed).

8.4 Graphical Representation of the Statistical Relationships Modelled

As the key research findings, the influence of critical built environment factors on occupants' productivity was determined. As discussed in previous Section 8.2, various statistically significant relationships were modelled in between occupants' productivity and built environment factors, such as, air quality, system control, acoustical partitioning, open plan office design, amount of space (independent variables). The Figure 8.5 illustrates the graphical representation of the statistical relationships existed between built environment and occupants' productivity in green certified office buildings. As per the research questions and the related research hypotheses developed, the influence of critical built environment factors on occupants' productivity and its degree of influence were determined by fulfilling the first three objectives of the research.

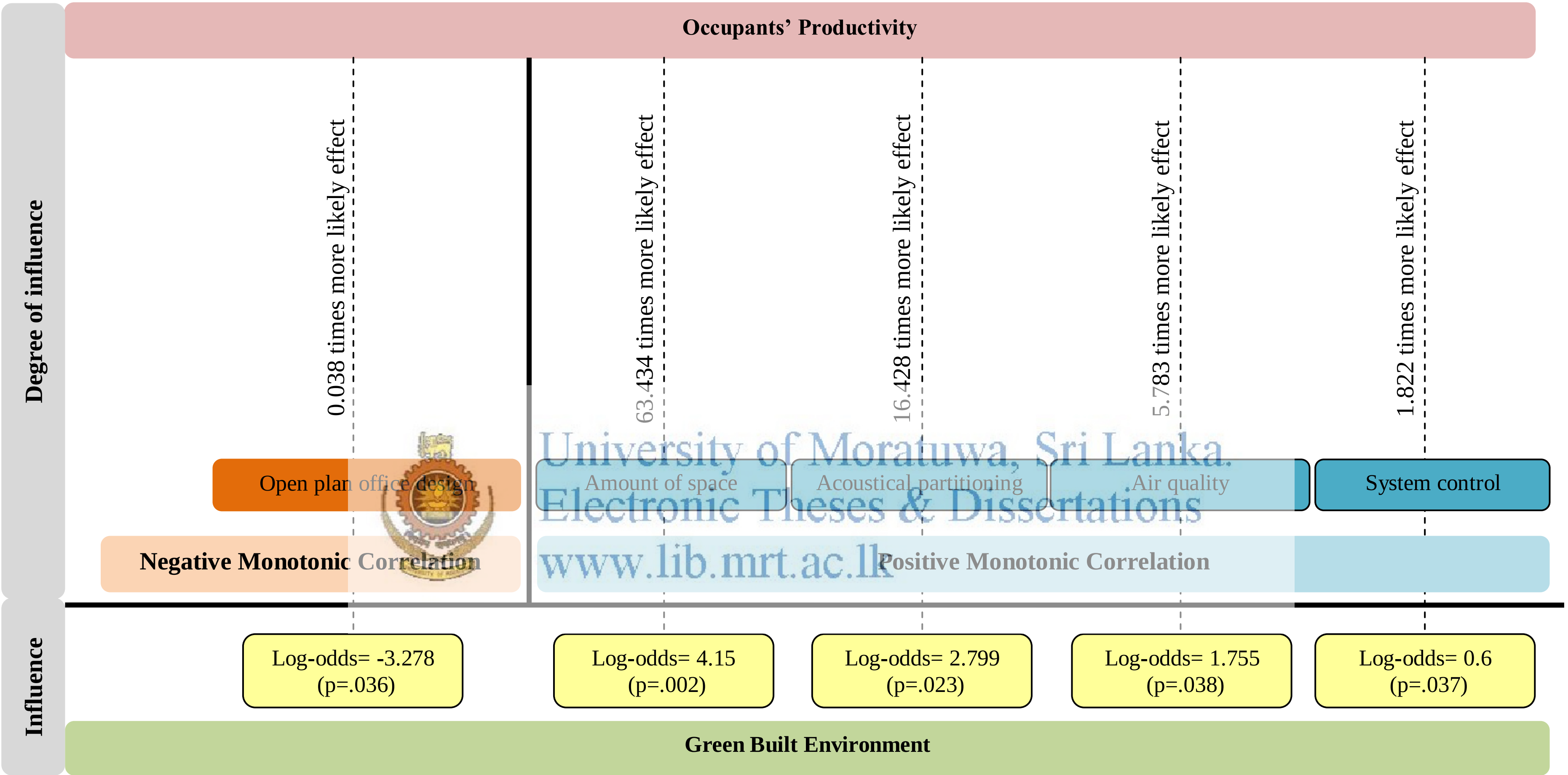


Figure 8.6: Graphical representation of statistical relationships modelled

8.5 Summary

This chapter was intended to discuss the key findings of the research which were derived through data analysis. The key research findings were compared and contrasted with the extant literature in order to test the hypotheses developed. Furthermore, the research findings were discussed along with the different perceptions of occupants for the purpose of validation. As discussed in this chapter, the relationship between critical built environment factors and occupants' productivity was determined under five sub headings as, significant built environment factors influencing occupants' productivity, air quality and occupants' productivity, acoustic quality and occupants' productivity, open plan design and occupants' productivity and, the amount of space and occupants' productivity. The key findings on each critical factor and their degree of influence were also conversed by strengthen the extant literature. Finally, all the relationships between critical built environment factors and occupants productivity in green certified office buildings were graphically modelled by fulfilling first three of objectives of the research.

9. THE REVIEW ON GREENSL® CERTIFICATION SYSTEM AND ENHANCEMENTS PROPOSED

9.1 Introduction

A major implementation of research outcome is to propose probable enhancements for the GREENSL® national certification system. It is because the enhancement of indoor environment would benefit to enhance occupants' productivity. Hence, the main objective of this chapter is to suggest probable enhancements of Indoor Environment Quality criterion in the GREENSL® national rating system. The existing provisions of IEQ are reviewed comparing to the key research findings, and further improvements are proposed in subsequent Sections of 9.4 and 9.5.

9.2 GREENSL®: The National Green Rating System in Sri Lanka

GREENSL® is introduced by the Green Building Council in Sri Lanka (GBCSL). The main purpose of the GREENSL® rating system is to encourage the design of buildings in an environmentally acceptable manner. GREENSL® Rating System of Green Building Council Sri Lanka (GBCSL) has been introduced, with the main aim of fundamentally changing the built environment by creating energy-efficient, healthy, productive buildings that reduce or minimise the significant impacts of buildings on the environment. This is achieved through the allocation of different credits to the selection of a proper site, better and efficient design, material selection, construction, operation, maintenance, removal, and possible reuse, etc (GBCSL, 2010).

In the sense of creating environmentally efficient buildings and to enhance the business image, most of organizations have been tended to obtain green certification nowadays. Most of modern buildings have green certified to obtain its vital benefits because of Indoor Environmental Quality is an important aspect which has received practically no attention in the built environment (Ileperuma, 2000). Facilitating a high quality working environment is one of the benefits of green certification, rather stays as a traditional building.

9.3 Provisions of GREEN$^{SL®}$ for Quality Built Environment

GREEN$^{SL®}$ consists of eight domains such as, management, sustainable sites, energy and atmosphere, water efficiency, indoor environment quality, materials and resources, innovation and design process, and social and cultural awareness. Each domain category has a number of aspects. The number and nature of aspects vary from one category to another according to the category itself and its importance matching the local context (Chandratilake & Dias, 2010 cited GBCSL, 2010). A study by Chandratilake and Dias further mentioned that 'sustainable sites' is the most important domain. And, energy and atmosphere, materials and resources, water efficiency and Indoor Environmental Quality are respectively in the top order.

The quality of built environment has addressed in the domain called 'Indoor Environment Quality' with the percentage of 13%. It mainly contains provisions of eleven (11) criteria, including minimum IAQ performance, smoke control, outdoor air delivery monitoring, increased ventilation, construction IAQ management plan, low emitting materials, indoor chemical and pollutant source control, controllability of systems, thermal comfort - design, thermal comfort - verification and daylight and views (GBCSL, 2011).

Further, first two criteria have been considered as 'prerequisites' to obtain credits for Indoor Environmental Quality whilst remaining nine factors were presented with predetermined credit values (points).

The credit values which have been allocated to each criterion are shown in Figure 9.1.

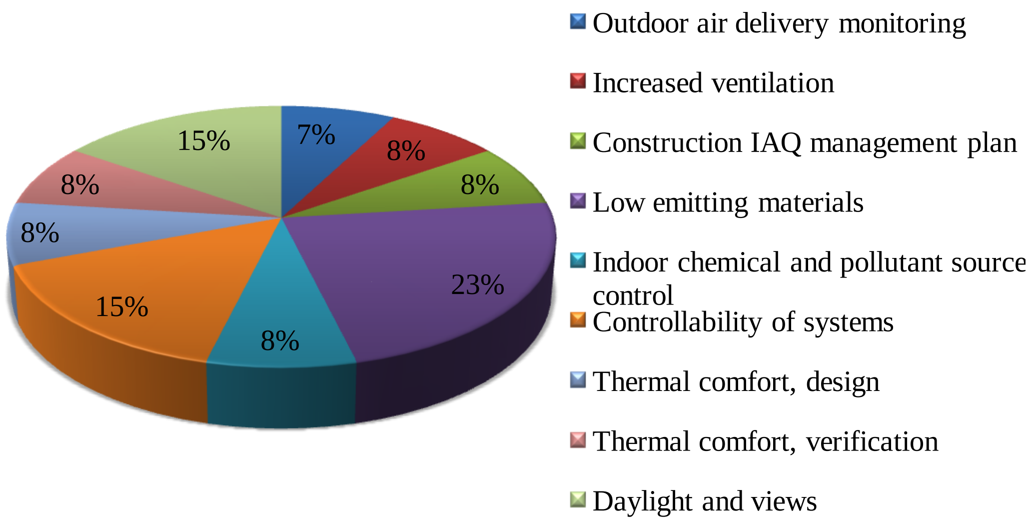


Figure 9.1: Credit values of IEQ criteria in GREEN^SL®

Source: GBCSL (2011)

The Table 9.1 illustrates the provisions of GREEN^SL® to facilitate a quality indoor environment. The review of the existing provisions proved that the existing rating system considered only about few built environment factors which are specially related to Indoor Environmental Quality. The rating system gives provisions for indoor air quality, ventilation, thermal quality and controllability of systems and day lighting and views. However, the addressed areas in each criterion are considerably few where such factors could consist of more strategies and measures as discussed in existing literature.

Table 9.1: Provisions of GREEN$^{SL®}$

Criteria	Purpose	Provisions
Minimum IAQ performance	to prevent the development of indoor air quality problems	▪ Design ventilation systems to meet or exceed the minimum outdoor air ventilation rates (ASHRAE 62.1-2004) ▪ Balance the impacts of ventilation rates on energy use and indoor air quality
Smoke control	Minimise exposure of building occupants, indoor surfaces and ventilation air distribution systems to Environmental Tobacco Smoke (ETS).	▪ Prohibit smoking in the building ▪ Locate any exterior designated smoking areas ▪ Locate designated smoking rooms to effectively contain, capture and remove ETS from the building ▪ Performance measurement of the smoking room differential air pressures
Outdoor air delivery monitoring	Provide capacity for ventilation system monitoring to help sustain occupant comfort and well-being.	▪ Monitor CO_2 concentrations within all densely occupied spaces ▪ Install CO_2 and airflow measurement equipment ▪ use the measurement equipment to trigger alarms in deficiencies
Increased ventilation	Provide additional outdoor air ventilation to improve indoor air quality for improved occupant comfort, well-being and productivity	▪ Use heat recovery, where appropriate, to minimize the additional energy consumption ▪ Follow ventilation system design steps in Carbon Trust Good Practice Guide 237 (develop design requirements, plan air flow paths, identify building uses, determine ventilation requirements, estimate external driving pressures, select ventilation device types, size ventilation devices and analyze the design).
Construction IAQ management plan	Prevent indoor air quality problems resulting from the construction/renovation process	▪ Adopt an IAQ management plan to protect the Heating, Ventilation and Air Conditioning (HVAC) system during construction ▪ Control pollutant sources and interrupt pathways for contamination. ▪ Sequence installation of materials to avoid contamination of absorptive materials ▪ Use of filtration media with a minimum efficiency reporting (ASHRAE 52.2-1999) ▪ Conduct a minimum two-week building flush-out prior to occupancy
Low emitting	Reduce the quantity of indoor air contaminants that are odorous or	▪ Specify low-volatile organic compound (VOC) materials in construction documents. ▪ Ensure that VOC limits are clearly stated in each section where adhesives, sealants, paints,

materials	potentially irritating harmful to the comfort and well-being	coatings, carpet systems, and composite woods are addressed.
Indoor chemical and pollutant source control	Minimize exposure of building occupants to potentially hazardous particulates and chemical pollutants.	▪ Design facility cleaning and maintenance areas with isolated exhaust systems for contaminants. ▪ Maintain physical isolation from the rest of the regularly occupied areas of the building. ▪ Install permanent architectural entryway systems. ▪ Install high-level filtration systems in air handling units.
Controllability of systems	Provide a high level of lighting system control by individual occupants or by specific groups in multi-occupant spaces to promote productivity, comfort and wellbeing of occupants.	▪ Design the building and systems with comfort controls ▪ Developing comfort criteria for building spaces and control strategies to allow adjustments ▪ System designs incorporating operable windows, hybrid systems integrating operable windows and mechanical systems, or mechanical systems alone. ▪ Individual thermostat controls, local diffusers at floor, desk or overhead levels, or control of individual radiant panels, or other means integrated.
Thermal comfort, design	Provide a comfortable thermal environment that supports the productivity and well-being of building occupants	▪ Establish comfort criteria per ASHRAE Standard 55-2004 ▪ Design building envelope and systems with the capability to deliver performance to the comfort criteria ▪ Evaluate air temperature, radiant temperature, air speed, and relative humidity
Thermal comfort, verification	Provide for the assessment of building thermal comfort over time	▪ Establishing thermal comfort criteria and the documentation and validation of building performance to the criteria (ASHRAE Standard 55-2004). ▪ Continuous monitoring and maintenance of the thermal environment.
Daylight and views	Provide a connection between indoor spaces and the outdoors through the introduction of daylight and views.	▪ Design the building to maximize day-lighting and view opportunities ▪ Building orientation, shallow floor plates, increased building perimeter, exterior and interior shading devices, high performance glazing, and photo-integrated light sensors ▪ Model day-lighting strategies with a physical or computer model to assess foot candle levels

Source: GBCSL (2011)

9.4 Suggestions to Enhance Indoor Environmental Quality (IEQ) Criteria

As key research findings, the relationship between built environment and occupants' productivity in green certified office buildings were determined. Further, five built environment factors were identified as critically influencing factors such as, air quality, system control, acoustical partitioning, open plan office design and amount of space. In the contrast of existing IEQ criterions in GREEN$^{SL®}$ with key research findings, several improvements were identified and proposed. The proposed suggestions can be considered to enhance the IEQ evaluation criteria in national green certification. The proposed enhancements are as follows,

- **Adopting other built environment factors into IEQ criteria**

As per the research findings, five critical built environment factors were identified among the 54 built environment factors influencing occupants' productivity. The existing national rating system only consists of IEQ related factors such as, minimum IAQ performance, smoke control, outdoor air delivery monitoring, increased ventilation, construction IAQ management plan, low emitting materials, indoor chemical and pollutant source control, controllability of systems, thermal comfort - design, thermal comfort - verification and daylight and views. However, many other built environment factors could critically influence occupants' productivity in green buildings.

Therefore, research findings suggests to incorporate those critical factors such as, system controls, acoustical partitioning, air quality, open plan office design, and amount of space into the IEQ criterion.

- **Introducing new provisions for air quality**

Air quality too requires further consideration, as it showed more likely effect on occupants' productivity. Hence, the existing provisions of air quality are required to be revised by adopting new provisions and strategies, such as, the implementation of air quality standards of Occupational Safety and Health Administration (OSHA) and Illinois Department of Public Health (IDHP) to fulfill the IAQ requirement of green buildings etc.

- **New provisions to reduce internal and external noises in green buildings**

According to the research findings, system control and acoustical partitioning are more likely effecting occupants' productivity. Hence, major consideration is required to ensure the acoustic quality in green buildings. However, among the other IEQ criterions in national green certification, acoustic quality has not been considered. Controllability of systems has introduced with the credit value of 15% only to enable adjustments to suit individual task needs and preferences of building systems such as, lighting and operable windows etc, rather than considering the internal noise control. Thus, major consideration is required to reduce both internal and external noise generation. It is because uncontrollable noise in green buildings has created the working environment really uncomfortable, especially in the buildings, which are located in the urban areas. The higher level of background noise has disturbed the concentration and work productivity of the occupants.

Therefore, the existing IEQ evaluation criteria could be revised and added with new provisions to ensure acoustical quality in green buildings. The provisions and strategies are required to enhance the system noise control to reduce the disturbance generated. Office spaces could also be designed with acoustical partitioning to reduce both internal and external noises. Use of sound absorbers, acoustical ceiling over building system installed areas and acoustical tiling are other options to enhance acoustic quality in green buildings.

- **Effective designing of office layout**

It is required to pay much attention in designing the office layout, as it was identified as major factor influencing occupants' productivity As the research findings, open plan design is negatively correlated to occupants' productivity. As verified by previous literature, open plan office spaces decrease the job performance, satisfaction to work and productivity of occupants, mainly due to the noise, overcrowding, lack of privacy and less individual control over their work environment. Hence, it may be worth taking into account the organizational culture, need of interaction, etc. when designing a workplace especially for office workers as they expect high concentration on their work. Further, the need of interaction may be different between different staff categories; clerical and senior staff etc.

- **Introducing new criteria for space planning**

The existing rating system has not provided the provisions for effective space planning. However, it was identified as one of the major factors influencing occupants' productivity in green buildings. Hence, the existing IEQ criteria need to be incorporated with the new criterion as 'effective space planning' that is important to create the workspace more productive. The space provided for each worker is another important factor that needs to be considered to enhance occupants' productivity. Hence, the office space needs to be designed with available interior space planning standards, thus; the rating system requires including new provisions for effective space planning.

- **Re-weighting of critical built environment factors**

Based on key research findings, the researcher propose a basis to re-weight the critical built environment criterions such as, air quality, system control, acoustical partitioning, open plan design and amount of space. The new evaluation criteria could be redeveloped by considering their actual degree of influence on occupants' productivity in green buildings. Accordingly, 5.783, 1.822, 16.428, 0.038 and 63.434 values (refer Table 7.8) could be considered respectively for air quality, system control, acoustical partitioning, open plan office design and the amount of space provided for an individual office worker.

9.5 Summary

As the final objective of the research, probable enhancement of IEQ criterion in GREEN$^{SL®}$ was proposed based on research outcomes. The certification system was critically reviewed and existing provisions and major enhancements were identified. The concern on existing factors in IEQ domain, such as, minimum IAQ performance, smoke control, outdoor air delivery monitoring, increased ventilation, construction IAQ management plan, low emitting materials, indoor chemical and pollutant source control, controllability of systems, thermal comfort - design, thermal comfort -

verification and daylight and views were identified as major areas which needs further examination. Further, acoustic quality and space planning have not taken a major consideration in the existing rating system whilst those factors showed more likely effect on occupants' productivity. Accordingly, the probable enhancements were proposed such as, adapting new provisions and strategies for air quality and acoustic quality, introducing criteria for effective space planning, paying attention on the selection of suitable workspace design. Finally, a basis to re-weight the evaluation criteria was also proposed by fulfilling the final objective of the research.

10. CONCLUSIONS AND RECOMMENDATIONS

10.1 Introduction

Whilst the previous chapters exhibited research analysis and findings of empirical investigation, this chapter focuses on summarization of key findings in order to draw out the conclusions and recommendations. Initially, the aim and objectives of the research are exemplified in the Section 10.2 comply with the research problem in order to afford obvious conviction about the research. Then, the Section 10.3 epitomises the key research findings with the intention of drawing conclusions on the overall research problem. Hence, the key findings are summarised and concluded to embrace the achievement of the research aim by attaining first, second and third objectives. Subsequently, the contribution of the research to the knowledge and industry are described in the Section 10.4. The Section 10.5 states the limitations of research while new research directions emerging from this study are elaborated in Section 10.6.

10.2 Aim and Objectives of the Research

Even though people tend to move green from non-green environments to obtain benefits of green buildings, there is no much concern for the green built environment and its influence on occupants' productivity. With the value of conducting this research, the study was intended to investigate the built environment factors critical for green buildings and their degree of influence on occupants' productivity in green office buildings in Sri Lanka as the aim of the research. In order to achieve the aim, occupant expectations of the green building environment were identified as the first objective. The second and third objectives are achieved respectively, by identifying built environment factors influencing occupants' productivity and, by developing a conceptual framework based on the identified factors and determining built environment factors critical for green buildings and their degree of influence on occupants' productivity. As the final objective, probable suggestions to enhance the Indoor Environmental Quality criterion in the national green rating system were proposed based on research outcomes. The attainment of first, second and third objectives are described in Section 10.3, which have ensured the fulfillment of the aim, as the final outcome of this research.

10.3 Summary of Key Research Findings

In this section, the first, second, third and fourth objectives were reached by drawing conclusions and recommendations based on key findings of the study.

Objective One - Identify occupants' expectations of green building environment

- According to the literature findings, occupants are more favourably disposed to green buildings as green buildings are more comfortable than conventional buildings; thereby making them more satisfying and productive in workplaces is important.
- Many organizations tend more towards 'green' to ensure fulfillment of the owner and occupier needs. There is a strong vested interest in energy efficiency, low running costs, low environmental impact and the high quality indoor environment.
- Thus, it is vital to ensure that the occupants' needs are being addressed and that claims of performance are warranted in green buildings as it can be directly affected on occupants' productivity.
- High quality indoor environment is the major expectation of building occupants thus, the main goal of green certification as it is directly affected on their health, well-being and the productivity.
- Moreover, green building design can be affected on organizational performance outcomes. Improved indoor environment is likely to have the greatest impact on well being and personal productivity.
- Occupants 'productivity is the most significant benefit of green buildings where 1%-1.5% productivity could gain from healthier indoor environments after moving to green buildings from their traditional work settings.
- Consequently, the major expectation of green buildings; facilitating better indoor environment to ensure occupants' productivity and, the potential interplay between quality of built environment and occupants' productivity in green buildings were identified.

Objective Two - Identify built environment factors influencing occupants' productivity and develop a conceptual framework based on the identified factors

<u>Built environment factors influencing occupants' productivity</u>

- According to literature findings, there is a continuous and dynamic interaction between the occupants and their surroundings as the majority of people spend most of their time indoors.
- Numerous studies have shown that indoor climate impacts both health and performance, which in turn affects productivity, thus, improving indoor environment is deemed to be the most important factor in the office productivity study.
- By reviewing key literature, 54 built environment factors were identified relating to the 12 major dimensions such as thermal quality, acoustic quality, Indoor Air Quality, ventilation, visual quality, spatial quality, office layout, appearance of workplace, social engagement, general building maintenance, building materials used and office type.

- Personal control on ambient conditions, Temperature, opening windows and personal thermal system control are **thermal quality** related factors whilst provisions of day lighting, radiation and electromagnetic fields, electric lighting quality, glare, controllable task-lighting, illuminance, colour, personal/task lighting, proximity to a window, view to outdoor environment, controllable lighting installations and lighting intensity are related to **visual quality**.
- **Indoor Air Quality** consists of many factors, such as, indoor air temperature, air quality, dust, odour, air freshness and air movement. **Ventilation** related factors are amount of ventilation, Natural ventilation and Mechanical ventilation where **Acoustic quality** consists of many factors, including background sound level, acoustical partitioning, sound privacy, system controls and sound absorption materials.
- Distractions, personal control workstations, privacy, office instrumentality, space arrangement, orientation of the office; and space flexibility are **spatial quality**

related factors whilst art and aesthetic, contact with nature and views, symbolism, floor coverings and wall hangings and architectural arrangement are **workplace appearance** related factors.

- Moreover, building maintenance and cleanliness as **building maintenance** related factors, cellular and open plan design as **office type** related factors, use of low emitting materials as **building materials** related factors, ergonomics, screen positions of work station, adjustability of furniture and amount of space as **office layout** related factors and space for informal meetings, psychological restoration and relaxation and access to documents as **social engagement** related factors were identified.

<u>The Conceptual framework</u>

- The conceptual framework was developed as a guide to address the main research question and sub questions by comprising four stages such as, Identification, Evaluation, Outcomes and Application.
- As the first stage, the key literature was reviewed and built environment related factors influencing occupants' productivity were identified.
- The second stage was developed to conduct the research analysis on identified built environment factors, in order to determine the factors critical for green buildings and their degree of influence on occupants' productivity.
- Stage three deals with the research outcomes. The relation and the degree of influence of critical built environment factors on occupants' productivity were tested and determined as the main research outcome.
- Final/fourth stage of the framework was intended to identify the applications of research outcomes. Accordingly, probable enhancements of the GREEN$^{SL®}$ national certification system were proposed.

Objective Three - Determine built environment factors critical for green buildings and its degree of influence on occupants' productivity

Built environment factors critical for occupants' productivity in green buildings

- According to the Spearman's Correlation test results, 20 built environment factors were identified as the significant built environment factors, which have showed a significant correlation to the major dimension.
- The identified significant built environment factors include opening windows, controllable lighting installations, personal lighting, view to outdoor environment, air quality, amount of ventilation, acoustical partitioning, system control, distractions, personal control workstations, art and aesthetic, maintenance, cleanliness, open plan design, use of low-emitting materials, adjustability of furniture, amount of space, space for informal meetings, access to documents, psychological restoration and relaxation.
- The significant built environment factors were further tested by performing Spearman's Correlation in SPSS statistical analysis software. According to the test statistics, five factors were significantly correlated to occupants' productivity in green buildings which have showed positive or negative monotonic correlation at the level of significance of 0.05.
- Among those, air quality has shown a statistically significant and weak positive monotonic correlation (r=.258, p=.038), acoustical partitioning has shown a weak positive monotonic correlation (r=.257, p=.039), whilst system control, open plan office design and amount of space have shown statistically significant strong positive (r=.347, p=.005), weak negative (r= -.253, p=.042) and weak positive (r=.252, p=.043) monotonic correlations to occupants' productivity respectively.
- Based on the level of significance and, the strength of correlation, air quality, system controls, acoustical partitioning, open plan office design and amount of space were identified as the critical built environment factors influencing occupants' productivity in green certified office buildings.

The relationship, influence and the degree of influence of critical built environment factors

- The relationship between the critical built environment factors and occupants' productivity was modelled and tested by the ordinal logistic regression.
- According to the test statistics, system controls (-.600) with much lower influence level, air quality with normal (-2.154) and slightly higher influence level (-1.755), acoustical partitioning with slightly higher influence level (-2.799), open plan design (3.278) and amount of space (-4.150) with normal influence level were determined as statistically significant factors which showed significant relationship to occupants productivity (-5.521).
- As per the model developed, a one unit increased in each individual critical factor, such as, air quality, system control, acoustical partitioning and amount of space, is expected to increase the level of occupants' productivity by its respective regression coefficient value whilst other variables are remaining constant.
- Among the other factors, open plan office design has showed a wondered result, as it showed a negative influence on occupants' productivity. However, most of previous researches have confirmed the negative effect of open plan office design. Thus, the research findings on open plan office design and occupants' productivity was validated through extant literature and occupants' perceptions.
- Another key finding of the research was the determination of the degree of influence of critical built environment factors effecting to occupants' productivity. The odds-ratios (exponential values) of the regression coefficient value of each critical factor were calculated to identify likely effect of each factor at the reference level to being in the higher level of productivity.
- According to the odds ratios (e^x) calculated, air quality was 5.783 times, system control was 1.822 times, acoustical partitioning was 16.428 times, open plan office design was 0.038 times and amount of space was 63.434 times more likely effected on occupants' productivity.
- All the research findings were finally validated through extant literature and the perceptions of occupants. Accordingly, the critical built environment factors and

their degree of influence on occupants' productivity were determined as the main research outcome by fulfilling the third objective of the research.

Objective Four - Propose probable suggestions to enhance the Evaluation criteria of Indoor Environmental Quality in the national green rating system

- The fourth objective was fulfilled as the application of research outcomes derived through first three objectives. Hence, the existing GREEN$^{SL®}$ national green certification system was reviewed compared to key research findings.
- GREEN$^{SL®}$ consists of eight domains such as, management, sustainable sites, energy and atmosphere, water efficiency, Indoor Environment Quality (IEQ), materials and resources, innovation and design process, and social and cultural awareness.
- IEQ consists of eleven aspects such as, minimum IAQ performance, smoke control, outdoor air delivery monitoring, increased ventilation, construction IAQ management plan, low emitting materials, indoor chemical and pollutant source control, controllability of systems, thermal comfort - design, thermal comfort - verification and daylight and views.
- Compared to key research findings, the gaps in existing IEQ criteria were identified, such as, focusing on few IEQ factors, less provisions on acoustic quality, office design and space planning etc.
- Accordingly, the probable enhancements were proposed such as, adapting new provisions and strategies for air quality and acoustic quality, introducing criteria for effective space planning, paying attention on the selection of suitable workspace design.
- Hence, the rating system could be revived as suited to the local context applications by adapting new provisions and strategies on air quality, acoustic quality and space planning.
- Further, the evaluation criteria could be redeveloped by considering the actual degree of effect of critical built environment factors determined in this research. Accordingly, weightings for five built environment factors were proposed as 5.783, 1.822, 16.428, 0.038 and 63.434 respectively for air quality, system

control, acoustical partitioning, open plan office design and amount of space provided for an individual office worker.

Consequently, the first, second, third and fourth objectives were accomplished by ensuring the achievement of the ultimate aim of this research.

10.4 Contribution to Knowledge and Industry

The research gives a vast contribution to the theory and to the industry.

10.4.1 Contribution to knowledge

- This research contributes to the knowledge by identifying the built environment factors which are critical for green buildings and its effect on occupants' productivity.
- Whilst most studies have focused only on single aspects of the built environment and, no evidences were found on which factors could critically influence occupants' productivity in green buildings, this research focused on the statistical relationship between built environment factors and occupants' productivity in green certified office buildings.
- Hence, the findings of extant literature (hypotheses constructed) were tested and critical built environment factors and its degree of influence were determined.

10.4.2 Contribution to industry

- As the major contribution, this study evaluated the relationship between green built environment and occupants' productivity, whilst most of organizations have tended towards 'green building designs' to gain its expected benefits.
- Among the other benefits, occupants' productivity improvement is one of major expectations of green built environment. Facilitating quality built environment is a great necessity to improve occupants' productivity and wellbeing.
- This study identified the built environment factors critical for occupants' productivity in green certified office buildings, and their degree of influence.
- Hence, as the major research contribution, probable enhancements were proposed to improve the IEQ criterion in GREEN$^{SL®}$ national green certification system to

enhance the quality of built environment to assure occupants' productivity improvements.

- Further, a basis to re-weight the evaluation criteria was also proposed, that could be considered in GREEN$^{SL®}$ national green certification system.
- Moreover, the findings of this research can be used as a basis to review and redevelop IEQ related criterions in green certification systems both nationally and internationally.

10.5 Limitations of the Research

This research was focused only on green certified office buildings to determine the relationship between built environment factors and occupants' productivity. The green buildings were selected by ensuring the similarity of green features. Hence, the building profile was limited to three GREEN$^{SL®}$ and LEED Gold awarded buildings from the administrative and banking sectors in Sri Lanka. Further, this research was limited to study the statistical relationship between built environment factors and occupants' productivity in green buildings. Accordingly, a statistical model was developed that could be used as the basis to evaluate green building designs in future research studies.

In the productivity measurement, perceived productivity (self-rated) measurement technique was used among the other subjective and objective measurement techniques, as it was identified as the most common and widely used method in productivity research. However, the data collected was based on subjective productivity measurement through questionnaire survey.

The generalisability of the survey was limited to the randomly selected 100 occupants in three selected green certified office buildings in Sri Lanka. As this research targeted the productivity of building occupants in green certified office buildings, the research findings can be generalised to the mentioned population with confidence.

10.6 Recommendations for Further Research

- This research was limited to determine the statistical significance of built environment factors and, the statistical relationship existed between green built environment and occupants' productivity. The statistical model developed could be used as a basis to evaluate the green building designs by conducting a detail investigation to test the real world implications.
- This research has revealed the statistical relationship between significant built environment factors and occupants' productivity in green buildings, thus only the effect of factors was evaluated. Future research in this genre can be conducted to identify and compare productivity improvement of occupants in green and non-green buildings.
- The similar study can be conducted in a different green working environment, such as, green factory buildings in Sri Lanka etc. to test the effect of built environment on occupants' productivity.
- The perceived (self rated) productivity measurement technique was applied in this research. Future research can be focused on other productivity measurement techniques including neurobehavioral approach, objective measurement or other subjective measurement techniques.

- The research context was limited to green certified office buildings in Sri Lanka. It will be interesting and useful to conduct this study in different contexts to identify possible effects of green building environment on occupants' productivity. This would also beneficial to enhance the green rating systems in different contexts. It is therefore recommended to conduct this study in other countries to allow comparative analysis to be undertaken.

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APPENDICES

Appendix 5.1 : Questionnaire developed for preliminary survey

Appendix 5.2 : Questionnaire developed

Appendix 5.3 : Interview guideline prepared

Appendix 6.1 : Spearman's correlation matrix of thermal quality

Appendix 6.2 : Spearman correlation matrix of visual quality

Appendix 6.3 : Spearman correlation matrix of IAQ

Appendix 6.4 : Spearman correlation matrix of ventilation

Appendix 6.5 : Spearman correlation matrix of acoustic quality

Appendix 6.6 : Spearman correlation matrix of spatial quality

Appendix 6.7 : Spearman correlation matrix of workplace appearance

Appendix 6.8 : Spearman correlation matrix of building maintenance and cleanliness

Appendix 6.9 : Spearman correlation matrix of office type

Appendix 6.10: Spearman's correlation matrix of building materials

Appendix 6.11: Spearman correlation matrix of office layout

Appendix 6.12: Spearman's Correlation matrix of social engagement

Appendix A : List of Research Publications, Achievements and Awards

Appendix 5.1: Questionnaire developed for preliminary survey

The Questionnaire Survey

Master of Philosophy (Research) – 2012/2014

OVERVIEW OF THE STUDY

Most of buildings have been tended to be green because of its ultimate benefits to people, economy and the environment. Occupants' productivity is one of important benefits facilitated by green buildings. No clear evidences have been identified whether green buildings have real impact on occupants' productivity. This research focuses on identifying built environment factors critical for green buildings and their degree of influence on occupants' productivity. Hence, this questionnaire covers the self judgment of occupants' on the influence of built environment features existed in green buildings on their self assessed productivity.

CONFIDENTIALITY STATEMENT

The information from this questionnaire will be used only for the purpose of fulfilling the Master of Philosophy research. All the responses of the occupants will be kept confidential. Further, to maintain the confidentiality, the actual names of the organisations and the respondents will not reveal and such responses will only be shared within department of Building Economics.

SURVEY PROCEDURE

The questionnaire will be distributed to the occupants' of the organisation (office employees). All relevant instructions will be provided in the questionnaire. I would be grateful if you could help with this questionnaire.

Researcher:

Ms. Harshini Mallawaarachchi
Lecturer
Bsc. (Hons) In Facilities Management
Department of Building Economics
University of Moratuwa

Research Supervisor:

Prof. Archt. Lalith De Silva
Dean/Senior Lecturer
Department of Building Economics
Faculty of Architecture
University of Moratuwa

GENERAL INFORMATION

Details of Respondent

Name of the respondent	
Designation	
Date	

Details of the organization

Name of the organization	
Core business function	
Green certification category	
Year received	

THE EVALUATION OF BUILT ENVIRONMENT FACTORS ON OCCUPANTS' PRODUCTIVITY

<u>Section - A</u>

This section is to determine the self assessed productivity covering the amount of work accomplished and quality of work performed.

1. Number of hours assigned to work per day………………………………………………
2. What are the duties and responsibilities of work assigned?

3. Are you productive in your works? (YES/NO)

Please score the most relevant answer with a '√' by considering your own productivity

My overall productivity in getting the works done		
	1 - Poor	
	2 - Below average	

	3 - Average	
	4 - Good	
	5 - Excellent	

Section - B

Previous studies have been identified various built environment factors can be influenced on occupants productivity. This section is attained to make occupants' judgments on such physical factors in the indoor working environment. Questions were also asked about personal health, job satisfaction and overall opinion about the indoor environment.

Please score the built environmental factors with a '√' by considering the criteria given below.

Built environment Factor	**Level of influence**				
	1 - Very Low	**2 - Low**	**3 - Neutral**	**4 - High**	**5 – Very High**
Ventilation					
Indoor air quality					
Contact with nature and views					
Thermal quality					
Day lighting and lighting quality					
Acoustical quality					
Spatial comfort					
Office layout					
Privacy					
Distractions					
Symbolism					
Functionality					
Office instrumentality					
Art and aesthetic					
Furniture					

Personal control workstations					
Sensory variability					
Psychological restoration & relaxation					
Personal control on ambient conditions					
Ergonomics					
Social engagement					
Building maintenance					
Cleanliness					
Building materials used					
Building type and design					
Outdoor environment quality					
Building refurbishment situations					
Radiation and electromagnetic fields					

……………………………… **THANK YOU**……………………………….............

Appendix 5.2: Questionnaire developed

The Questionnaire Survey
Master of Philosophy (Research) – 2012/2014

OVERVIEW OF THE STUDY

Most of buildings have been tended to be green because of its ultimate benefits to people, economy and the environment. Occupants' productivity is one of important benefits facilitated by green buildings. No clear evidences have been identified whether green buildings have real impact on occupants' productivity. This research focuses on identifying built environment factors critical for green buildings and their degree of influence on occupants' productivity. Hence, this questionnaire covers the self judgment of occupants' on the influence of built environment features existed in green buildings on their self assessed productivity.

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Dean/Senior Lecturer
Department of Building Economics
Faculty of Architecture
University of Moratuwa

GENERAL INFORMATION

Name of the organization	
Name of the respondent	
Designation	
Date	

Section A

SELF ASSESSMENT OF PERCEIVED PRODUCTIVITY

This section is to determine the self assessed perceived productivity covering the amonut of work accomplished and quaity of work performed.

1. Number of hours assigned to work per day ……………….

2. What are the duties and responsibilities of work assigned?

3. Please score the level of your own productivity which is influenced (increased or decreased) by the built environmental conditions in the building?

Much Lower	Slightly Lower	Normal	Slightly Higher	Much Higher
1	2	3	4	5

Section B

EVALUATION OF BUILT ENVIRONMENT FACTORS

Previous studies have been identified various built environment factors can be influenced on occupants productivity. This section is attained to make occupants' judgments on such physical factors in the indoor working environment. Questions were also asked about personal health, job satisfaction and overall opinion about the indoor environment.

Please score the built environmental factors with a '√' by considering the criteria given below.

	Level of influence on productivity				
	Much Lower	**Slightly Lower**	**Normal**	**Slightly Higher**	**Much Higher**
	1	**2**	**3**	**4**	**5**
Thermal quality					
Personal control on ambient conditions					
Temperature					
Opening windows					
Personal thermal system control					
Visual quality					
Provisions of day lighting					
Radiation and electromagnetic fields					
Electric lighting quality					
Glare					
Controllable task-lighting					
Illuminance					
Controllable lighting installations					
Lighting intensity					
Colour					
Personal/task lighting					
Proximity to a windo					
View to outdoor environment					

Indoor air quality					
Indoor air temperature					
Air quality					
Dust					
Odour					
Air freshness					
Air movement					
Ventilation					
Amount of ventilation					
Natural ventilation					
Mechanical ventilation					
Acoustic quality					
Background sound level					
Acoustical partitioning					
Sound privacy					
System controls					
Sound absorption materials					
Spatial quality					
Distractions					
Personal control workstations					
Privacy					
Office instrumentality					
Space arrangement					
Orientation of office					
Space flexibility					
Appearance of the workplace					
Art and aesthetic					
Contact with nature and views					
Symbolism					

Floor coverings and wall hangings					
Architectural arrangement of workplace					
Building maintenance and cleanliness					
Building Maintenance					
Cleanliness					
Office type					
Open plan					
Cellular					
Building materials used					
Law emitting materials					
Office layout					
Ergonomics					
Screen positions of work station					
Adjustability of furniture					
Amount of space					
Social engagement					
Space for informal meetings					
Access to documents					
Psychological restoration and relaxation					
Overall rating for green built environment					

……………………………… THANK YOU…………………………………...........

SAMPLE COPY

The Questionnaire Survey

Master of Philosophy (Research) – 2012/2014

OVERVIEW OF THE STUDY

Most of buildings have been tended to be green because of its ultimate benefits to people, economy and the environment. Occupants' productivity is one of important benefits facilitated by green buildings. No clear evidences have been identified whether green buildings have real impact on occupants' productivity. This research focuses on identifying built environment factors critical for green buildings and their degree of influence on occupants' productivity. Hence, this questionnaire covers the self judgment of occupants' on the influence of built environment features existed in green buildings on their self assessed productivity.

CONFIDENTIALITY STATEMENT

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SURVEY PROCEDURE

The questionnaire will be distributed to the occupants' of the organisation (office employees). All relevant instructions will be provided in the questionnaire. I would be grateful if you could help with this questionnaire.

Researcher:

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Research Supervisor:

Prof. Archt. Lalith De Silva
Dean/Senior Lecturer
Department of Building Economics
Faculty of Architecture
University of Moratuwa

GENERAL INFORMATION

Name of the organization	
Name of the respondent	
Designation	QS
Date	28/07/2014

Section A

SELF ASSESSMENT OF PERCEIVED PRODUCTIVITY

This section is to determine the self assessed perceived productivity covering the amonut of work accomplished and quaity of work performed.

1. Number of hours assigned to work per day ……8 hours….

2. What are the duties and responsibilities of work assigned?

BOQ preparation and Tendering

3. Please score the level of your own productivity which is influenced (increased or decreased) by the built environmental conditions in the building?

Much Lower	Slightly Lower	Normal	Slightly Higher	Much Higher
1	**2**	**3**	**4**	**5**
			√	

Section B

EVALUATION OF BUILT ENVIRONMENT FACTORS

Previous studies have been identified various built environment factors can be influenced on occupants productivity. This section is attained to make occupants' judgments on such physical factors in the indoor working environment. Questions were also asked about personal health, job satisfaction and overall opinion about the indoor environment.

Please score the built environmental factors with a '√' by considering the criteria given below.

	Level of influence on productivity				
	Much Lower	**Slightly Lower**	**Normal**	**Slightly Higher**	**Much Higher**
	1	**2**	**3**	**4**	**5**
Thermal quality			√		
Personal control on ambient conditions			√		
Temperature	√				
Opening windows			√		
Personal thermal system control				√	
Visual quality				√	
Provisions of day lighting					√
Radiation and electromagnetic fields			√		
Electric lighting quality			√		
Glare		√			
Controllable task-lighting			√		
Illuminance				√	
Controllable lighting installations				√	
Lighting intensity			√		
Colour			√		
Personal/task lighting			√		
Proximity to a window				√	
View to outdoor environment			√		

Indoor air quality				√	
Indoor air temperature			√		
Air quality				√	
Dust		√			
Odour		√			
Air freshness			√		
Air movement			√		
Ventilation				√	
Amount of ventilation			√		
Natural ventilation				√	
Mechanical ventilation			√		
Acoustic quality				√	
Background sound level					√
Acoustical partitioning				√	
Sound privacy			√		
System controls			√		
Sound absorption materials			√		
Spatial quality				√	
Distractions				√	
Personal control workstations			√		
Privacy			√		
Office instrumentality				√	
Space arrangement			√		
Orientation of office		√			
Space flexibility			√		
Appearance of the workplace			√		
Art and aesthetic			√		
Contact with nature and views				√	

Symbolism				√	
Floor coverings and wall hangings		√			
Architectural arrangement of workplace	√				
Building maintenance and cleanliness			√		
Building Maintenance			√		
Cleanliness			√		
Office type		√			
Open plan		√			
Cellular		√			
Building materials used				√	
Law emitting materials			√		
Office layout				√	
Ergonomics				√	
Screen positions of work station			√		
Adjustability of furniture			√		
Amount of space				√	
Social engagement			√		
Space for informal meetings			√		
Access to documents				√	
Psychological restoration and relaxation			√		
Overall rating for green built environment				√	

……………………………… THANK YOU……………………………….........

Appendix 5.3: Interview guideline prepared

Study of factors influencing Occupants' productivity in green buildings

Master of Philosophy (Research) – 2012/2014

Interview Guide

1. What is your opinion on a workplace which is connected to natural environment?

2. Are you aware about the green building concept applied in your workplace? (YES/NO)
3. Are you willing to work in a green building? (YES/NO)
4. What are the difficulties faced, by moving to green working environment from non-green work environment?

5. What are re the issues in existing green rating system with respect to Indoor Environment Quality?

6. What are your suggestions to enhance national green rating system?

……………………………… **THANK YOU**……………………………….............

SAMPLE COPY

Study of factors influencing Occupants' productivity in green buildings

Master of Philosophy (Research) – 2012/2014

Interview Guide

7. What is your opinion on a workplace which is connected to natural environment?

It gives better working place to the employees. It increases the efficiency and effectiveness of the work

8. Are you aware about the green building concept applied in your workplace? (YES/~~NO~~)
9. Are you willing to work in a green building? (YES/~~NO~~)
10. What are the difficulties faced, by moving to green working environment from non-green work environment?

Sometimes it gives less concentration on work due to surrounding disturbances

11. What are re the issues in existing green rating system with respect to Indoor Environment Quality?

We are working here very happily as the environment is comfortable with this natural environment than our previous building. However, it would be beneficial to further concern on controlling the noise generated inside and outside the building.

12. What are your suggestions to enhance national green rating system?

New provisions to reduce noises

……………………………… THANK YOU…………………………………...........

Appendix 6.1: Spearman's correlation matrix of thermal quality

		Thermal quality	Personal control on ambient conditions	Temperature	Opening windows	Personal thermal system control
Thermal quality	**Spearman's Correlation**	1.000	.105	-.111	.285*	-.079
	Sig. (2-tailed)		.407	.381	.022	.531
	N	65	65	65	65	65
Personal control on ambient conditions	**Spearman's Correlation**	.105	1.000	.263*	.116	.083
	Sig. (2-tailed)	.407		.034	.356	.512
	N	65	65	65	65	65
Temperature	**Spearman's Correlation**	-.111	.263*	1.000	.007	.141
	Sig. (2-tailed)	.381	.034		.954	.263
	N	65	65	65	65	65
Opening windows	**Spearman's Correlation**	.285*	.116	.007	1.000	-.028
	Sig. (2-tailed)	.022	.356	.954		.826
	N	65	65	65	65	65
Personal thermal system control	**Spearman's Correlation**	-.079	.083	.141	-.028	1.000
	Sig. (2-tailed)	.531	.512	.263	.826	
	N	65	65	65	65	65

Appendix 6.2: Spearman correlation matrix of visual quality

		Visual quality	Provisions of daylighting	Radiation and electromagnetic field	Electric lighting quality	Glare	Controllable task lighting	Illuminance	Controllable lighting installations	Lighting intensity	Colour	Personal lighting	Proximity to window	View to outdoor environment
Visual quality	r	1.000	.135	-.045	-.074	.037	.139	.047	-.260*	.021	.102	.248*	.119	-.388**
	Sig. (2-tailed)		.282	.724	.558	.773	.270	.713	.037	.870	.419	.047	.345	.001
	N	65	65	65	65	65	65	65	65	65	65	65	65	65
Provisions of daylighting	r	.135	1.000	.399**	-.082	.058	-.097	-.080	.006	-.185	.143	-.017	.151	.107
	Sig. (2-tailed)	.282		.001	.514	.648	.442	.529	.965	.140	.255	.891	.230	.394
	N	65	65	65	65	65	65	65	65	65	65	65	65	65
Radiation and electromagnetic field	r	-.045	.399**	1.000	.008	-.117	-.408**	-.123	.006	-.195	.183	.018	-.104	.228
	Sig. (2-tailed)	.724	.001		.948	.355	.001	.330	.961	.120	.144	.884	.410	.067
	N	65	65	65	65	65	65	65	65	65	65	65	65	65
Electric lighting quality	r	-.074	-.082	.008	1.000	.090	-.021	.079	-.087	-.012	-.251*	-.053	.113	-.070
	Sig. (2-tailed)	.558	.514	.948		.477	.869	.534	.489	.925	.044	.674	.372	.580
	N	65	65	65	65	65	65	65	65	65	65	65	65	65
Glare	r	.037	.058	-.117	.090	1.000	.251*	-.052	-.080	.135	.171	.150	.127	-.129
	Sig. (2-tailed)	.773	.648	.355	.477		.044	.679	.527	.285	.172	.232	.313	.305
	N	65	65	65	65	65	65	65	65	65	65	65	65	65
Controllable task lighting	r	.139	-.097	-.408**	-.021	.251*	1.000	-.003	-.033	.048	.014	.189	-.258*	-.188
	Sig. (2-tailed)	.270	.442	.001	.869	.044		.983	.795	.703	.912	.131	.038	.133
	N	65	65	65	65	65	65	65	65	65	65	65	65	65
Illuminance	r	.047	-.080	-.123	.079	-.052	-.003	1.000	.186	-.051	-.028	-.208	-.188	-.071
	Sig. (2-tailed)	.713	.529	.330	.534	.679	.983		.139	.685	.824	.096	.134	.576
	N	65	65	65	65	65	65	65	65	65	65	65	65	65
Controllable lighting installations	r	**.260***	.006	.006	-.087	-.080	-.033	.186	1.000	.189	.131	-.085	-.139	.263*
	Sig. (2-tailed)	**.037**	.965	.961	.489	.527	.795	.139		.131	.298	.503	.270	.034
	N	65	65	65	65	65	65	65	65	65	65	65	65	65
Lighting intensity	r	.021	-.185	-.195	-.012	.135	.048	-.051	.189	1.000	.114	.134	-.075	-.062
	Sig. (2-tailed)	.870	.140	.120	.925	.285	.703	.685	.131		.365	.288	.554	.626
	N	65	65	65	65	65	65	65	65	65	65	65	65	65
Colour	r	.102	.143	.183	-.251*	.171	.014	-.028	.131	.114	1.000	.440**	.128	-.218
	Sig. (2-tailed)	.419	.255	.144	.044	.172	.912	.824	.298	.365		.000	.308	.081
	N	65	65	65	65	65	65	65	65	65	65	65	65	65
Personal lighting	r	**.248***	-.017	.018	-.053	.150	.189	-.208	-.085	.134	.440**	1.000	.186	-.169
	Sig. (2-tailed)	**.047**	.891	.884	.674	.232	.131	.096	.503	.288	.000		.137	.179
	N	65	65	65	65	65	65	65	65	65	65	65	65	65
Proximity to window	r	.119	.151	-.104	.113	.127	-.258*	-.188	-.139	-.075	.128	.186	1.000	.018
	Sig. (2-tailed)	.345	.230	.410	.372	.313	.038	.134	.270	.554	.308	.137		.889
	N	65	65	65	65	65	65	65	65	65	65	65	65	65
View to outdoor environment	r	**.388****	.107	.228	-.070	-.129	-.188	-.071	.263*	-.062	-.218	-.169	.018	1.000
	Sig. (2-tailed)	**.001**	.394	.067	.580	.305	.133	.576	.034	.626	.081	.179	.889	
	N	65	65	65	65	65	65	65	65	65	65	65	65	65

Appendix 6.3: Spearman correlation matrix of IAQ

		Indoor_Air_Quality	Indoor_air_temperature	Air_ quality	Dust	Odour	Air freshness	Air movement
Indoor_Air_ Quality	Correlation Coefficient	1.000	.059	-.253*	.042	.062	.045	-.021
	Sig. (2-tailed)		.639	.042	.740	.625	.723	.866
	N	65	65	65	65	65	65	65
Indoor_air_t emperature	Correlation Coefficient	.059	1.000	-.158	.076	.075	.125	-.252*
	Sig. (2-tailed)	.639		.207	.546	.554	.322	.042
	N	65	65	65	65	65	65	65
Air_quality	Correlation Coefficient	**.253***	-.158	1.000	-.026	-.151	-.083	-.107
	Sig. (2-tailed)	**.042**	.207		.834	.231	.513	.395
	N	65	65	65	65	65	65	65
Dust	Correlation Coefficient	.042	.076	-.026	1.000	.146	.160	.386**
	Sig. (2-tailed)	.740	.546	.834		.247	.202	.002
	N	65	65	65	65	65	65	65
Odour	Correlation Coefficient	.062	.075	-.151	.146	1.000	-.255*	-.009
	Sig. (2-tailed)	.625	.554	.231	.247		.040	.942
	N	65	65	65	65	65	65	65
Air_freshnes s	Correlation Coefficient	.045	.125	-.083	.160	-.255*	1.000	.093
	Sig. (2-tailed)	.723	.322	.513	.202	.040		.461
	N	65	65	65	65	65	65	65
Air_movem ent	Correlation Coefficient	-.021	-.252*	-.107	.386**	-.009	.093	1.000
	Sig. (2-tailed)	.866	.042	.395	.002	.942	.461	
	N	65	65	65	65	65	65	65

Appendix 6.4: Spearman correlation matrix of ventilation

		Ventilation	Amount_of_ventiation	Natural_ventilation	Mechanical_ventilation
Ventilation	Correlation Coefficient	1.000	.254*	.143	.134
	Sig. (2-tailed)		.041	.257	.286
	N	65	65	65	65
Amount_of_ventilation	Correlation Coefficient	.254*	1.000	.236	.122
	Sig. (2-tailed)	.041		.059	.333
	N	65	65	65	65
Natural_ventilation	Correlation Coefficient	.143	.236	1.000	.112
	Sig. (2-tailed)	.257	.059		.374
	N	65	65	65	65
Mechanical_ventilation	Correlation Coefficient	.134	.122	.112	1.000
	Sig. (2-tailed)	.286	.333	.374	
	N	65	65	65	65

Appendix 6.5: Spearman correlation matrix of acoustic quality

		Acoustic_quality	Background_noise_level	Acoustical_partitioning	Sound_privacy	System_controls	Sound_absorption_materials
Acoustic_quality	Correlation Coefficient	1.000	.193	-.025	-.189	.281*	.048
	Sig. (2-tailed)		.124	.845	.132	.023	.702
	N	65	65	65	65	65	65
Background_noise_level	Correlation Coefficient	.193	1.000	.159	-.031	.084	.193
	Sig. (2-tailed)	.124		.207	.806	.506	.123
	N	65	65	65	65	65	65
Acoustical_partitioning	Correlation Coefficient	**.248***	.159	1.000	.070	-.001	.158
	Sig. (2-tailed)	.047	.207		.582	.996	.208
	N	65	65	65	65	65	65
Sound_privacy	Correlation Coefficient	-.189	-.031	.070	1.000	-.001	.075
	Sig. (2-tailed)	.132	.806	.582		.991	.551
	N	65	65	65	65	65	65
System_controls	Correlation Coefficient	**.281***	.084	-.001	-.001	1.000	.060
	Sig. (2-tailed)	**.023**	.506	.996	.991		.634
	N	65	65	65	65	65	65
Sound_absorption_materials	Correlation Coefficient	.048	.193	.158	.075	.060	1.000
	Sig. (2-tailed)	.702	.123	.208	.551	.634	
	N	65	65	65	65	65	65

Appendix 6.6: Spearman correlation matrix of spatial quality

		Spatial_quality	**Distractions**	**Personal_control_workstations**	**Privacy**	**Office_instrumentality**	**Space_arrangement**	**Orientation_of_office**	**Space_flexibility**
Spatial_quality	Correlation Coefficient	1.000	.250*	.249*	.192	.066	-.100	-.127	.160
	Sig. (2-tailed)		.045	.045	.125	.603	.428	.315	.202
	N	65	65	65	65	65	65	65	65
Distractions	Correlation Coefficient	**-.250***	1.000	.092	.389**	.315*	.137	.048	.063
	Sig. (2-tailed)	**.045**		.468	.001	.011	.277	.706	.620
	N	65	65	65	65	65	65	65	65
Personal_control_workstations	Correlation Coefficient	**.249***	.092	1.000	.159	.210	.234	.046	.092
	Sig. (2-tailed)	**.045**	.468		.206	.094	.061	.717	.465
	N	65	65	65	65	65	65	65	65
Privacy	Correlation Coefficient	.192	.389**	.159	1.000	.342**	.117	.122	.296*
	Sig. (2-tailed)	.125	.001	.206		.005	.353	.335	.016
	N	65	65	65	65	65	65	65	65
Office_instrumentality	Correlation Coefficient	.066	.315*	.210	.342**	1.000	.310*	.096	.212
	Sig. (2-tailed)	.603	.011	.094	.005		.012	.447	.090
	N	65	65	65	65	65	65	65	65
Space_arrangement	Correlation Coefficient	-.100	.137	.234	.117	.310*	1.000	.298*	.067
	Sig. (2-tailed)	.428	.277	.061	.353	.012		.016	.595
	N	65	65	65	65	65	65	65	65
Orientation_of_office	Correlation Coefficient	-.127	.048	.046	.122	.096	.298*	1.000	.044
	Sig. (2-tailed)	.315	.706	.717	.335	.447	.016		.726
	N	65	65	65	65	65	65	65	65
Space_flexibility	Correlation Coefficient	.160	.063	.092	.296*	.212	.067	.044	1.000
	Sig. (2-tailed)	.202	.620	.465	.016	.090	.595	.726	
	N	65	65	65	65	65	65	65	65

Appendix 6.7: Spearman correlation matrix of workplace appearance

		Appearance_of_workplace	Art_and_aesthatic	Contact_with_nature_and_views	Symbolism	Floor_coverings_and_wall_hangings	Architectural_arrangement_of_workplace
Appearance_of_workplace	Correlation Coefficient	1.000	.295*	.115	.040	-.154	.050
	Sig. (2-tailed)		.017	.364	.752	.221	.694
	N	65	65	65	65	65	65
Art_and_aesthatic	Correlation Coefficient	**.295***	1.000	.235	.243	-.079	-.141
	Sig. (2-tailed)	**.017**		.059	.052	.531	.264
	N	65	65	65	65	65	65
Contact_with_nature_and_views	Correlation Coefficient	.115	.235	1.000	.286*	-.144	-.131
	Sig. (2-tailed)	.364	.059		.021	.252	.298
	N	65	65	65	65	65	65
Symbolism	Correlation Coefficient	.040	.243	.286*	1.000	-.040	-.095
	Sig. (2-tailed)	.752	.052	.021		.752	.452
	N	65	65	65	65	65	65
Floor_coverings_and_wall_hangings	Correlation Coefficient	-.154	-.079	-.144	-.040	1.000	-.085
	Sig. (2-tailed)	.221	.531	.252	.752		.501
	N	65	65	65	65	65	65
Architectural_arrangement_of_workplace	Correlation Coefficient	.050	-.141	-.131	-.095	-.085	1.000
	Sig. (2-tailed)	.694	.264	.298	.452	.501	
	N	65	65	65	65	65	65

Appendix 6.8: Spearman correlation matrix of building maintenance and cleanliness

		Building_Maintenance_and_cleanliness	Building_maintenance	Cleanliness
Building_Maintenance_and_cleanliness	Correlation Coefficient	1.000	.276*	.552**
	Sig. (2-tailed)		.026	.000
	N	65	65	65
Building_maintenance	Correlation Coefficient	**.276***	1.000	.207
	Sig. (2-tailed)	**.026**		.097
	N	65	65	65
Cleanliness	Correlation Coefficient	**.552****	.207	1.000
	Sig. (2-tailed)	**.000**	.097	
	N	65	65	65

Appendix 6.9: Spearman correlation matrix of office type

		Office_type	Open_plan	Cellular
Office_type	Correlation Coefficient	1.000	.518**	.178
	Sig. (2-tailed)		.000	.156
Open_plan	Correlation Coefficient	.518*	1.000	.089
	Sig. (2-tailed)	.004		.482
	N	65	65	65
Cellular	Correlation Coefficient	.178	.089	1.000
	Sig. (2-tailed)	.156	.482	
	N	65	65	65

Appendix 6.10: Spearman's correlation matrix of building materials

		Building_materials	Use_of_low_emmitting_materials
Building_materials	Correlation Coefficient	1.000	.559**
	Sig. (2-tailed)		.000
	N	65	65
Use_of_low_emmitting_materials	Correlation Coefficient	.559**	1.000
	Sig. (2-tailed)	.015	
	N	65	65

Appendix 6.11: Spearman correlation matrix of office layout

		Office_layout	Ergonomics	Screen_position_of_work station	Adjustability_of_furniture	Amount_of_space
Office_layout	Correlation Coefficient	1.000	.210	.046	.389**	.261*
	Sig. (2-tailed)		.093	.716	.001	.036
	N	65	65	65	65	65
Ergonomics	Correlation Coefficient	.210	1.000	.445**	.497**	.397**
	Sig. (2-tailed)	.093		.000	.000	.001
	N	65	65	65	65	65
Screen_position_of_workstations	Correlation Coefficient	.046	.445**	1.000	.398**	.360**
	Sig. (2-tailed)	.716	.000		.001	.003
Adjustability_of_furniture	Correlation Coefficient	.389**	.497**	.398**	1.000	.420**
	Sig. (2-tailed)	.001	.000	.001		.000
	N	65	65	65	65	65
Amount_of_space	Correlation Coefficient	.261*	.397**	.360**	.420**	1.000
	Sig. (2-tailed)	.036	.001	.003	.000	
	N	65	65	65	65	65

Appendix 6.12: Spearman's Correlation matrix of social engagement

		Social_engagement	Space_for_informal_meetings	Access_to_documents	Psychological_restoration_and_relaxation
Social_engagement	Correlation Coefficient	1.000	.512**	.449**	.512**
	Sig. (2-tailed)		.000	.000	.000
	N	65	65	65	65
Space_for_informal_meetings	Correlation Coefficient	.512**	1.000	.388**	.114
	Sig. (2-tailed)	.000		.001	.368
	N	65	65	65	65
Access_to_documents	Correlation Coefficient	.449**	.388**	1.000	.206
	Sig. (2-tailed)	.000	.001		.100
	N	65	65	65	65
Psychological_restoration_and_relaxation	Correlation Coefficient	.512**	.114	.206	1.000
	Sig. (2-tailed)	.000	.368	.100	
	N	65	65	65	65

Appendix A: List of Research Publications, Achievements and Awards

Research Awards

Built Environment Project and Asset Management (BEPAM) Highly Commended Paper Award, awarded at 4th World Construction Symposium, Colombo, Sri Lanka, June 2015

National and International Conferences

Mallawaarachchi, H., De Silva L., and Rameezdeen R. (2015). Indoor environmental quality and occupants' productivity: green certified office buildings in Sri Lanka. CIOB World Construction Symposium 2015, organized by Ceylon Institute of Builders (CIOB) and Building Economics and Management Research Unit, University of Moratuwa, Sri Lanka on June 2015, Colombo, Sri Lanka.

Mallawaarachchi, H., De Silva L., and Rameezdeen R. (2014). Differentiating green buildings from conventional buildings. CIOB World Construction Symposium 2014, organized by Ceylon Institute of Builders (CIOB) and Building Economics and Management Research Unit, University of Moratuwa, Sri Lanka on 20th-22nd June 2014, Colombo, Sri Lanka.

Mallawaarachchi, H., De Silva, L. & Rameezdeen, R. (2014). Built environment factors influencing occupants' productivity in green buildings. 5th International Conference on Sustainable Built Environment 2014, organized by University of Peradeniya, University of Moratuwa, University of Melbourne, University of Calgary and Green Building Council Sri Lanka on 12th & 5th December 2014, Kandy, Sri Lanka.

Mallawaarachchi B.H., De Silva L., and Rameezdeen R. (2013). Importance of occupants' expectations for acceptance of green buildings: a literature review. CIOB World Construction Conference 2013, organized by Ceylon Institute of Builders (CIOB) and Building Economics and Management Research Unit, University of Moratuwa, Sri Lanka on 14th-15th June 2013, Colombo, Sri Lanka.

Mallawaarachchi, H., De Silva L., and Rameezdeen R. (2013). Green buildings, resilience ability and the challenge of disaster risk. International Conference on Building Resilience 2013, organized by Centre for Disaster Resilience 2013, University of Salford, Royal Melbourne Institute of Technology (RMIT) University, Australia, Queensland University of Technology (QUT) on 17th-19th September 2013, Heritance Ahungalla, Sri Lanka.

Mallawaarachchi, H., De Silva L., and Rameezdeen R. (2013). Potential design implications of indoor environment quality improvements in green buildings. 4th International Conference on Structural Engineering and Construction Management 2013, organized by University of Peradeniya, University of Moratuwa and University of Ruhuna on13th, 14th &15th December 2013, Kandy, Sri Lanka.

Mallawaarachchi B.H., De Silva L., Rameezdeen R. and Chandrathilaka S.R. (2012). Green Building Concept to Facilitating High Quality Indoor Environment for Building Occupants in Sri Lanka. CIOB World Construction Symposium 2012, organized by Ceylon Institute of Builders (CIOB) and Building Economics and Management Research Unit, University of Moratuwa, Sri Lanka on 28 – 30 June 2012 at Cinnamon Grand Hotel, Colombo, Sri Lanka.

Mallawaarachchi, B.H. & De Silva, M.L. (2012). Green framework to improve indoor air quality in buildings: reducing the impact of sick building syndrome on office workers in Sri Lanka. 2nd International Conference on Sustainable Built Environment 2012, organized by University of Peradeniya, University of Moratuwa, University of Melbourne, University of Calgary and Green Building Council Sri Lanka on 14th, 15th &16th December 2012, Kandy, Sri Lanka.