GREEN BUILDING CONCEPT TO FACILITATING HIGH QUALITY INDOOR ENVIRONMENT FOR BUILDING OCCUPANTS IN SRI LANKA

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ABSTRACT

Well-being is an important aspect determining the quality of life of an occupant. Hence, it is essential to have a good indoor environmental quality, as it affects the productivity and health of such occupants. Further, indoor air quality, acoustic, day-lighting and thermal comfort contribute to better indoor environment quality, and have a positive effect on an occupant's productivity and performance. Accordingly, many studies believed that the green building design will become more common practice once the human benefits are identified, primarily the productivity gains believed to be associated with the provision of high quality indoor environments. Hence, buildings are increasingly designed or required to be 'green' in recent years, giving the quality of the indoor environment new importance. Therefore, several green building assessment tools have been applied worldwide namely, Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) and Green Star etc in facilitating high quality indoor environment. Indoor Environmental Quality (IEQ) has considered as a major criteria in such tools. Thus, various IEQ factors relate to temperature and humidity, acoustic, ventilation, indoor air quality, day lighting and lighting quality, thermal comfort and access to views have been considered in these techniques. Similarly in Sri Lanka, GREEN$^{SL®}$ Rating System is applied for buildings in local context so as to obtain green certification. Even though, it emerges IEQ as an important aspect, it is considerably less compared to other domains. Thus, four green assessment tools were suggested which can be applied for buildings in Sri Lankan context through the review of key research papers. Accordingly, such green building tools can be considered for Sri Lankan buildings as a new concept/tool or even the existing system can be further enhanced so as to provide a better quality indoor environment for building occupants.

Keywords: *Indoor Environmental Quality, Building Occupants, Green Building Concept, Green Assessment Tools.*

1. INTRODUCTION

Well-being is an important aspect in determining the quality of life of an occupant (EU, 2007 cited Bluyssen, 2009). It can be taken as axiomatic that the majority of people spend most of their time indoors and that various aspects of the indoor environment affect their well-being and performance in this context (Kamaruzzman *et al.*, 2010). Since, there is a continuous and dynamic interaction between occupants and their surroundings that produce physiological and psychological effects on the person (Lan and Lian, 2009).

In recent years there has been an increase in public awareness about the effects of the indoor environment on people's comfort and health. It is widely accepted that the indoor environmental is important for public health and that a high level of protection against adverse health effects due to inadequate quality of the indoor environment should be assured (Kosonen and Tan, 2004). Further, in light of growing concerns about productivity, much more attention has focused on the indoor environment (Bluyssen, 2009; Mendell, 2003 cited Huang *et al.*, 2011).

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 office spaces (Mahdavi and Unzeitig, 2003).

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Once the occupants are satisfied with the overall environmental quality of their workspace are widely assumed to be more productive (Leaman and Bordass, 2007; Humphreys, 2007 cited Kim and Dear, 2011). In addition, it seems that "occupants are being regarded like consumers of the product (building) and as such, entitled to be satisfied with the indoor environmental product" (Kim and Dear, 2011, p.33).

Consequently, many ways, tools and concepts have been developed to determine performance indicators and criteria for healthy and comfortable buildings with high quality indoor environment, focusing in general on the prevention of health and comfort problems (Bluyssen, 2009). Green Building (GB) has emerged as a new building philosophy among other concepts for mitigating impacts of buildings on their occupants by encouraging the use of more environment friendly materials, the implementation of techniques to improve IEQ (Thormark, 2006 cited Lacouture *et al.*, 2008). LEED, BREEAM, CASBEE and Green Star are the most popular assessment tools used in green building concept which can be applied for facilitating high quality indoor environment. Therefore, this study is expected to convince about the importance of introducing green building concept to ensure high quality indoor environment for the building occupants with special emphasis on the application of green assessment tools. Hence, key research papers were reviewed for identifying green assessment tools used in worldwide, which can be applied for buildings in Sri Lanka in order to facilitate high quality indoor environment for building occupants.

2. LITERATURE REVIEW

2.1. INDOOR ENVIRONMENTAL QUALITY (IEQ)

The indoor environment is where people spend 90% of their time (Kosonen and Tan, 2004). Hence, the occupant exposure to microbial, chemical and building-physical factors in indoor environments can lead to a series of health symptoms ranging from discomfort to clinical disease (EPA, 1995 cited Prakash, 2005; Metzger, 1998). Further, this is incorporated in the human right to a healthy indoor environment as formulated in the World Health Organisation (WHO) 1985 Constitution (Kosonen and Tan, 2004). Consequently, enhancing the quality of indoor environment highly concerns in recent years.

The term Indoor Environmental Quality (IEQ) is referring to "the environmental qualities within a building, used especially in relation to the health and comfort of building occupants" (Hobday, 2011). Hence, IEQ refers to all aspects of the indoor environment that affect the health and well-being of such occupants (Levin, 1995). According to a studies by Prakash (2005), Portman *et al.* (2006 cited Lee *et al.*, 2009) and Lee (2010), IEQ is one of five categories of the LEED (Leadership in Energy and Environmental Design) building assessment system, developed by the Green Building Council of the United States of America including sustainable site, energy and atmosphere, water efficiency, materials and resources, and indoor environmental quality.

2.2. INDOOR ENVIRONMENTAL QUALITY FACTORS

Under the category of IEQ in the LEED checklist, IEQ comprises of indoor air quality (IAQ), including, environment tobacco smoke, Carbon dioxide monitoring, indoor chemical and pollutant source, thermal comfort, and daylight and views. According to a study by Levin (1995), among the other indoor environmental factors that must be considered are the quality of thermal, light, acoustic, privacy, security, and functional suitability. Henceforth, IEQ generally encompasses factors such as temperature, humidity, ventilation, indoor air quality, day lighting and lighting quality, thermal comfort and access to views. Indoor air quality (IAQ) concerns are among many indoor environmental issues that must be addressed to avoid adverse impacts on occupants' health and well being (Levin, 1995; Ning *et al.*, 2006). In addition to health problems, poor indoor air quality will also cause a decline in productivity for occupants who spend most of their workday in offices. Moreover, buildings perceived to have poor indoor air quality have noticeably lower overall occupant satisfaction, while buildings perceived to have good indoor air quality have higher overall satisfaction of the occupants (Kim and Dear, 2011). Therefore, indoor air should be of sufficient quality so that contaminants in the air are not at a harmful concentration level and the majority of people feel satisfied (ANSI/ASHRAE Standard 62-2007 cited Huang *et al.*, 2011).

Furthermore, Day lighting and thermal comfort contributed to better IEQ, and had a positive effect on occupant's perception of productivity and performance (Prakash, 2005; Lan and Lian, 2009). According to a study by Ramsey and Beshir (1998 cited Prakash, 2005), excessively hot or cold environments can affect motor and cognitive behaviour of individuals. Extremely hot conditions can lead to loss of performance capacity of the occupants and their slow production output, while excessively cold environments have affected on manual agility, and sometimes are associated with pain. As further verified by Atsusaka (2003 cited Edwin *et al.*, 2009), enhanced daylight and reduced toxicity in indoor environments can increase employee productivity by up to 16%. Kim and Dear (2011) declared when a building's lighting is perceived as comfortable there is a positive improvement in occupant overall workspace satisfaction (Kim and Dear, 2011). However, any dysfunction in the indoor environment potentially affects occupant health and well-being. When buildings fail to do what they are intended to do, indoor environmental pollution in the form of indoor air pollution, noise, glare, etc. cause occupant discomfort, health problems, and poor performance (Levin, 1995).

2.3. APPLICATION OF GREEN BUILDING CONCEPT FOR IEQ

As such environmental impacts of building activities on building occupants due to poor indoor climate become more apparent, a movement called "Green Building (GB)" is gaining momentum (Edwin *et al.*, 2009). Thormark, (2006 cited Lacouture *et al.*, 2008) verified that GB has emerged as 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. Henceforth, GB practices are perceived by many construction industry professionals to be part of the solution to problems regarding indoor environment of buildings (Hashim *et al.*, 2011). Green, or sustainable building, is the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition (US Green Building Council, 2007; EPA GB, 2008 cited Edwin *et al.*, 2009). It offers an opportunity to create environmentally efficient buildings by using an integrated approach of design so that the negative impact of building on the environment and occupants' is reduced (Ali *et al.*, 2009 cited Hikmat *et al.*, 2009).

As a study by Edward (2007) mentioned that the concept of GB has applied in most of the countries as to reduce the impact of buildings on environment and human health. As Edward further stated that 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 fashionable terms such as "Green consumption", "Green living" and "Green illumination" have been broadly used. In Taiwan, currently, "Green" has been used as a symbol of environmental protection in the country. Edward (2007) further asserted that the GB policy is important and represents a positive first step toward reducing environmental impact and promoting sustainable development in countries with limited resources and a high-density population. According to studies by Edwards (1998), Lacouture *et al.* (2008) and Karkanias *et al.* (2010), other benefits of bioclimatic or green buildings include lower energy and operational costs, market advantages for the building developer, higher indoor environmental quality and therefore living quality or higher productivity and lower long-term exposure to environmental or health endangering factors thus, it reduces health cost. Consequently, a recent trend toward increased concern about the impacts of buildings on the larger environment has led many building design professionals to design so-called "sustainable architecture" or "green buildings" (Levin, 1995). Their efforts are intended to reduce harmful environmental impacts of buildings, especially to minimise indoor environment quality hazard on well-being of building occupants.

2.4. ASSESSMENT OF IEQ IN GREEN BUILDINGS

Once the evaluation and assessment of environmental impact of a building is carried out before it is built and when only the representation of the building is available, environmental impacts from that building could be prevented. In that case, knowledge about the environment has to be integrated with knowledge about the building. Environmental assessment tools for buildings are designed to provide objective evaluation of resource use, ecological loadings and indoor qualities (Cole, 2005 cited Wallhagen 2010) and make it possible to evaluate a number of different environmental aspects of buildings in a systematic

way. Hence, key research papers were reviewed in order to identify green assessment tools available, their level of concern on IEQ among the other sustainable criteria and IEQ factors considered in different green assessment tools.

GREEN ASSESSMENT TOOLS

According to a study by Westerberg and Glaumann (2002) and McKay (2007), green assessment tools were primarily developed to assess, or measure specific aspects of a building, pertaining 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 can also be used to produce guidelines, benchmarks, ratings and incentives to construct buildings with low environmental impact and to work as environmental management tools. The most representative and widely used green assessment tools are Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) and Green Star (Roderick *et al.*, n.d.; Boonstra and Pettersen, 2003; McKay, 2007).

- ***LEED***

LEED® is a U.S. national sustainable building benchmark as well as green building rating system adopted nationally and internationally (Roderick *et al.*, n.d; USGBC, 2007 cited Lee and Kim, 2008; InBuilt, 2010). The current version for new construction is LEED-NC v2.2 which is based on a set of prerequisites and credits. Each credit refers to one of following aspects; sustainable sites, water efficiency, energy and atmosphere, materials and resources, IEQ, and innovation and design process. LEED is available for a number of different project categories, but the LEED for new construction and major renovations is the most common (Lopus, 2011). As Roderick *et al.* (n.d.) and Lee and Guerin (2009) further mentioned that it is the most widely recognised building environment assessment schemes. Moreover, the interest in the LEED certification system became global. Hence, the registered projects have covered 24 different countries. Currently, many of LEED-certified projects are located in Asia including China, India, and Korea (InBuilt, 2010; Lopus, 2011).

- ***BREEAM***

BREEAM was launched by the U.K. building research establishment and is adopted by the U.K. government as a measure of best practice in environmental design and management. It is the most widely used in UK (Haapio, 2008). Although it is a voluntary standard, the energy performance assessment adopts the UK building regulation as a benchmark to rate the level of performance improvement. Latest version for office buildings is BREEAM offices 2008. It defines categories of credits according to the building impact on the environment including management, health and wellbeing, energy, transport, water, materials, waste, land use and ecology and pollution (Roderick *et al.*, n.d; Grace, 2000 cited Haapio and Viitaniemi, n.d.). According to a study by Haapio and Viitaniemi (n.d.), a variety of different BREEAM tools exist for building products, whole buildings and whole building assessment frameworks.

- ***CASBEE***

The CASBEE was introduced in 2002. It involves the evaluation of building quality and environmental impacts (Glaumann, 2010 cited Wallhagen, 2010). The categories are defined in accordance with hypothetical boundaries around a building site (Boonstra and Pettersen, 2003). Boonstra and Pettersen (2003) further described CASBEE tool comprises four assessment tools and a design process. Among the tools, only the "design for environment" tool has been completed. Others concern pre-design assessment, eco-labelling and sustainable operations and renovation.

- ***Green Star***

Green Star was launched by Green Building Council of Australia (GBCA) and is established as a national guide to evaluate the environmental design and achievements of buildings. All three schemes are based on rating system of collecting credits that applies to a wide range of building types, both new and existing buildings. All cover a range of environmental issues such as materials, energy, water, pollution, IEQ and building site (Roderick *et al.*, n.d). A most followed voluntary building environmental assessment scheme

in Australia. It was developed to accommodate the need of buildings in hot climates where cooling systems and solar shading are of major importance. It has also been adapted in New Zealand and South Africa (Green Building Council Australia, n.d. cited Roderick *et al.*, n.d). Current version for new offices is Green star-office as design v3. The credits are organised in following aspects of the building and process: management, IEQ, energy, transport, water, materials, land use and ecology, emissions, and innovation (Roderick *et al.*, n.d).

2.5. GREEN ASSESSMENT OF IEQ

Assessment tools were primarily developed to assess, or measure specific aspects of a building, pertaining to sustainability goals. To develop the green assessment tools, the authors used 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 (McKay, 2007). Among those sustainable factors, IEQ is a major concern in developing such green assessment tools due to its considerable impact on wellbeing of the building occupants. Thus, most of green assessment tools specially LEED, BREEAM, Green Star and CASBEE techniques have developed considering the IEQ as a major criteria towards sustainable buildings.

Table 1: Criteria Comparison between Green Assessment Tools
(Source: Boonstra and Pettersen, 2003; Haapio, 2008; Wallhagen, 2010; InBuilt, 2010)

	% of IEQ			
Criteria	**LEED**	**BREEAM**	**CASBEE**	**Green Star**
Management	04	16	05	09
Health and wellbeing/IEQ	**21**	**16**	**23**	**19**
Energy	23	15	18	18
Transport	06	13	00	19
Water	10	05	03	12
Materials	18	11	12	19
Land use	08	08	19	06
Pollution	10	15	20	07

As illustrated in the above Table 1, LEED, CASBEE, Green Star and BREEAM green assessment tools have shown a great importance of IEQ among the other factors. Specially, CASBEE and LEED assessment tools have considered that the IEQ is most significant criteria compared to other techniques. Furthermore, each assessment tool covers various IEQ factors in order to ensure high quality indoor environment within buildings through the green assessment. Thus, various IEQ factors under each technique can be clearly identified as mentioned in Table 2.

According to the comparison between green assessment tools namely, LEED, BREEAM, CASBEE and Green Star (Table 2) , indoor air quality, day lighting and lighting quality, are highly concerned IEQ measures in each technique while CASBEE contains many factors on temperature and humidity, acoustic and ventilation compared to other assessment tools. Furthermore, thermal comfort and access to views are considered in IEQ criteria of LEED, BREEAM and Green Star tools excepting CASBEE.

Consequently, different nations would be able to implement different green assessment tools in order to ensure high quality indoor environment for building occupants. Specially, LEED, BREEAM, CASBEE and Green Star are major assessment tools available in green building concept which can be considered in improving indoor environmental quality in buildings. However, the considerations for those rating systems can be changed as the environmental conditions; level of development and the availability of resources in different countries (GBCSL, 2010).

Table 2: Comparison of IEQ Measures Available in Different Green Assessment Tools
(Source: Boonstra and Pettersen, 2003; Malmborg, 2004; Haapio, 2008; Wallhagen, 2010)

IEQ factor	LEED	BREEAM	Green Star	CASBEE
Temperature and humidity	Controllability of systems	Local temperature control		Room temperature setting Variable loads and following-up control Zoned control Temperature and humidity control
Acoustic	Controllability of systems	Noise	Internal noise levels	Background noise Equipment noise Sound insulation of openings Sound insulation of partition walls Sound absorption
Ventilation	Environmental tobacco smoke control Co2 monitoring Ventilation efficiency	Operable windows Air intake Fresh air	Ventilation rates	Ventilation rate Natural ventilation performance Consideration for outside air intake Air supply planning
Indoor Air Quality	Indoor chemical and pollutant source control Minimum IAQ performance Construction IAQ management plan	Smoking Clean carpets	Air change effectiveness Co_2 and VOC monitoring and control Hazardous materials	Type of A/C Co_2 monitoring Control of smoking
Day Lighting and Lighting Quality	Low-emitting materials Day lighting	80% adequately day light Window antiglare Ballets Illuminance levels Independent lighting control	Daylight Daylight glare control High frequency ballets Electric lighting levels	Daylight factor Openings by orientation Daylight devices Glare from light fixtures Daylight control Illuminance level Uniformity ratio of illuminance Lighting controllability
Thermal Comfort	Thermal comfort	Thermal comfort	Thermal comfort	-
Access to Views	Views	Desks location	External views	-

2.6. APPLICATION OF GREEN BUILDING CONCEPT FOR IEQ IN SRI LANKAN BUILDINGS

Similarly in Sri Lanka, most of modern buildings have tended to be green certified building to obtain its vital benefits because of indoor environment quality is an important aspect which has received practically no attention in built environments (Ileperuma, 2000). Further, facilitating a high quality working environment for the building occupants is one of the major concerns of obtaining a green certification rather stays as a traditional building. Accordingly, GREEN$^{SL®}$ 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).

GBCSL (2010) further stated that GREEN$^{SL®}$ Rating System contains eight criteria namely, management, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation and design process, social and cultural awareness. Each domain category has number of aspects. The number and nature of aspects varies from one category to another according to the category itself and its importance matching the local context (Chandratilake and 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.

2.7. SUGGESTIONS ON GREEN ASSESSMENT TOOLS SUITED FOR IEQ IN SRI LANKAN BUILDINGS

Even though, the indoor environment quality is a major concern in many green assessment tools including LEED, BREEAM, GREEN STAR, CASBEE and GREEN$^{SL®}$ rating system, containing factors can be differ as mentioned in Figure 1. When specially consider about the GREEN$^{SL®}$ rating system in Sri Lanka, it has developed suited for local context. Thus, it contains some similar factors as the other assessment tools while some factors are not considered within Sri Lankan context (Figure 1). 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, daylight and views can be identified as common factors among LEED, BREEAM, GREEN STAR, CASBEE and GREEN$^{SL®}$ rating system.

However, LEED assessment tool covers two factors as CO_2 monitoring and ventilation efficiency which are not mentioned in the local rating system in Sri Lanka. Further, local temperature control, noise, operable windows, air intake, fresh air, clean carpets, window antiglare, ballets, illuminance levels, independent lighting control and desks location factors were additionally included in BREEAM tool while Green Star and CASBEE tools contain many other several IEQ factors which have not considered within GREEN$^{SL®}$ rating system in Sri Lanka. Thus, in consideration of facilitating high quality indoor environment for building occupants, it is vital to go for another suited green assessment tools namely LEED, BREEAM, CASBEE, and Green Star or making possible enhancements in existing green rating system compared with another techniques.

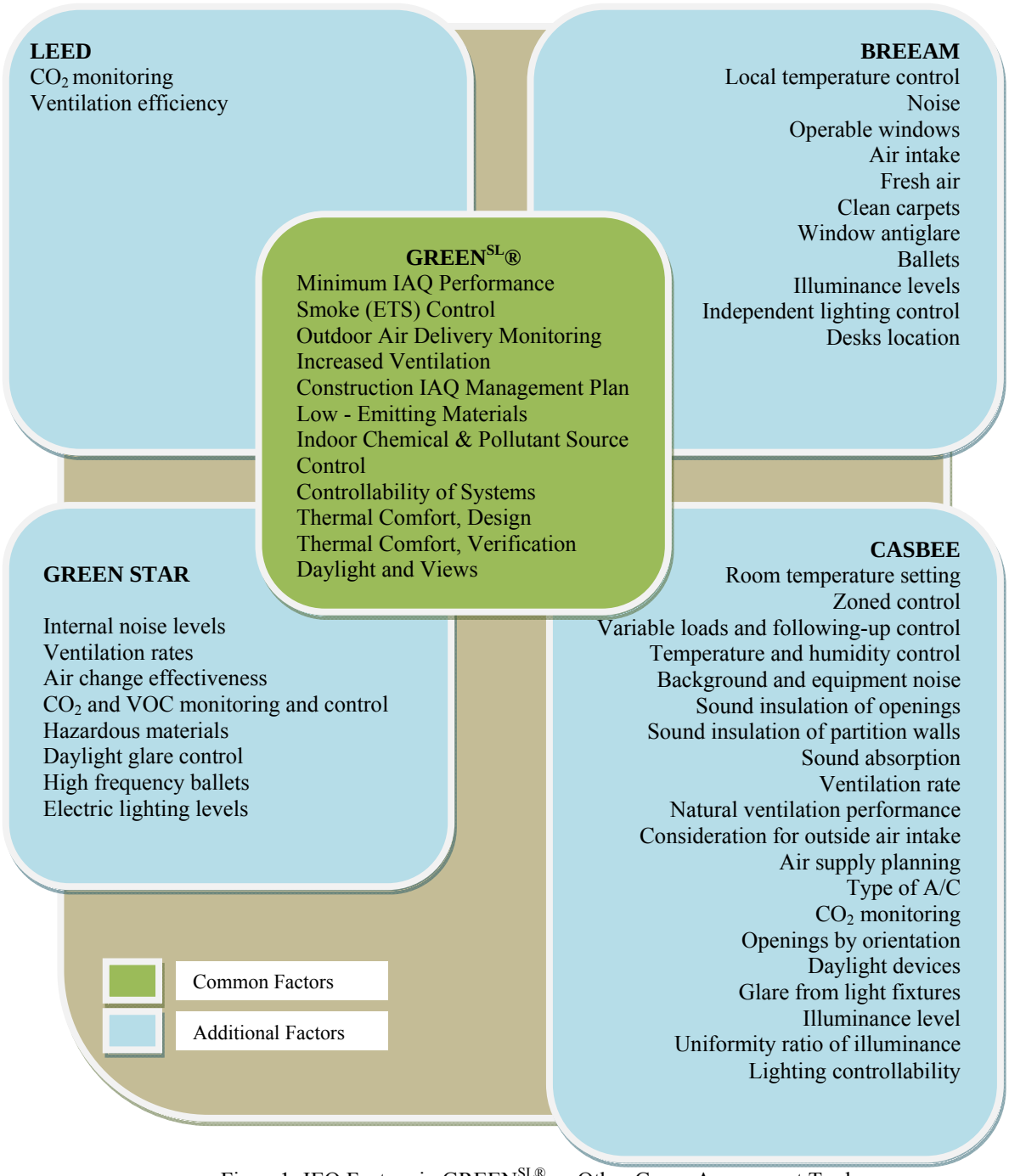

Figure1: IEQ Factors in GREEN$^{SL®}$ vs Other Green Assessment Tools

3. SUMMARY

Well-being is an important factor in determining the quality of life of building occupants. As majority of people spent their life indoors, it is widely accepted that the indoor environmental is important for public health and well-being of occupants. Hence, it emerges the importance of facilitating high quality indoor environment within buildings. Consequently, many tools and concepts have been developed to determine criteria for healthy and comfortable buildings with high quality indoor environment. Green building concept has emerged as a new building philosophy in order to provide better and healthier indoor environment for building occupants. There are several assessment tools of green building concept can be applied in facilitating IEQ namely, LEED, BREEAM, CASBEE and Green Star etc. This study was done for evaluating IEQ criteria and related factors of above mentioned tools so as to suggest implementation of

new green building tool fulfilling the IEQ requirement of buildings in Sri Lanka. Even though, there is a local green rating system within Sri Lankan context namely GREEN$^{SL®}$, it only concern about few factors within the IEQ domain. However, within other tools, considerable attention has given for the IEQ in buildings. Thus, such green building tools can be considered for buildings in Sri Lanka as a new concept/tool or even the existing system can be further enhanced so as to provide a better quality indoor environment for their building occupants.

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