CONTRIBUTION OF BUILDING MANAGEMENT SYSTEM TOWARDS SUSTAINABLE BUILT ENVIRONMENT

W. H. C. D. Kumara* and K. G. A. S. Waidyasekara
Department of Building Economics, Universityof Moratuwa, Sri Lanka

ABSTRACT

The biggest challenge faced by the community is controlling and monitoring the performance of built environment facilities in a sustainable way. From this dimension, effective use of Building Management System (BMS) in the built environment is representing a significant strategy in relation to economic, environment and social perspectives. Higher energy efficiency, lower operating and maintenance costs, better indoor air quality, greater occupant comfort and productivity are the major achievements of a successful BMS. Therefore, at present it is so evident that, many organizations are enhtuastic to allocatea substantial investment, inorder to, install, commissioning, operation and maintenance of BMS. However, to obtain the optimum use of BMS is still challenging among the building users. Thus, the requirement of developing a framework for functionality of BMS is essential in order to gain maximum benefits through operating building automation and control systems.

The aim of the paper is to investigate the contribution of BMS in achieving a sustainable built environment. The findings are achieved through conducting literature and documentary review available in the built environment andanalyzing green building rating systems to find out the input of BMS towards sustainable built envionemnt. Therfore, comparative study conducted between LEED, BREEAM and GreenSLrating systems.Based on the findings, theoretical framework was developed to facilitate contribution of BMS in sustainable development. Moreover, the paper is engaged in analysisngthe credit contribution of BMS in order to gain the green rating certification.

***Keywords**: Building Management System; Green Building Assessment Tools: Sustainable Built Environment.*

1. INTRODUCTION

The biggest challenge, faced by the community is controlling and monitoring the performance of built environment facilities in a sustainable way. As explained by Forsberg and Malmborg (2004), built environment plays a vital role in the society of today, being a result of a number of social and economic processes that are central to the sustainable development. From the recent years, the pursuit of sustainability has become a mainstream of building design objectives as the physical environment of the earth is deteriorating (Wong and Fan, 2012). Therefore, sustainable development is now become the fundamental approach of creating the competition over built environment and more and more methods, put into practices to achieve sustainable built environment. Building Management System (BMS) is one of the new and innovative technologies, which has emerged in recent years and makes potential achievement of more sustainable designs. KMC Controls (2011) justified that the building sustainability could be achieved through higher energy efficiency, lower operating and maintenance costs, better indoor air quality, greater occupant comfort and productivity through implementing BMS.

In addition, Sinou and Kyvelou (2006) stated that the growth and the use of building performance assessment methodologies are further known as the green building rating systems, for an example LEED (Leadership in Energy and Environment Design) in the United States, BREEAM (Building Research Establishment Environmental Assessment Method) in United Kingdom, CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) in Japan, Green Starin Australia contribute greatly for the integration of methods and practices favouring sustainability in the

*Corresponding Author: e-mail - kchamaradimuthu@gmail.com

building sector. Consequently these building performance assessment methodologies act as the pathway of achieving sustainability in the built environment.

According to KMC Controls (2011), sustainability may be driven by a number of factors such as environmental stewardship, the desire for green building certification, or the financial promises of lower operating costs. Hodges (2005) stated that implementing sustainability and green building approaches, organizations will be benefited through greater financial returns, increased standing in the community, improved productivity and reduced detrimental effects on the environment.Moreover, Waidyasekara and Sandamali (2012) mentioned that green buildings provide many benefits to the organisation, for its employees and to the whole society over to its initial cost.Therefore, selection of the appropriate sustainable approach is represented with a crusialstrategy in the design and construction of a building. Croome, *et al.*, (2004) recognised the rational use of natural resources and appropriate management of the building stock will contribute for saving scarce resources, reducing energy consumption, and for improving environmental quality. As revealed from literature, building management systems or automation systems is empowered to play a vital role in controlling and monitoring the functions of building in a sustainable way (Brown, 1990; KMC Controls, 2011). However, the input of BMS in sustainable rating systems and its contribution towards sustainability were given the least priority in the available literature.

Therefore, the aim of the paper is to investigate the contribution of BMS in achieving sustainable built environment. The following objectives were set in order to achieve the above aim.

- Identifying features and functions of BMS and its contribution to sustainability
- Developing a theoretical framework for the contribution of BMS under the philosophy of sustainable built environment
- Identifyingthe inputs of the BMS in green rating systems towards green certification

2. LITERATURE REVIEW

2.1. SUSTAINABILITY IN BUILT ENVIRONMENT

Sustainability, as a concept is emerged with the establishment of the World Commission on Environment and Development (WCED) by the United Nations in 1983. According to Carew and Mitchell (2008), the sustainability literature supports the subdivisions of the broader concept into the secondary interrelated concepts like environmental, social and economic sustainability. The Brundtland Commission (1987 as cited in Fellows, 2006) defined sustainable development as “the development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. This is the common and most popular definition used to describe sustainable development. As stated by Shah (2007), over 500 definitions of sustainability and sustainable development were spawned by various governments, professional bodies, institutions and organizations.

Akadiri and Olomolaiye (2012) pointed out that, the building industry is a vital element of any economy which has a significant impact towards the environment. With respect to such significant influence of the building industry, the sustainable building approach has a high potential to make a valuable contribution to sustainable development. Croome**,** *et al.*, (2004) identified five objectives for sustainable buildings such that resource efficiency, energy efficiency (including greenhouse gas emissions reduction), pollution prevention (including indoor air quality and noise abatement), harmonisation with the environment, and integrated and systemic approach. Three dimensions of sustainability; environmental, economic and social were interpreted for a sustainable building by Kohler (1999) as shown in Figure 1. According to Kohler (1999), Ecological Sustainability can be quantitatively analysed with respect to the energy and mass flows in time and space within a life cycle assessment in terms of resource and ecosystem. In addition to that, Economic sustainability can be divided into two as investment and use costs. Hence, instead of minimizing investmentcost through crossing low-cost of building processes and products, it is preferable for a given investment to find solutions that have the highest durability and reusability. Hence, it will pave the way towards, the social and cultural aspects of sustainability including comfort and health protection, and preservation of values, which is one of the main motivations behind any conservation projects (Kohler, 1999).

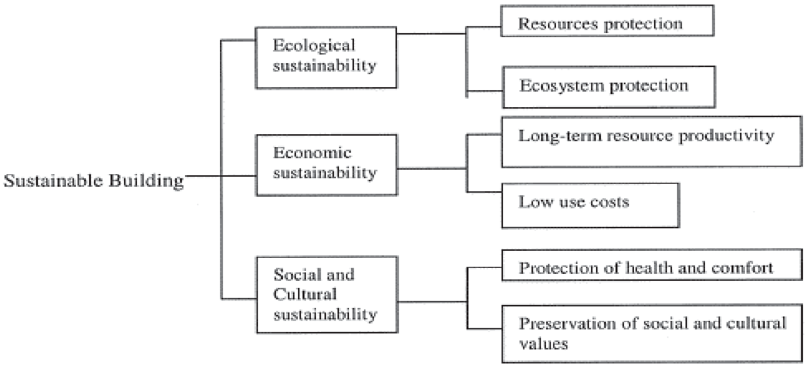

Figure 1: Three Dimensions of Sustainable Building, (Source: Kohler, 1999)

2.2. INTRODUCTION TO BUILDING MANAGEMENT SYSTEM (BMS)

Brown (1990) defined BMS as "a system designed and implemented to control and monitor the functions of a building and its associated plant". As depicted in literature, the term Building Automation System (BAS) and Building Control System (BCS) similar terms which are utilised to refer the BMS. As explained by Brown (1990), all subsystems of BMS work together in a single building. Moreover, BMS is shared with the same building information affecting each other. Therefore, it should be an integrated within the same information platform. In order to achieve specific goals, several integrated BMS solutions have been worked out, however, these solutions may differ according to the requirements as explained by Brown (1990). Jiang *et al.*, (2011) elaborated the general structure of BMS as illustrated in Figure 2. According to Figure 2, BMS uses computer based monitoring to coordinate, to organise and to optimise building control sub systems such as security, fire/life safety, elevators, and others. Howevr, it is aoded in controling connected plant to maintain a preset requirementof the building. BMS is also connected in monitoring inputs such as temperature readings and process them using digital controllers to give control outputs back to the building. All the subsystems of the building are interconnected and information is passed across them using the network.

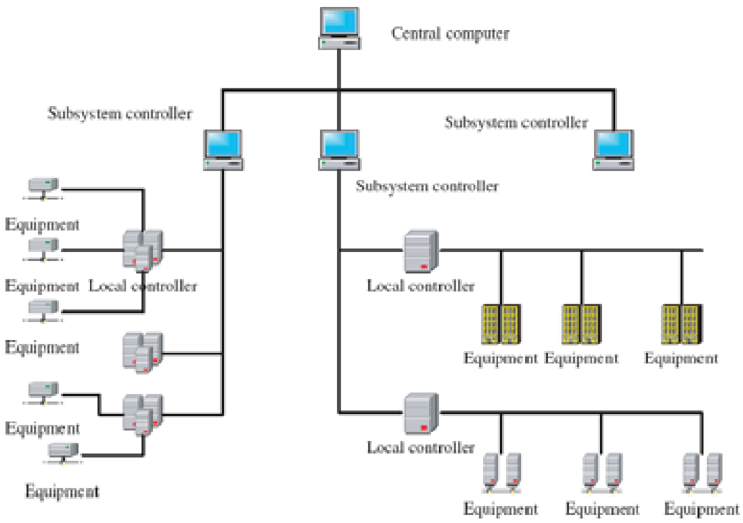

Figure 2: BAS System (Source: Jiang, *et al.*, 2011)

Allen and Remke (2008) stated that, the building automation or management system is used to control functions of a Heating, Ventilating and Air-Conditioning (HVAC) system including temperature and ventilation, as well as equipment scheduling. Apart from that, monitoring of utility demand, energy use, building conditions, climatic data, and equipment status are identified as the additional features which are includedinthe system.In addition, BAS is integrated with the additional building features such as video surveillance, access control, lighting control, and interfacing with the fire and security systems. Moreover, as mentioned by Allen and Remke (2008), utility load profiles, the trends and operation logs of equipment, and the generation of maintenance schedules are some outputs of BMS. The University of Bristol (2004) summarised the common capabilities of BMS include the followings.

- Equipment scheduling (turning equipment off and on as required)
- Optimum start/stop (turning heating and cooling equipment on in advance to ensure the building is at the required temperature during occupancy)
- Operator adjustment (accessing operator set-points that tune system to changing conditions)
- Monitoring (logging of temperature, energy use, equipment start times, operator logon)
- Alarm reporting (notifying the operator of failed equipment, out of limit temperature/pressure conditions or need for maintenance)

As stated by Anon (2005), incorporating the above capabilities a building can:

- Make the operation and management easy in complex mechanical and electrical services environments
- Monitor and control sophisticated equipment
- Ensure that building users are satisfied with the services provide all the time in a high service level expectancy environment.
- Enhance the lifetime of the plants and machinery
- Optimize energy consumption and save energy
- Disaster management and safety
- Meet regulations

Even though BMS is included with many features, as mentioned inCIBSE Guide H (1999), when deciding on the appropriate type of control system to specify for a building, it is essential to consider the benefits of a modern control system that are matched with the requirement of different groups of users involved with the building. Moreover, in order to gain the expected benefits, the system should be properly specified, installed, commissioned, operated and maintained. Table 1 listed some of the benefits to be achieved with an effective modern BMS according to the type of building stakeholder. In addition, Wang and Xie (2002) explained that the Facility Managers need BMS to control building performance, manage and distribute services, adapt rapidly changed the requirements and to provide important management information. Moreover, Wang (2010) highlighted main typical benefits of having BAS as; increased reliability of plant and services, reduced operating costs, building management, enhancing staff productivity, and protection of people and equipment.

The report CIBSE Guide F (2004) highlighted, BMS is empowered to improve the overall management and performance of buildings, promoting a holistic approach to controls and providing operational feedback. Furthermore, the same report cited 10% to 20% energy savings can be achieved by installing a BMS compared to independent controllers for each system.

Table 1: Benefits of BMS (Source: CIBSE Guide H, 1999)

Building Stakeholder	Benefits
Building owner	Higher rental value Flexibility on change of building use Individual tenant billing for services
Building tenant	Reduced energy consumption Effective monitoring and targeting of energy consumption Good control of internal comfort conditions Increased staff productivity Improved plant reliability and life
Occupants	Better comfort and lighting Possibility of individual room control Effective response to HVAC related complaints
Facilities manager	Control from central supervisor Remote monitoring possible Rapid alarm indication and fault diagnosis Computerised maintenance scheduling Good plant schematics and documentation
Controls contractor	Bus systems simplify installation Supervisor aids setting up and commissioning Interoperability enlarges supplier choice

2.3. CONTRIBUTION OF BMS IN SUSTAINABLE ENVIRONMENT

The concept of sustainability is regarded to be three-folds; environmental, social and economic, out of which environmental sustainability is considered to be the backbone of the other two. Morelli (2011) defined environmental sustainability as the meeting the resources and services needs of current and future generations without compromising the health of the ecosystems and this allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by human actions diminishing biological diversity. Gadakari, *et al.* (2012) explained economic sustainability is the term used to identify various strategies that make it possible to utilise available resources to best advantage and encourages its responsible use. Moreover, economic parametermake sure that the business is making a profit while addressing environmental concerns and contributing to the financial welfare of the owners, employees, and the community where the business is located. Social sustainability is the idea that “future generations should have the same or greater access to social resources as the current generation (inter-generational equity), while there should also be equal access to social resources within the current generation (intra-generational equity)”.

As stated in the previous section, functions of BMS such as stop and start equipment when needed; monitoring space conditions and occupancies; and implementing sophisticated strategies will reduce overall energy use. Furthermore, BMS is contributed to improve indoor air quality through continual ventilation adjustments and air-quality monitoring; and maximise day lighting by automating shading systems (Gadakari, et al, 2012). Wu and Noy (2010) mentioned that a building knows when and where it is occupied able to limit its own energy use by confining the operation of power-hungry HVAC and lighting systems to the hours and areas of the building which are needed. Occupancy sensors are used to enhance the presence detection and accurate localised occupancy information to provide solutions that are energy-efficient without compromising on occupant comfort and productivity (Dounis et al., 2011 and Pandharipande and Caicedo, 2011). Johnson Controls, a leading producer of energy-saving equipment, explained that the companies could reduce energy bills by 20% to 25% by using efficiently programmed and monitored BMS and through other intelligent controls (Mazza, 2008). Ferguson, Director of Johnson Controls, said that the biggest savings arise through the management of heating and cooling. One degree Centigrade down in heating temperature will provide around 7% savings on the energy necessary to heat the building (Clarke, 2008). Katz and Skopek (2009) recognise not only the benefits of the BMS as decrease in building maintenance and energy costs; increase in productivity, rental incomes but also the guard against repair costs, productivity loss, revenue loss, and loss of customers to competitors. As stated by Gadakari, *et al*, (2012), social implication of intelligent technologies on our lifestyles needs to possese a delicate attention to ensure an enriching environment to make life meaningful amidst all the technological progress. Moreover, KMC Controls (2009) mentioned, a control system is fruitful for both individual comfort control as well as for an efficient use of equipment and power. And also historical data can be used either to improve building performance while maintaining occupant productivity.

3. RESEARCH METHOD

Literature available in the built environment and the documentary review were used to achieve the research objectives. Theoritcal framework for BMS towards sustainable built environment was developed based on the keyliterature findings. International green rating systems, Building Research Establishment Envionmental Assessment Method (BREEAM) as the world longest established rating system andLeasership in Energy and Envionmetal Design (LEED) as the most popular and widely used building assessment tool selected for the comparative analysis of BMS input towards green certification. In addition Local rating system Green^{SL} too considered during the analysis.

4. PROPOSED THEORETICAL FRAMEWORK FOR BMS TOWARDS SUSTAINABLE BUILT ENVIRONMENT

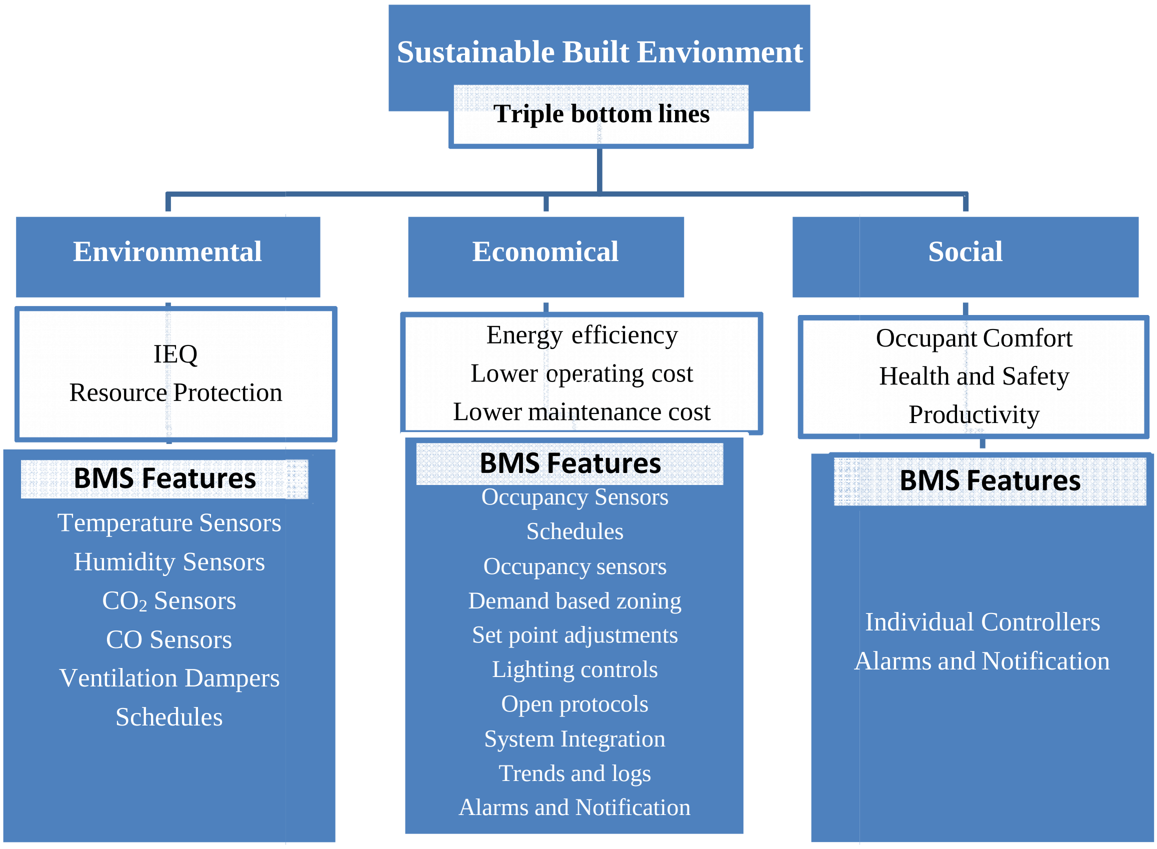

Figure 3: Proposed Theoretical Framework for BMS Contribution in Sustainable Built Environment

Sections 2.2 and 2.3 have discussed about the functions, features of BMS and its contribution in a sustainable built environment. Based on the key literature findings, theoretical framework was developed as illustrated in Figure 3. It is being facilitatedin identifying the contribution of BMS and justified characteristics that should be achieved in order of gaining sustainable built environment through BMS features. Since this research is at the initial stage, an expert opinion survey will be carried out as the next step to check the validity of the framework developed.

5. BMS INPUTSINGREEN BUILDING RATING SYSTEMS

A green building rating system provides an effective framework for assessing building environmental performance and integrating sustainable development into building and construction processes (Cole, 2003 cited Ali and Nsairat, 2008). Cole and Kernan (1996) stated that assessment measurements based on building life cycle is empowered to produce significant long-term benefits for building owners and occupants as this system support for solving existing building problems, limiting environmental impacts, creating healthier and more productive places and reducing building operations cost. LEED in United States, BREEAM in United Kingdom, CASBEE in Japan, Green Mark in Singapore, GRIHA in India and Green Star in Australia are some of the well-known rating systems around the world (Wikipedia, 2013). Although many green rating systems are currently available LEED, BREEAM and Green^{SL} were selected for the comparative study.

5.1. LEED - LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN – UNITED STATES

LEED is a credit based building rating system developed by the United States Green Building Council (USGBC). According to USGBC (2009), "LEED is a voluntary rating program, goal is to evaluate environmental performance from the whole building perspective over the building's Lifecycle, providing a definitive standard for what constitutes a green building". According to USGBC (2009), LEED is is involved with the promotion of a whole-building approach to sustainability by recognising performance in Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Regional priority, and Innovation and Design Process areas. KMC Controls (2011) highlighted the fact that a properly designed and installed building control system is eligible in leading fulfilled credits worth up to 48 points in the LEED rating system.In LEED, building automation hasan impactin gaining credits gain from Energy and Atmosphere (E and A), Indoor Environmental Quality, Water Efficiency, and Sustainable Sites sections (KMC Controls, 2011).Energy and Atmosphere (E and A) is the most impact section out of them (Please Refer Table 2).

5.2. BREEAM-BUILDING RESEARCH ESTABLISHMENT ENVIRONMENTAL ASSESSMENT METHOD – UNITED KINGDOM

The Building Research Establishment (BRE) of UK introduced the Building Research Establishment Environmental Assessment Method (BREEAM) in 1990, which was the first environmental assessment tool to be used internationally (Cassidy, 2003). The primary aim of BREEAM 2011 New Construction is to mitigate the life cycle impacts of new buildings on the environment in a robust and cost effective manner. According to the BREEAM 2011 NC, assessed the performance of buildings under the ten main sections and allocated different points for each section. They are Management, Health and Wellbeing, Energy, Transport, Water, Materials, Waste, Land use and Ecology, Pollution, and Innovation. Currently in the UK, clients, planners, development agencies and developers are using BREEAM to specify the sustainability performance of their buildings in a way that is quick, comprehensive and visible in the marketplace (Gowri, 2004; Potbhare *et al.*, 2009). Table 2 summarised the relevant sections that the BMS could contribute against the green certification in the BREEAM.

5.3. GREENSL RATING SYSTEM

Green^{SL} rating system was developed in 2010 by the Green Building Council Sri Lanka (GBCSL) for a new and existing buildings based on LEED rating system. Mudalige (2012) stated, GREEN^{SL} rating system has been introduced for the first time in Sri Lanka for built environment taking up the challenge to create sustainable buildings for the future.

Table 2: BMS Contribution in Green Rating Systems

LEED NEW		**GREEN SL**		**BREEAM**	
Sustainable Sites		**Sustainable Sites**		**Pollution**	
Light Pollution Reduction	1	Light Pollution Reduction	1	Reduction of Night Time Light Pollution	1
Energy and tmosphere		**Energy and Atmosphere**		**Energy**	
Fundamental Commissioning of Building Energy Systems	Required	Fundamental Building Systems Commissioning	Required	Reduction of Carbon Dioxide Emissions	15
Minimum Energy Performance	Required	Minimum Energy Performance	Required	Sub-Metering of Substantial Energy Uses	1
Optimize Energy Performance	1 to 19	Optimize Energy Performance	1 to 10		
On-site Renewable Engy	1 to 7	Renewable Energy	1 to 8	Sub-Metering of High Energy Load and Tenancy Areas	1
Enhanced Commissioning	2	Additional Commissioning	1		
Enhanced Refrigerant mgt	2	Ozone Depletion	1	External Lighting	1
Measurement and Verification	3	Measurement and Verification	1	Lifts	2
Indoor Environmental Quality		**Indoor Environmental Quality**		**Health & Wellbeing**	
Minimum Indoor Air Quality Performance	Required	Minimum IAQ Performance	Required	Glare Control	1
Environmental Tobacco Smoke (ETS) Control	Required	Smoke (ETS) Control	Required	Internal & External Lighting	1
Outdoor Air Delivery Monitoring	1	Outdoor Air Delivery Monitoring	1	Lighting Zones & Controls	1
Increased Ventilation	1	Increased Ventilation	1	Potential for Natural Ventilation	1
Indoor Chemical and Pollutant Source Control	1	Indoor Chemical and Pollutant Source Control	1	Indoor Air Quality	1
Controllability of Systems—Lighting	1	Lighting Controls	1	Thermal comfort	1
Controllability of Systems-thermal comfort	1	Comfort Controls	1	Thermal Zoning	1
Thermal Comfort-design	1	Thermal comfort, design	1		
Thermal Comfort	1	Thermal Comfort,	1		
Water Efficiency		**Water Efficiency**		**Water**	
Water Use Reduction	2 to 4	Water Use Reduction	2 to 4	Water Consumption	2
				Water meter	1
				Major Leak detection	1
Total contributory points	**45**	**Total contributory points**	**33**	**Total contributory points**	**32**

The GREENSL Rating System for Built Environment is a set of performance standards for certifying Built Environments in the form of commercial or institutional buildings and high-rise residential buildings of all sizes, both public and private. The intent is to promote high performance, healthy, durable, affordable, and environmentally sound practices for new and existing buildings (GBCSL, 2011). GreenSL rating system for built environment is addressed to eight aspects. Such that Management (MN), Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), Indoor Environmental Quality (IEQ), Innovation and Design process (ID), and Social and Cultural awareness (SC).

Table 2 summarised the contribution of building automation and control system in green building rating systems. LEED and Green^{SL} possess a similar structure. Instead of Indoor environment quality and sustainable site used in LEED and Green^{SL}, Health & wellbeing and Land use & ecology terms used respectively in the BREEAM rating system, althoughprovide with thesimilar meaning. After reviewing each rating system it was found that, building automation has the most impact on the 'Energy' section. In addition, BMS impacts on the IEQ, water, sustainable sites and pollution sections as well. However its contribution in each section is very. As mentioned in KMC controls (2011), it is important to understand the difference between a contributory credit and a compliance credit. It is furthermore eloberated, with rare exception, the use of a particular product or type of product cannot, in and of itself, lead to credit compliance. For the most part,products, of whatever type, contribute to the fulfilment of particular credits.How the particular features of BMS contribute to the fulfilment of particular credits in rating systems is shown from Table 2. It was found that BMS is contributed with the maximum points of 45, 33 and 32 for the green certification in LEED, Green^{SL} and BREEAM respectively.Another vital fact is that in each rating system credit achievement is impossible without the contributory help of the control system.

6. CONCLUSIONS

BMS is one of the innovative technologies emerged in recent years to make potential achievement of the sustainable designs.This research was carried out to determine how BMS features contribute towards a sustainable built environment. The paper is presented a theorical framework that developed for BMS based on the key findings of literature review and the documentary review. Furthermore, it was found that in order to get the maximum benefits from BMS,the system should be properly specified, installed, commissioned, operated and maintained in an addition match with the type and requirements of users involved in the building. Moreover, the paper is analysed itself on LEED, Green^{SL} and BREEAM rating systems to review the input of BMS in green certification. It was revealed thatthe building management system has the most impact on the Energy section. IEQ, water, and sustainable siteare other sectionsthat BMS is eligible to contributefuthrermore.The next step of the research is to develop an assessment framework to evaluate the contribution of BMS in acheiving the sustianble built environment.

7. REFERENCES

Akadiri, P.O., and Olomolaiye, P.O., 2012.Development of sustainable assessment criteria for building materials selection.*Engineering, Construction and Architectural Management*, [online] 19(6), pp. 666-687.

Anon. 2005. A Study on Application and Performance of Building Automation System in Intelligent Building [online]. Available from: http://www.docstoc.com/docs/13474722 [Accessed 10 Feb 2013].

Ali, H.H. and Nsairat, S.F.A., 2009. Developing a green building assessment tool for developing countries – case of Jordan. *Building and environment*, 44, pp. 1053-1064.

Allen, P.J., and Remke, R., 2008. Building Automation Systems (BAS): Direct Digital Control. In Encyclopedia of Energy Engineering and Technology. Taylor and Francis: New York.

Brown, R.G., 1990. Building management systems. *Property Management*, [online] 8(3), pp. 212-219.

Carew, A.L. and Mitchell, C.A., 2006. Teaching sustainability as a contested concept: capitalizing on variation in engineering educators' conceptions of environmental, social and economic sustainability. *Journal of cleaner production*, 16(1), pp. 105-115.

Cassidy, R., 2003. White paper on sustainability – a report on the green building movement.*Building design & construction*, 11, pp. 1-47.

CIBSE Guide F, 2004. Energy efficiency in building - CIBSE Guide F. 2nd ed. Great Britain: Page Bros.

CIBSE Guide H, 1999. Building control systems - CIBSE Guide H. Great Britain: Bath, Avon.

Clarke, E., 2008. The truth about... intelligent buildings [online]. Available at: http://www.climatechangecorp.com/content.asp?ContentID=5471 [Accessed February 2013].

Cole, R. & Kernan, P., 1996. Life-cycle energy use in office buildings.*Building and environment*, 31(4), pp.307–317.

Croome, D. C., Jeronimids, G., and John, G., 2005. Sustainable building solutions: a review of lessons from the natural world. *Building and Environment*, 40, pp. 319-328.

Dounis, A.I., Tiropanis, P., Argiriou, A. & Diamantis, A., 2011. Intelligent control system for reconciliation of the energy savings with comfort in buildings using soft computing techniques.*Energy and Buildings*, 43(1), pp.66-74.

Fellows, R., 2006. Sustainability: A matter of energy?.*Property Management*, 24(2), pp. 116-131.

Forsberg, A. and Malmberg, F. V., 2004. Tools for environmental assessment of the built environment. *Building and Environment,* 39, pp. 223-228.

Gadakari, T., Mushatat, S., and Newman, R., 2012.Can Intelligent Buildings Lead Us to a Sustainable Future?[online]avalableat:http://www.ppml.url.tw/EPPM/conferences/2012/downioad/SESSON1/32%20E163.pdf[Accessed 5 March 2013].

Gowri, K., 2004. Green building rating systems- an overview. ASHRAE journal, 56-59.

Green Building Council Sri Lanka, 2011. *GREEN^{SL} Rating System for Built Environment (1st ed.)*. Nugegoda

Hodges, C.P., 2005. A Facility Manager's approach to sustainability.*Journal of Facilities Management*, 3(4), pp. 312 – 324.

Jiang, Z. Xia, J., and Jiang, Y., 2009. An information sharing building automation system. *Intelligent Buildings International*, 1(3), pp.195-208.

Katz, D. and Skopek, J., 2009. The CABA Building Intelligence Quotient programme. *Intelligent Buildings International*, 1(4), pp.277-295.

KMC Controls, 2011.Building sustainability through building automation. [online]Availabeat:*http://www.kmccontrols.com/docs/Building_Sustainability.pdf*[Accessed 28 January 2013].

Kohler, N., 1999. The relevance of the green building challenge: an observer's perspective. *Building Research & Information*, 27 (4/5), pp. 309–320.

Mazza, P., 2008. Making green buildings intelligent: how to link green buildings and the Smart Grid [online]. Available at: http://www.smartgridnews.com/artman/publish/Industry/Making_green_buildings_intelligent_how_to_link_green_buildings_and_the_Smart_Grid_printer.html[Accessed 4 February 2013].

Morelli, J., 2011. Environmental sustainability: Definition for environmental professionals. *Journal of Environmental Sustainability*, 1, pp. 19-27.

Mudalige, D., 2012. Taking up challenges to create sustainable buildings: Green rating system introduced in SL. Daily News. [internet] January 17. Available at: http://www.dailynews.lk/2012/01/17/fea03.asp[Accessed 28 January 2013].

Pandharipande, A. and Caicedo, D., 2011. Daylight integrated illumination control of LED systems based on enhanced presence sensing. *Energy and Buildings*, 43(4), pp. 944-950.

Shah, S., 2007.*Sustainable practice for the facilities manager*. Oxford: Blackwell publishing Ltd.

Sinou, M., and Kyvelou, S., 2006.Present and future of building performance assessment tools.*Management of Environmental Quality: An International Journal*, [online] 17(5), pp. 570-586.

University of Bristol, 2004. A building management system the general concept [online].University of Bristol. Available from: http://www.bristol.ac.uk/environment/energy/BMS_Overview.pdf [Accessed 10 March, 2013].

USGBC, 2008. LEED 2009 for new construction and major renovations rating system [online]. Available from: http://www.usgbc.org/ShowFile.aspx?DocumentID=5546 [Accessed 5 February, 2013].

Waidyasekara, K. G. A. S. and Sandamali, R. L. N., 2012.Impact of green concept on business objectives of an Organisation.In : World Construction Conference 2012, Global Challenges in Construction Industry. Colombo, 28 – 30 June Sri Lanka

Wang, S., and Xie, J., 2002. Integrating building management system and facilities management on the Internet.*Automation in Construction*, 11, pp. 707-715.

Wang, S., 2010. Intelligent Buildings and Building Automation. London: Spon Press.

Wikipedia, 2013. Green building [online]. Available from: http://en.wikipedia.org/wiki/Green_building [Accessed 5 February, 2013].

Wong, K. A., and Fan, Q., 2012. Building Information Modelling (BIM) for sustainable building design. *Facilitie*s, [online] 31(3), p.1.

Wu, S. and Noy, P., 2010. A conceptual design of a wireless sensor actuator system for optimizing energy and well-being in buildings. *Intelligent Buildings International*, 2(1), pp. 41-56.