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APPLICABILITY OF SMART BUILDING CONCEPT TO ENHANCE SUSTAINABLE BUILDING PRACTICE IN SRI LANKA

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ABSTRACT

With the expansion of economic activities, sustainable development in construction industry got more attention worldwide. Hence, industry practitioners are more concerned on achieving sustainable construction goals to make more effective and efficient services. The Smart Building concept can be implemented with advanced building technologies to achieve clients' requirements with in the economic, environmental and social parameters while enhancing building performances efficiently. To explore the applicability of Smart Building concept to enhance sustainable building practices in Sri Lanka, the qualitative research approach was used in this research. The opinions of the smart and sustainable construction experts were obtained through semi-structured interviews. Smart Building concept is novel to the Sri Lankan construction industry and the implementation is still in the initial stage. However, the perception of the construction industry on the Smart Building concept is focused on a strong and positive direction. The recognised sustainable benefits of Smart Building concept implementation can be used as a promoting tool to make interest on Smart Buildings. Most of these benefits are long term and most of the clients do not recognise the value of Smart Buildings in terms of sustainability. Therefore, improving the knowledge and awareness of the developers is vital during the implementation process within the local context. Lack of financial resources, complex technology requirement, reluctant to commence new technologies and lack of knowledge of developers and owners are the main barriers that are existing within the local context. Mitigating these barriers will expedite the implementation process of Smart Building concept and will upgrade the performance of the local construction industry dramatically.

Keywords: *Applicability; Smart Buildings; Sustainable Development.*

1. INTRODUCTION

In the building sector, achieving sustainability is a key challenge due to its unlimited resource consumption (Kumara *et al*., 2016). Having sustainable construction goals is important to achieve economic, social and environmental parameters of the sustainable development (Adetunji *et al*., 2003). Instead of using a balanced approach of environmental, economic and social sustainable features, most of the stakeholders are concerned only on economic parameter. This has happened mainly because of the wide gap of awareness and knowledge on sustainable building practices (Shari and Soebarto,

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2013). Developing smart solutions for sustainability has been enhanced through the maximum efficiency in urban systems with the quality living standards (Elias and Krogstie, 2017). Smart Buildings (SB) integrate intelligence, enterprise, control, materials and construction to the entire building system, to achieve building progression, energy efficiency, comfort and satisfaction (Buckman *et al*., 2014).

The concept of smart receives a great amount of worldwide attention for solving sustainability issues (Ghaffarianhoseini *et al*., 2013). A SB is one that is responsive to the requirements of occupants, different organisations and the society. It is sustainable in terms of energy and water consumptions besides being lowly polluting in terms of emissions and waste: healthy in terms of well-being for the people within it; and functional according to the occupants' needs (Clements-Croome, 2009). Thereby smart solutions are much promoted worldwide for sustainability issue, makes use of interconnected technologies which generates a high level of occupant's comfort (Ghaffarianhoseini *et al*., 2013). However, SB concept is still novel to the Sri Lankan context and the practice is still in the primary stage. Therefore, Sri Lankan buildings are not in a stage to fully acquire the sustainable features delivered by the SBs (Shabha, 2006). Since, the adaptation of SB concept brings the occupant's satisfaction and effective performance of buildings in a sustainable way it is a timely need to carry out a study in Sri Lanka to explore the applicability of SB concept to enhance sustainable building practices.

2. LITERATURE FINDINGS

2.1 CONCEPT OF SUSTAINABILITY

The concept of sustainability increases the demand for sustainable construction which will bring benefits from the environment, economic and social factors (Pitt *et al*., 2009). However, various definitions of 'sustainable construction' clearly explains the responsibilities that the construction industry should be undertaken to achieve sustainability (Zhou and Lowe, 2003). Further, the three pillars of sustainability mainly connected with the selections made in the design stage and with the building and outdoor living space construction. These pillars are reflecting the responsible development of natural, human, and economic capital towards balancing the planet, people, and profits (Kajikawa, 2008; Schoolman *et al*., 2012).

Construction can be considered as a major sector which create a greater impact on the country's economy and at the same time, it also creates a massive impact on the natural resources (Pitt *et al*., 2009). Sfakianaki (2015) identified the construction industry as one of the largest end users of environmental resources and a polluter of the environment. Miyatake (1996), proposed 6 principles to provide a comprehensive perspective to the sustainable construction. They are resource consumption minimization, maximization of resource reuse, use renewable and recyclable resources, natural environment protection, healthy and non-toxic environment creation and pursuit of the quality build environment. When it comes to the buildings, there are number of environmental problems in its life cycle with the consumption of huge amount of energy and natural resource which can create negative influences on climate change by affecting the quality of air and water (Vyas *et al*., 2014). The necessity of sustainability for the building sector is identified with the view of protecting the natural resources while reducing environmental impact, resource consumption and waste production (Bastianoni *et al*., 2007).

2.2 CONCEPT OF SMART BUILDING

Implementation of SB systems to buildings was increased with the owner's awareness with the built environment and human productivity, which will achieve the energy efficient environment with maximum occupants' efficiency (Wong *et al*., 2008). Recent evidence suggests that SBs are developed upon Intelligent Building concepts (Wong and Li, 2009; Agarwal *et al*., 2010). According to Buckman *et al*. (2014), SBs have additional features than the Intelligent Buildings like a control mechanism, enterprise, material and construction. Sinopoli (2010) explained SBs as a concept which integrated with advanced technologies like building automation, life safety, user system, telecommunication and facility management systems. The Climate Group identified SB as "a suite of technologies used to make the design, construction and operation of buildings more efficient, applicable to both existing and new-build properties" (The Climate Group, 2008). As per Buckman *et al*. (2014), SBs are buildings which integrate and account for intelligence, enterprise, control, and materials and construction as an entire building system, with adaptability, not reactivity, at the core, in order to meet the drivers for building progression: energy and efficiency, longevity, and comfort and satisfaction.

2.3 CONTRIBUTION OF SMART BUILDINGS TOWARDS SUSTAINABLE DEVELOPMENT

The main objectives of SBs are considered as efficient and effective use of the environment and maximising return on investment (Darwish, 2016). In the process of achieving these objectives, SBs will deliver multiple economic, social and environmental benefits. The identified benefits from various literatures are presented in Table 1.

Table 1: Contribution of smart buildings towards sustainable development

Benefits of smart buildings	Citations
Economic Benefits	
• Energy Savings - Reduce energy consumption	Wolfgang (2002); Yang (2013); Zhang *et al*. (2013)
• Time Saving- Save time with automating daily routines	Fujie and Mikami (1991)
• Reduce redesign cost by detecting faulty situation- fire, gas leaks and water	Darwish (2016)
• Minimum life cycle costs	Yang (2013)
• Minimising operations and maintenance expenses	Zhang *et al*. (2013)
• Maximize technical performance	Kaya and Kahraman (2014)
• Operation efficiency	Ghaffarianhoseini *et al*. (2016)
Environmental Benefits	
• Adapting to climatic changes	Kiliccote *et al*. (2011)
• Energy efficiency - protect natural resources	Wolfgang (2002); Yang (2013)
• Expert Systems - Contain information about requirements	Batov (2015)
• Optimising asset utilisation	Zhang *et al*. (2013)
• Less environmental pollution in operation stage	Morelli (2013)

Benefits of smart buildings	Citations
Social Benefits	
• Occupants comfort - Learn occupants' performance and attempts to increase comfort	Yang (2013); Brad and Murar, (2014)
• Capable of learning and adjusting performance from its occupancy and the environment	Kaya and Kahraman (2014)
• Maximise flexibility	Kaya and Kahraman (2014)
• Time saving	Fujie and Mikami (1991)
• Operation efficiency	Ghaffarianhoseini *et al*. (2016)
• Health and care - Revealed unsuitable temperature, air condition and light intensity parameters	Derek and Clements-croome (1997)
• Assistive domestics - Support in daily routines, warns in an emergency, reduce a sense of isolation	Batov (2015)

3. RESEARCH METHODOLOGY

The research was aimed at exploring the applicability of SB concept to enhance sustainable building practice in Sri Lanka. At the outset, a literature survey was carried out to identify the key features and principles of sustainability and SB concepts to recognise the relationships between the two concepts. Since the smart and sustainable concepts are new to the Sri Lankan construction industry there were only few numbers of respondents who were capable of being experts of this research study. Moreover, to fulfil the aim of this research, it was required to investigate the perception of the construction stakeholders and expert's opinions, experiences and knowledge. Since, expert interviewing is a useful data collection technique to assess attitudes, perceptions and values (Oswald *et al*., 2018), qualitative research approach was undertaken.

The purposive sampling method was used to select professionals in SB and Sustainable concepts. As a result of that, eight number of industry professionals who are actively and passionately involved in designing and managing SBs and sustainable building were selected. These professionals were selected from different fields which related to smart and sustainable practices such as MEP, civil engineering, facilities management and building automation. Semi-structured interviews were conducted with open-ended questions. Manual content analysis was carried out to facilitate clear outcome for establish the ideas gathered from the interviews. The experience and exposure of the interviewees with related to the SB and Sustainable concepts were given in the Table 2.

Table 2: Composition of respondents

Respondent	Profession/ Designation	Industry Experience	Level of awareness	Level of Experience in practice
R1	Managing director/ Senior MEP engineer	Above 20 years	High	High
R2	Managing engineer	Above 15 years	High	High
R3	Professor/Civil engineer	Above 15 years	High	Moderate
R4	Manager-Building Automation	Above 15 years	High	High
R5	Managing director	Above 25 years	High	High

Respondent	Profession/ Designation	Industry Experience	Level of awareness	Level of Experience in practice
R6	Chief operating officer	Above 15 years	High	Moderate
R7	Maintenance Engineer	Above 10 years	High	Moderate
R8	Project Engineer (BMS)	Above 10 years	High	Moderate

4. RESEARCH FINDINGS AND DATA ANALYSIS

4.1 SRI LANKAN STAKEHOLDERS' PERCEPTION TOWARDS SMART BUILDINGS

In order to explore the applicability of SB concept to enhance sustainable building practices, the perceptions of the Sri Lankan construction stakeholders' needs to be examined. If their perceptions are positive it could be concluded that the basis is there in the Sri Lankan context to obtain sustainable benefits through SBs. As per R1, Sri Lankan construction industry is still adopting conventional methodologies and technologies and the change to adopt new innovations is happening in a sluggish manner. Moreover, R6 identified the low level of technological knowledge of clients as the main obstacle in implementing SB concept in Sri Lanka. R4 mentioned that, with the weak legal enforcements for sustainable construction, Sri Lankan property developers are only considering about minimising the initial cost of construction and they are not concerning about the running cost of buildings. Furthermore, this has created a situation where building sector is responsible for a massive proportion of energy waste in Sri Lanka. Therefore, the R4 emphasised the importance of having a strong legal background for sustainable construction within Sri Lankan context. As per R7, building automation can be resulted in loss of job opportunities for employees in the fields of building security, maintenance and facilities management. Further, he explained that, "since the Sri Lankan labour policy is directed on creating more job opportunities SB concept may be against this policy and also against the social parameter of the sustainable development". However, opposing to his argument R8 stated that SB increases the job opportunities of the facilities managers by enabling them to focus on strategic problems, software and automation leading to overall growth in the number of professionals. By considering all of these arguments it can be concluded that the Sri Lankan construction industry stakeholder's perception on using SBs for improving sustainable construction is directed on a positive way.

4.1.1 Current Status of Smart Building Implementation in Sri Lanka

To gain the advantages of SB concept it needs to be practiced well in the industry. Therefore, it is important to recognise the current level of application of SB concept. All the respondents mentioned that current adoption of the SB has been at a marginal level in Sri Lanka. As per the respondents there are number of projects that have fully completed and quite a few numbers of projects will be completed in near future. As per R3, the levels of smartness of these buildings are not identical to each other as it varies within a huge range which depends on various factors such as availability of funds, client requirement and knowledge level. As per R1, the practicing level of the smart concept in Sri Lanka has been gone up to 60% - 70% and not fully adopt within the facilities. According to R7, SB concept is mainly implementing in Sri Lanka within hotel sector projects which demand guest room management systems and building projects which demand Building

Management Systems (BMS). All respondents without any contradictory opinions stated that, the lack of knowledge as the major problem that needs to be addressed immediately in order to increase the current level of application of SB concept. Moreover, findings disclosed lack of technology, lack of material, misconceptions, resistance to change and insufficient management support as the reasons behind slow progression of SBs. Further, R3 expressed that proper implementation, under a proper procedure, will upgrade the implementation of SB concept in the local construction industry dramatically.

4.1.2 Contribution of Smart Buildings towards Sustainable Development

The experts' ideas on the sustainability of SB revealed different opinions. According to R4, SBs usually blend with useful building services which enhance overall effectiveness of systems and make occupants productive and comfort. As per R6, it further enhances illumination, thermal comfort, air quality, security, and many more at a lower cost with minimum impacts to the environment. R1 stated that SB concept mainly address the active side of the sustainability which concerned on the building operation stage rather than the passive side which concerned with building design stage. In addition, R8 identified BMS as the main system that impacts on building automation and its sustainability. Further, R3 stated that the sustainable features of SB will bring long term benefits rather than short term benefits. Therefore, lot of people do not recognise the value of SB in terms of sustainability. The number of identified sustainable factors of SBs are less than the main factors identified from the literature review. This demonstrates the Sri Lankan construction experts' lack of awareness in smart and sustainability concepts. By confirming this fact, R6 explained that, *"When it compared the Sri Lankan smart and sustainable practice with the global content, it is in a lower level, due to the lack of education and training."* Further, R8 demonstrated that *"The smart concept is still new to the Sri Lankan construction industry than the sustainability. We have a limited number of professionals for both the concept to assign in projects. This has reduced the level of performance that could be achieved otherwise."* Therefore, when considering both opinions, SBs and its sustainable impacts will constructively change with the education and training to the professionals in the construction industry.

4.2 BENEFITS OF SMART BUILDINGS TOWARDS SUSTAINABLE CONSTRUCTION

Table 3 presents the identified benefits of smart buildings towards achieving sustainable construction.

Table 3: Benefits of smart buildings towards sustainable construction

Benefits	Applicability to Sri Lanka							
	R1	R2	R3	R4	R5	R6	R7	R8
Economic Benefits								
Energy Savings - Reduce energy consumption	√	√	√	√	√	√	√	√
Time Saving- Save time with automating daily routines	√	√	√	√	√	√	√	√
Reduce redesign cost by detecting faulty situation	√	√	√	√	√	√	√	√
Minimum life time costs	√	√	√	√	√	√	√	√
Minimising operations and maintenance expenses	√	√		√	√	√	√	√
Maximize technical performance,	√	√	√	√	√	√	√	√

Operation efficiency	√	√	√	√	√	√	√	√
Increase property value after construct	-	-	√	-	√	√	√	√
Environmental Benefits								
Adapting to climatic changes	√	√	-	√	√	√	√	√
Energy efficiency – protect natural resources	√	√	√	√	√	√	√	√
Expert Systems - Contain information about requirements	√	√	√	√	√	√	√	√
Optimising asset utilisation	√	√	√	√	√	√	√	√
Less environmental pollution in operation stage	√	√	√	√	√	√	√	√
Operation efficiency	√	√	√	-	√	-	√	√
Less embodied energy use	√	√	√	-	-	-	√	-
Good appearance and cleanliness to the city	√	√	-	√	√	√	-	√
Healthy and non-toxic environment creation	√	-	√	√	√	-	√	-
Use renewable and recyclable resources	√	√	√	√	√	√	-	√
Social Benefits								
Occupants Comfort	√	√	√	√	√	√	√	√
Capable of learning and adjusting performance from its occupancy and environment	√	√	√	√	√	√	√	√
Maximise flexibility	√	√	√	√	√	√	√	√
Time Saving	√	√	√	√	√	√	√	√
Operation efficiency	√	√	√	√	√	√	√	√
Maximise Health and Care	√	√	-	-	√	√	√	√
Assistive Domestics - Support in daily routines, warns in an emergency, reduce a sense of isolation	√	√	√	√	√	√	√	√
Quick respond to the occupants	√	√	-	√	-	-	√	√

For many developing countries like Sri Lanka, economic benefit is the main concerned factor in SB projects, rather than expecting environmental or social benefits. All the respondents recognised energy savings under environmental benefits and economic benefits. By explaining this fact, R3 mentioned that, *"Energy saving reduce the total CO_2 emission and reduce the purchasing cost of energy resources."* Moreover, R2 stated that detecting failures in systems like fire, gas and water is important since it minimise the redesign cost. All eight experts agreed that if the developer willing to pay a high cost during the initial stage of the SB construction, long term life cycle cost can be reduced. When it comes to the social category, two of eight respondents did not identify maximize health and care as a benefit due to the negative impacts on human health from the mechanized systems. R1 highlighted that, *"SB can automatically control the accurate percentage of carbon dioxide and the quality of fresh air by providing occupancy comfort while increasing its social value."* By considering all these benefits it can be concluded that the SBs can bring sustainable benefits to the Sri Lankan context.

4.3 BARRIERS IN IMPLEMENTING SMART BUILDINGS IN SRI LANKA

Table 4 presents the identified barriers to implementing smart buildings in Sri Lanka.

Table 4: Barriers of smart building implementation

Barriers	Applicability to Sri Lanka							
	R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**
Economic Barriers								
Less financial resources	√	√	√	√	√	√	√	√
Necessity of complex design and construction technologies	√	√	√	√	√	√	√	√
The cost in procurement practices	√	-	-	√	-	√	-	√
Risk of investment	√	√	√	√	√	√	-	√
Opportunity cost	-	√	-	√	√	√	-	√
Environment Barriers								
Insufficient response to sustainability	√	-	-	√	-	√	-	√
Environmental damages in construction by the design	-	√	-	-	√	√	-	√
Social Barriers								
Lack of knowledge of developers and owners	√	√	√	√	√	√	√	√
Reluctant to commence new technologies	√	√	√	√	√	√	√	√
Lack of knowledge on the environmental impact by inefficient buildings to the developers and owners	-	-	-	-	-	-	-	-
Less information on opportunities offered by intelligent technologies	√	√	-	√	√	√	-	√
Less cooperation and networking	√	√	√	-	√	√	√	√
Less motivation to professionals	√	-	√	√	√	-	√	√
Regulatory, Technical and Other Barriers								
Client opinions of essential services delivered.	√	√	√	√		√	√	√
Lack of support and inspire by Institutional structures	√	√	-	√	√	√	-	√
No evaluation system to assess the level of intelligence of smartness of a system	√	√	√	√	√	√	√	√
Not much practically used building codes, mandatory labelling, certificate schemes	√	√	√	√	√	√	√	√
Health and safety requirements by authorities	-	√	-	√		√	-	-
The scarcity of required material and skill tradesmen	√	√	√	√	√	√	√	√
Less political sense	√	√	√	√	√	√	√	√

As a developing country, economic barriers are the main obstacles by Sri Lankan developers in SB projects construction. Less financial resources for this type of projects can be considered a common issue. As per R1, R4, R6 and R8, other than the cost of complex technologies involved during the design, construction and operation phases, there is a cost occurred during procurement practice in terms of tendering and risk mitigation. According to the R3, social barriers mainly come from the users and the workers inside the building who concerned on comfort, human health protection and wellbeing. As per R6, there is reluctant to commence new technologies, because of fear of failure. R2 mentioned that, *"SBs required a close collaboration between professionals, users and suppliers since it require a high level of compatibility among design,*

construction and operation stages. However, Sri Lankan construction industry is a customer base industry, where others have very less control over the processes." Further, majority of interviewees argued that there are no adequate institutional structures to inspire and support the SBs. There were instances where special technologies and experts were imported specifically for SB projects. The scarcity of required material and skill tradesmen is a significant barrier when implementing SB concept.

5. CONCLUSIONS

Smart Building concept is undertaken all over the world with the aim of improving the performance of the buildings with the use of advanced technologies like building automation, life safety, user systems, telecommunication and facility management. Even though the concept has been rapidly grown in the developed countries with appropriate knowledge and sense, the situation in developing countries is far too different. The findings of the study disclosed that, sustainable and smart concepts have different aims while targeting on developing different aspects of a project. However, both the concepts are inline while providing the benefits to the construction projects. Sri Lankan construction industry has recognized the involvement of SB towards the sustainable project delivery. Mainly, the stakeholders' perception towards the implementation of SB concept is focused on a favourable direction with the massive number of sustainable features it brings in to the building. However, implementation of SB concept needs to expedite and expand in order to obtain the numerous sustainable opportunities that are available. The implementation of SB concept is associated with numerous benefits and barriers where the barriers can be mitigated with a suitable set of strategies. The proper implementation process of SB concept, under a proper procedure, will upgrade the implementation of SB concept in the local construction industry and will expand the performance dramatically.

6. REFERENCES

Adetunji, I., Price, A., Fleming, P., and Kemp, P., 2003. Sustainability and The UK Construction Industry - A Review. *Proceeding of Institution of Civil Engineers - Engineering Sustainability,* 156, pp.185–199.

Agarwal, Y., Balaji, B., Gupta, R., Lyles, J., Wei, M., and Weng, T., 2010. Occupancy-Driven Energy Management for Smart Building Automation. *The 2nd ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Building,* pp.1–6.

Bastianoni, S., Galli, A., Pulselli, R. M., and Niccolucci, V., 2007. Environmental and Economic Evaluation of Natural Capital Appropriation Through Building Construction: Practical Case Study in The Italian Context. *A Journal of the Human Environment*, 36(7), pp.559–565.

Batov, E. I., 2015. The Distinctive Features of " Smart " Buildings. *Procedia Engineering*, 111, pp.103–107.

Brad, B. S., and Murar, M. M., 2014. Smart Buildings Using IoT Technologies. *Construction of Unique Building Structures*, 5(20), pp.15-27.

Buckman, A. H., Mayfield, M., Beck, B. M., and Stephen., 2014. What is a Smart Building? *Smart and Sustainable Built Environment,* 3, pp.92–109.

Clements-Croome, D., 2011. Sustainable Intelligent Buildings for People: A Review. *Intelligent Buildings International*, 3(2), 67-86.

Darwish, A. S., 2016. Sustainable Green Smart Buildings: Future Energy Survivor. *ISESCO Journal of Science and Technology*, 12(21), pp.35–42.

Derek, J., and Clements-Croome, D., 1997. What Do We Mean by Intelligent Buildings? *Automation in Construction*, 6(5), pp.395–400.

Elias, S., and Krogstie, J., 2017. Smart Sustainable Cities of The Future: An Extensive Interdisciplinary Literature Review. *Sustainable Cities and Society*, 31, pp.183–212.

Fujie, S., and Mikami, Y., 1991. Construction Aspects of Intelligent Buildings. *IEEE Communications Magazine*, 29(4), pp.50–57.

Ghaffarianhoseini, A., Berardi, U., Alwaer, H., Halawa, E., Ghaffarianhoseini, A., and Clements-Croome, D., 2016. What Is an Intelligent Building? Analysis of Recent Interpretations from an International Perspective. *Architectural Science Review,* 59(5), pp.338–357.

GhaffarianHoseini, A. H., Dahlan, N. D., Berardi, U., GhaffarianHoseini, A., and Makaremi, N., 2013. The Essence of Future Smart Houses: From Embedding ICT To Adapting to Sustainability Principles. *Renewable and Sustainable Energy Reviews,* 24, pp.593–607.

Kajikawa, Y., 2008. Research Core and Framework of Sustainability Science. *Sustainability Science*, 3(2), pp.215–239.

Kaya, İ., and Kahraman, C., 2014. A Comparison of Fuzzy Multicriteria Decision Making Methods for Intelligent Building Assessment. *Journal of Civil Engineering and Management*, 20(1), pp.59–69.

Kiliccote, S., Piette, M. A., and Ghatikar, G., 2011. Smart Buildings and Demand Response. *AIP Conference Proceedings*, 1401, pp.328–338.

Kumara, W. H. C. D., Waidyasekara, K. G. A. S., and Weerasinghe, R. P. N. P., 2016. Building Management System for Sustainable Built Environment in Sri Lanka. *Built Environment Project and Asset Management*, 6(3), pp.302–316.

Love, P., and Arthur Bullen, P., 2009. Toward the Sustainable Adaptation of Existing Facilities. *Facilities*, 27(9/10), pp.357–367.

Miyatake, Y., 1996. Technology Development and Sustainable Construction. *Journal of Management in Engineering*, 12(4), pp.23–27.

Morelli, J., 2013. Environmental Sustainability: A Definition for Environmental Professionals. *Journal of Environmental Sustainability*, 1(1), pp.1–10.

Oswald, D., Zhang, R.P., Lingard, H., Pirzadeh, P. and Le, T., 2018. The use and abuse of safety indicators in construction. *Engineering, construction and architectural management*, *25*(9), pp.1188-1209.

Pitt, M., Tucker, M., Riley, M., and Longden, J., 2009. Towards Sustainable Construction: Promotion and Best Practices. *Construction Innovation*, 9(2), pp.201–224.

Schoolman, E. D., Guest, J. S., Bush, K. F., and Bell, A. R., 2012. How Interdisciplinary is Sustainability Research? Analysing the Structure of An Emerging Scientific Field. *Sustainability Science*, 7(1), pp.67–80.

Sfakianaki, E., 2015. Resource-Efficient Construction: Rethinking Construction Towards Sustainability. *World Journal of Science, Technology and Sustainable Development*, 12(3), pp.233–242.

Shabha, G., 2006. A Critical Review of The Impact of Embedded Smart Sensors on Productivity in The Workplace. *Facilities*, 24(13/14), pp.538–549.

Shari, Z., and Soebarto, V., 2013. Investigating Sustainable Practices in The Malaysian Office Building Developments. *Construction Innovation*, 14(1), pp.17–37.

The Climate Group., 2008. SMART 2020 Enabling the Low Carbon Economy in The Information Age. available from: www.smart2020.org/

Vyas, S., Ahmed, A. S., and Parashar, A. A., 2014. Bureau of Energy Efficiency and Green Buildings. *International Journal of Research*, 1(3), pp.23–32.

Wolfgang, F. E., 2002. Intelligent Office Building Performance Evaluation. *Facilities*, 20(7/8), pp.279–287.

Wong, J. K. W., and Li, H., 2009. Development of Intelligence Analytic Models for Integrated Building Management Systems (IBMS) in Intelligent Building. *Intelligent Buildings International*, 1(1), pp.5–22.

Wong, J.K.W., Li, H., and Lai, J., 2008. Evaluating the System Intelligence of The Intelligent Building Systems Part 1: Development of Key Intelligent Indicators and Conceptual Analytical Framework. *Automation in Construction*, 17(3), pp.284–302.

Yang, R., 2013. *Development of Integrated Building Control Systems for Energy and Comfort Management in Intelligent Buildings.* Thesis (PhD). University of Toledo.

Zhang, D., Shah, N., and Papageorgiou, L. G., 2013. Efficient Energy Consumption and Operation Management in A Smart Building with Microgrid. *Energy Conversion and Management*, 74, pp.209–222.

Zhou, L., and Lowe, D. J., 2003. Economic Challenge of Sustainable Construction. *RICS COBRA Foundation Construction and Building Research Conference*, pp.1–2.