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Application of Building Management System towards a Sustainable Built Environment in Sri Lanka: Implementation Process

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Abstract

Managing a built environment in a sustainable way is the biggest challenge for the built environment professionals. Building Management System (BMS) is one of the solutions that has been identified recently, considering its potential capabilities for managing a sustainable building. BMS is a computer based system that used to monitor, coordinate, organize, and optimize building subsystems such as HVAC, lighting, security, fire/life safety, elevators, and others. The system provides various supports for the operation and maintenance functions of a building. However, the application of BMS towards a sustainable built environment is still challenged in Sri Lankan context and thus there is a need for a suitable implementation process in succeeding BMS outcomes. Therefore, this paper aims to investigate the implementation process of BMS towards a sustainable built environment. A comprehensive literature survey was conducted to identify the concept of sustainability and the BMS. An opinion survey was conducted with the six industrial professionals. The study identified five sequence steps of BMS implementation process namely: identifying user requirement, identifying BMS features, designing, installation and commission, and operation and maintenance. The cost, lack of confidence in result, lack of knowledge and skilled person are some prevailing issues among building professionals to implement the system in a sustainable manner.

Keywords: Building Management System, Built environment, Sustainability, building service systems

Introduction

A Building Management System (BMS) has become an inevitable tool in the hands of building operations personnel in recent years. In fact, buildings are widely accepted a BMS as a tool for controlling and monitoring the functions of buildings and its associated services plants more productively (Brown, 1990). According to Figueiredo and Martins (2010), a BMS could improve the interaction between the building systems and the habitants/users of the buildings. The system results higher energy efficiency, lower operating and maintenance costs, better indoor air quality, greater occupant comfort, and productivity of the buildings (Wang, 2010; CIBSE Guide H, 1999). Moreover, the facility managers implement BMS to control building performance, manage building services, manage important information, and adapt rapidly to changing requirements (Wang and Xie, 2002). Sethi (2001) justified that building owners invest in BMS to automate their buildings. According to KMC Controls (2011), building sustainability can be achieved by implementing a BMS. Similarly, it is apparent that the BMS caters to various operational and management functions of buildings. However, the empirical evidence suggested that over 90% of the BMS are under-utilized (Sethi, 2001). Further, it was highlighted by Webster (2005) that installing a BMS with various features does not create its full potentials. Although this system is crucial for optimising building performance and creating the buildings into more sustainable manner, it has been widely reported that users are not utilizing their systems' facilities effectively (Lowery, 2002; Webster, 2005). Hence, there should be a proper approach to utilize BMS to accomplish anticipated outcomes. Although, there is a high motivation to adopt BMSs, low performance, lack of knowledge and unexpected results have created unpopular and insufficient systems among the building sector professionals. Thus, this paper focuses to identify the basic steps of the implementation process of BMS towards a sustainable environment.

Literature Review

Sustainable Built Environment

The Brundtland Commission defined sustainable development as the development that should meet the needs of the present without compromising the ability of future generations to meet their own needs. According to Lai and Yik (2006), sustainable development is unattainable without sustainable buildings. Sethi (2001) defined sustainable building as an efficient, productive, comfortable, safe, and healthy environment that supports the business needs of the occupants. Organization for Economic Co-operation and Development (OECD) project defined sustainable buildings as buildings that have minimum adverse impacts on the built and natural environment, in terms of the buildings themselves, their immediate surroundings, and the broader regional and global settings (John, et al., 2005). Further, the OECD project (John, et al., 2005) identified five objectives of sustainable buildings as;

i) Resource efficiency
ii) Energy efficiency (including greenhouse gas emissions reduction)
iii) Pollution prevention (including indoor air quality and noise abatement)
iv) Harmonization with the environment
v) Integrated and systemic approaches settings

The authors further defined sustainable buildings in terms of building practices, which strive for integral quality, including economic, social, and environmental performance in a broad way. Carew and Mitchell (2008), justified that the sustainability literature supports the subdivisions of a broader concept into the secondary interrelated concepts as environmental, social, and economic sustainability.

Building Management System (BMS)

A BMS denotes to a system where components communicate with each other and form a central administrator to permits monitoring and controlling of the building from a single point (CIBSE Guide H, 2000). According to Panke (2002), five basic hardware components such as sensors, actuators, microprocessor-based field panels (controllers), communication links, and a central operator station are used in BMSs. The sensors transmit information that defines a single operating condition, such as temperature or pressure. This information is supplied to the field panels (controllers) for monitoring or decision-making purposes. The actuators are the mechanical interfaces that implement actions initiated by the field panels in accordance with the inputs received. Information relating to the entire process has transmitted over the communication links to a central operator station. According to Jiang et al., (2009), a BMS controls connected plant to maintain a preset requirement of a building. A BMS monitors inputs such as temperature readings and process them using the digital controllers to give control outputs back to the building. Figure 1 illustrates the typical structure of a BMS. According to Figure 1, all the sensors and controllers of subsystems are linked to a central computer and all the sub systems can be monitored and controlled through a single computer. In literature, Building Automation System (BAS), and Building Control System (BCS) terms are also used interchangeably to refer BMS.

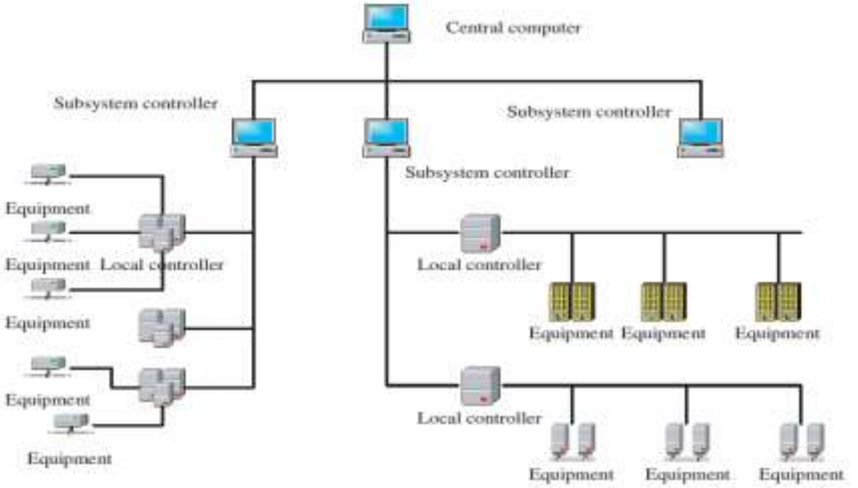


Figure 1: Typical structure of BMS, (Jiang, 2009)

Historically, BMSs were developed for automatic control of heating, ventilation, air-conditioning (HVAC) systems, simultaneously improving human comfort and reducing energy costs. In last decades, several other domains were added to BMS such as: telecommunications, office automation, computer building management, and security systems (Figueiredo and Martins, 2010). Agarwal (2003) depicted following typical subsystems that integrate with the BMS:

- HVAC consisting of control and monitoring of systems, subsystems and devices pertaining to the air conditioning system for example Air Handling Units (AHU), boilers, chillers, fan coils, Variable Air Volume (VAV) boxes
- Building illumination takes care of the lighting controllers, control panels, sensors, lighting panels along with other lighting devices
- Fire and Life Safety consists of monitor and control of fire panels, alarms, detectors and other ancillary subsystems and devices
- Access Control and Security takes care of security system, access control, Closed Circuit Television (CCTV)

In addition, a BMS connects with other building service systems such as video surveillance, access control, lighting control, and interfacing with the fire and security systems (Allen and Remke, 2008). According to Brown (1990), a BMS provides three characteristics as:

i. Greater flexibility and range of control strategies than conventional controls
ii. Remote operation and interrogation
iii. The provision of management information

It is noticeable that with the new technological development, BMSs has increasingly modified to addresses built environment issues and to enhance the system efficiency.

BMS Features and Functions

A BMS is a multi-functional system that integrates all the building services in to a common platform. A BMS consists of various features to perform the anticipated tasks. The features shall be selected by the clients based on the organizational requirement. Utility load profiles, trends and operation logs of equipment, and the generation of maintenance schedules are some features of the BMS. Utility demand, energy use, building conditions, climatic data, and equipment status can be observed through monitoring feature of the BMS (Allen and Remke, 2008). Moreover, University of Bristol (2004) highlighted the key features of BMS as, monitoring and controlling, optimum start/stop, operator adjustment, alarm reporting and equipment scheduling. The trending and monitoring features of BMS are powerful for improving HVAC and lighting and for reducing energy use (Pandharipande and Caicedo, 2012). Makarechi and Kangari (2011) noted that variety of facility management operations, building administration and opportunities for efficient and flexible operations can be performed through the evolving technologies of the BMS.

Wang (2010) identified typical functions of the BMS 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, that the BMS enables to improve overall management and performance of the buildings, promoting a holistic approach to controls and providing operational feedback. The same report cited that 10% to 20% energy savings can be achieved by installing a BMS compared to independent controllers for each system. Anon (2005), further mentioned following functions of a BMS as:

- *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*

As stated in the previous section, features of a BMS such as stopping and starting equipment when needed, monitoring space conditions and occupancies and implementing sophisticated strategies will reduce the overall energy use. A BMS also improve indoor air quality through continual ventilation adjustments and air-quality monitoring; and maximise day lighting by automating shading systems (Gadakari, et al, 2012). Katz and Skopek (2009) recognised that the BMS capable of decreasing building maintenance and energy costs, increasing productivity of systems and also guarding against the repair costs, productivity loss, loss of customers to competitors, and revenue loss. Moreover, as per KMC Controls (2009), BMS records a historical data that can be used to improve building performance while maintaining occupant productivity. Xia and Yan, (2015) mentioned that the real time operational data are collected and stored to determine the building operational performance where these data able to manage building effectively. According to Vasseur and Dunkels (2010), a BMS improves the security and safety of the built environment by monitoring and controlling the installed physical security and fire system. Sethi (2001) justified that a well-utilized BMS performs to operate a building at optimum efficiency, lowers the operating costs, enhances comfort levels, increases productivity, improves code compliance, and maintains a sustainable built environment. Accordingly, the BMS is a multifunctional system that accomplishes the sustainable dimensions of environmental, economic and social.

Benefits of BMS

Even though BMS includes many features and functions, it is essential to consider the benefits of a modern control system that matches with the requirement of the different groups of users involved in the building. Table 1 lists some of the benefits that can be achieved in a modern BMS according to the type of building stakeholder. The BMS enables to improve the overall management and performance of buildings, promoting a holistic approach to controls and monitor the building systems (CIBSE Guide F, 2004).

Table 1: Benefits of BMS

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 Computerized maintenance scheduling Good plant schematics and documentation
Controls contractor	Bus systems simplify installation Supervisor aids setting up and commissioning Interoperability enlarges supplier choice

Source: CIBSE Guide H, 1999

Issues for underperformance of the BMS

It is apparent that the system brings various issues and difficulties for operators resulting various unexpected outcomes. Further, the system fails due to the various stakeholders actions. However, an effective result depends on the high degree of trust in the relationships and on the professionalism of all parties (Webster, 2005). Piper (2004) identified number of common factors that cause to inefficient use of BMS as;

- *Fear of Change* - New technologies are slow to gain acceptance. There is a great resistance to change how things are done.
- *Lack of Training* - Lack of training in the system operation is a major reason for system inefficiency.
- *Lack of Planning* - underperformance of the system capabilities is a lack of planning. BMS systems must be matched to the needs of a facility.
- *Insufficient Staffing* - Maintenance personnel are required to regularly test and check the operation of the system.
- *Failure to Tune the System* - If they are to be kept in optimal condition, ongoing maintenance will be required. System expansions and upgrades. Facilities are constantly changing. The facility's BMS must keep up with those changes to remain effective.

Further, the actions and perceptions of various stakeholders are also influence the use of BMS applications. Table 2 presents common issues and attitudes of stakeholders when implementing BMS.

Table 2: Current issues and attitudes of stakeholders

Stakeholder	Issues and attitudes
Owner/architect	Do not understand controls and BMS technology
Mechanical engineer	Inadequate resources (and/or controls knowledge) to specify quality solutions
BMS vendors	Sell the potential, lock-in proprietary solutions and on-going service
Mechanical and controls contractors	Incentive is to meet minimum requirements and get off the job
Facilities services group	No clout; limited influence or involvement in decision making about BMS solutions

Source: Watson as cited in Webster, 2005

Lowery (2002) listed out deficiencies of BMS that rejected its full potentials as user interface, overelaborated design, over-sophisticated control strategies and difficulties in adapting software to specific installations, and the users' lack of knowledge and self-confidence in using a BMS. The interplay of vested interests, lack of continuity and top down control over the process are weakening the effective functionality of the BMS (Watson, as cited in Webster, 2005). Moreover, Webster (2005) pointed out that the system is very complex for inadequately trained operators to understand. The lack of implementation and/or documentation of sophisticated control and management functions are key factors that make a BMS underutilized.

Selecting a BMS

It is discovered the fact that installing a BMS does not achieve its full potentials. A properly designed process needs to be carefully selected in utilizing a BMS towards a sustainable built environment. In most cases, the primary problem is not the capabilities of the BMS but the fact that many of the capabilities are underutilized (Webster, 2005). Several scholars have addressed these deficiencies by introducing alternative approaches for BMS performance. Doukas (2007) developed a decision support system for continuous energy management of a typical building. The system preserves the comfort conditions of the occupants and minimizes the energy consumption and cost. According to Brown (1990), the precise route to obtaining a BMS is varied with the nature of the project, i.e new build or retrofit, and the contractual relationships already extant. Author further mentioned the implementation process for BMS as;

i) *Define the building management strategy*: detailed functional specification can be developed, usually by a specialist consultant and select suitable supplier
ii) *Installation and commissioning*: checking the specification and project planning have been correctly done. Some instants building owner will appoint a project manager to manage the project
iii) *Training system operators*: providing training for the operators and staff ranging from administrative management to security guards involved in the operation and maintenance of the building to have a basic knowledge
iv) *Communications*: developing a communications standard to simplify system-to-system communication
v) *Extending the system*: extending the scope of the system by integrating other systems for future plans

Piper (2004) identified two elements of successful BMS implementation. The first is to make sure that the system is running properly and the second is to make sure that the system is using its capability. Webster (2005) mentioned that design, installation, commissioning, operations, the building management structure, and the interactions between all of these must be considered in utilizing a BMS. Five key parameters for building automation performance were identified by Makarechi (2011) as cost, user needs, simplicity, integration, and availability of service and maintenance. In addition to above mentioned parameters, significant issues such as: human factor, building power demand, and energy use, were noted and 'Reliability' and 'Accuracy' were cited with low frequencies. Webster (2005) ensured that technical, organizational, and operational should be considered for BMS system effectiveness. Ted et al., (2002) defined least four ways that "effectiveness" of BMS can be compromised as:

i) *Design and specification:* System is improperly designed and/or specified its capabilities and functionality
ii) *Installation:* Full commissioning of these systems instead of relying on cost

iii) *Utilization:* Using the BMS as a tool for improving energy and comfort performance with the well knowledgeable operators

iv) *Performance:* To detect whether a system actually saves energy and/or cost requires analysis

The literature findings highlighted the fact that the BMS should be properly managed to gain its full potentials. The system could perform ineffectively or insufficiently, though it is occupied with the latest advanced technologies due to unavailability of a proper implementation process. A proper system is relatively unknown to most facility staff. The literature findings draw the attention on the key steps for the implementation process as design, installation and commission, and operation and maintenance. Further, it is found that BMS can be used as a strategy that can achieve sustainable built environment due to its various functionality. However, these findings need to be further investigated to identify its relevancy for the Sri Lankan built environment. Figure 2 presents the literature findings; steps of implementation process that will direct to create a sustainable built environment through the applications of BMS. However, the primary factors that need to consider in each step is still under researched.

Figure 2: BMS implementation process: compiled from literature

RESEARCH METHODOLOGY

A literature survey was carried out to identify the concept of sustainable buildings, BMS features and functions, and its implications to create an effective BMS that cater sustainability. The study intends to develop an implementation process of BMS in creating a sustainable built environment. Beliefs, understandings, experience, opinions, and views of people need to be analyzed in addressing the research gap. By using a qualitative approach, the researcher will study the whole population as individuals or groups and will identify beliefs, understandings, opinions, and views of people and analyses them to find solutions (Fellows and Lui, 2003). Hence, the qualitative approach was used and an experts' opinion survey with the semi structured interview guidelines was selected. Face to face interviews were conducted to gather relevant information. The opinion survey was mainly focused to identify the BMS implementation process and barriers for successful implementation of the BMS. Six industrial professionals, who involve in the process of selection, operation, and maintenance of BMS, were selected. The selection criteria was further categorized into experience in sustainability, BMS service providers (Vendor) and experience in operating and managing BMS in building. Two experts were selected from each category. Table 3 lists details of the respondents. General opinions of interviewees are presented as narratives and quotations form.

Table 3: Details of the respondents

Respondents ID	Designation	Years of experience
Respondent 1	Engineer in Sustainability	12
Respondent 2	Sustainability coordinator in Green certified facility	3
Respondent 3	Director project coordinator in BMS providing company (Engineer)	6
Respondent 4	Engineer in BMS vendor organization	4
Respondent 5	Manager infrastructure solutions in LEED certified company	3
Respondent 6	Facilities Manager in high rise commercial building	5

Data Analysis

The data were arranged in to two sections based on the objectives of the study as follows:

i) *Implementation process of BMS*
ii) *Primary concerns in implementation process*

In general, the six respondents hold very much similar opinions towards the above sections. However, interviewees disclosed various significant factors during the interview discussions. The detail discussion of each heading presents in the following sections.

Implementation Process of BMS towards Sustainable Built Environment

Three key stages of implementing a BMS in buildings namely; design, installation and commissioning and operation and maintenance were highlighted through the literature survey. All the six respondents agreed the literature findings. Most of the respondents mentioned that there should be a conceptual stage. Respondent 3 and Respondent 4 who are Engineers in BMS installation process mentioned that "*most of our client does not understand the main purpose of adopting a BMS to the buildings. They expect various functions.* According to the respondents' opinion, understanding the main user requirement is essential for implementing an effective BMS for a sustainable environment. Further, it was highlighted by the Respondent 1 that in the initial stage, client or BMS operator should decide the BMS functions including sustainable characteristics. Deciding the user requirements from the early stage would be a cost effective strategy for both client and BMS vendor, rather than attaching various features during the installation and operation stages. The two facilities managers also agreed to identify the user requirements in the early stage.

Moreover, Respondent 3 stated that identifying BMS features is important for both client and service provider before designing the system. According to Respondent 4, client/building owner who is interesting in implementing a BMS in their organization shall select the BMS features. Respondents further mentioned that "*we are customizing BMS based on the client requirement and therefore client should have an idea about their requirements and features of the BMS."* According to the respondents, various features can be attached to the BMS and careful selection of each feature is essential to create a sustainable built environment. Respondent 1 and Respondent 2 also agreed the above statement. However, the Respondent 5 argued that the identified two steps namely: identifying user requirement and identifying BMS features should be included in the design stage of BMS implementation. However, there are more factors to be considered under each step and which are more significant for the successful implementation. Therefore, the two steps: identifying user requirement and identifying BMS features were considered as separate stages during the analysis. Finally, with the discussions of respondents, the study identifies the basic stages of the BMS process as follows:

i) *Identifying user requirements*
ii) *Identifying features for BMS*
iii) *Designing the system*
iv) *Installation and commission*
v) *Operation and maintenance*

In each stage, it was revealed that, client or building operator focus different perspectives to attain a sustainable built environment through implementing a BMS. Thus, following section discusses the primary concerns in each stage.

Primary Concerns for basic stages or steps BMS Implementation Process

First step: Identifying user requirements

It was identified that there is a comparatively high trend of installing the BMSs among different built environment in Sri Lanka. The building owners stimulate in adopting BMS technology for the mere reason of reducing energy cost of the building. Respondent 5, and Respondent 6 stated that the main purpose of installing BMS was to cut down massive energy Bill. Apart from that, they are installing BMS as a tool for energy efficiency. In addition, Respondent 6 mentioned that "*BMS is one of the marketing tools that we used to rent out our space. This has created a value addition to our buildings. Customers are very happy if the BMS facility is available.*" Respondent 5 also agreed with the Respondent 6 comments. Further, the Respondent 5 mentioned that "*one of the main reasons for installing a BMS is to obtain LEED certificate. As a result, we got the approval easily from our top management.*" According to the Respondent 2, reducing operational cost, improving maintenance strategies, applying for green building certification and add value to the buildings are the key requirements of implementing a BMS in their facility. Moreover, Respondent 3 stated that all most all the clients are requesting energy efficiency and operational cost reduction through a BMS. Respondent 1 claimed Indoor Environmental Quality (IEQ), energy efficiency, and maintenance should be included in user requirement to create a sustainable built environment through a BMS.

Second step: Identifying features for BMS

It was revealed that a proper combination of BMS features and functions are essential to gain maximum use of BMS in achieving a sustainable built environment. The literature survey was identified five features of BMS (as shown in Table 4) and six respondents agreed with these features. In addition, respondents disclose some other features of BMS as well. For instance, Respondent 3 stated that "*features and functions depend on the client requirement. Anyhow, at the design stage we clearly demonstrate all the functions, and based on their preference, we input the features."* As Respondent 4, *"most of the client requests to install a scheduled routing feature to their major energy consumers, especially for Air Conditioning systems."* It is found that the BMS facilitates to start the sub systems in different time intervals to avoid high electricity consumption through the scheduling routine operations and custom workflows options. Respondent 1 stated that, *"scheduling is an advanced feature in the modern BMS since this feature facilitates to improve energy efficiency and optimize equipment usage by cutting down unnecessary energy wastages."*

Respondent 5 said that, *"BMS is a supportive tool for maintenance management; it could show the correct time when some equipment needed maintenance. Most of the time, we forget to do necessary maintenance to machines and equipment at the right time. But if we can get a message at the right time, then it will be easy*." Respondent 2 stated that, *"If system can directly send any error/issue report to our phone, or if we can operate the system from our homes or if the system can visually emphasized the alarm, it is better. Moreover, this system will avoid human errors and save money."* Respondent 1 believed that building owners accept fully automated system from a BMS. Thus, the practitioners satisfied when the system could respond to emergencies. Respondent 4 stated an example as "*when there was a fire in the building, subsystems such as Air Conditioning, may suddenly shut down through BMS to avoid spreading of fire"* Therefore, the custom work flow is another function of a BMS in order to increase the safety of building equipment though it is expensive. Duty cycling of equipment, programming, custom workflows to integrate subsystems and scheduling routine operations and disaster management were added to the list as per experts' opinions. The BMS features identified through the literature survey and the Experts opinion survey was listed in Table 4.

Table 4: BMS features

BMS Features	Literature review	Additional factors from Expert survey
Optimum start/stop	√	
Monitoring and controlling	√	
Alarming general faults	√	
Effective reporting via short message service (sms), e-mail and visual alarms		√
Operator adjustment	√	
Equipment scheduling	√	
Programming Custom workflows to integrate subsystems		√
Trending past and real time values	√	
Disaster management and Safety		√
Supportive tool for maintenance management		√
Scheduling routine operations and workflows		√
Duty cycling of equipment		√

Third Step: Design the system

In this stage, a BMS vendor will design the BMS for a facility based on the client's user requirements and the BMS features. All the respondents have mentioned various factors to consider in this stage. Respondent 4 mentioned that, clients need to decide the required sub systems to integrate. It was noticed that most of the organizations use BMS to integrate the HVAC system only. Respondent 2 provided an example, as "*if one building is connected only with AC and another has connected AC, Lighting and elevator, the second building contributes more towards energy efficiency approaches than the previous building."* Similarly, Respondent 1 confirmed that the BMS contribution to the sustainability is fluctuated with the integrated subsystems and the technologies. It was found that HVAC, lighting, fire system, boilers, water distribution system, access control, security, and lifts as commonly integrated subsystems.

Moreover, Respondent 3 and Respondent 4 stated that the sub-systems, and capacity of the system should be decided in the initial design stage. Afterwards, cost component will be decided and negotiated with the client. Respondent 1 mentioned that maintenance cost and periodical maintenance procedures, life time of the system and future expansions should be considered when designing a system as sustainable parameters. Respondent 5 stated that *"most important is to quantify the benefit. In our case, we calculate payback period and this allows to get approval from our corporate."* Respondent 6 stated that "*initial cost is very high so that we have to select the optimum system that suite for the building. Cost, service agreement, lifetime, and reliable vendor should also carefully selected"*

From the interviews, it was revealed that border perspectives of BMS should be considered in applying BMS. In the design phase, careful selection of BMS is essential to create a sustainable built environment.

Fourth Step: Installation and commission

The next step is installation and commission which exists when a vendor or installation team commences to install a proposed system to the facility. According to Respondent 2, installation team has to play a key role in this stage and has a major responsibility to develop the proposed system. Respondent 3 and Respondent 4 mentioned that "*in installations we always make sure to achieve the proposed system and we are very much adhering to the specification*." Respondent 1 mentioned "*in terms of sustainability, it is required to check whether, the installation team is following the proposed specification accurately."* Other respondents also hold similar opinions as Respondent 1. Respondent 2 said that it is unexpected to meet the design specification practicality. Therefore, suitable decisions should also be taken during the instillation period to avoid design issues. In addition, Respondent 5 mentioned the importance of checking the specification after completing the BMS installation. As per the Respondent 6, it is the client's responsibility to test and verify the system before the takeover. Respondent 6 said "*in testing period, we are identifying lots of design errors and system errors"* Respondent 2 mentioned that, clients should ensure whether the system has the proposed capabilities and expected outcomes.

Fifth Step: Operation and Maintenance

The operation and maintenance stage is the longest period of the BMS lifecycle. Respondent 3 mentioned "*after installing BMS, the biggest issue faced by the Sri Lankan companies is the lack of skilled person to operate the systems. So that expected outcome of BMS won't be achieved*" Recruiting a skilled person is recommended by other respondents as well. Respondent 6 stated "*our organization is utilizing BMS very well due to skilled human resource that we recruited."* Further, it was identified by Respondent 4 that some of the organizations are not updating BMS with the latest technology. BMS operators ignore the maintenance procedures for the BMS as well. Therefore, the continuous performance of the BMS has become an issue. According to Respondent 1, organizations are not evaluating or measuring the performance of BMS periodically. Hence, under performance or over performance of BMS cannot be identified and it is a threat to the BMS operation. Therefore, majority of the respondents' opinion was that BMS operator should consider maintenance requirement, technology, and performance and continues improvement to utilize BMS efficiently. Respondent 2 said "*installing a latest technical BMS is not provided huge benefit, in fact, there should be a person to utilize BMS efficiently and for sustainability*" Therefore, it is obvious that attention should be given in the operation stage to utilize BMS appropriately.

Barriers for successful introduction of BMS

The study further looks at the barriers for successful introduction of BMS in the Sri Lankan context. Even though certain barriers could be identified by reviewing the literature, its relevance in the local context needed to be checked. The interviewees were asked to identify the barriers when introducing the BMS. All the respondents agreed with the barriers identified in literature survey. In addition, Respondent 2 stated that, "*lack of confidence in end result has become a major barrier in Sri Lankan context."* Respondent 3 confirmed by stating that *"Most of the organizations afraid to invest high initial cost as they are not confident in end result.*" Incapability of the subsystem integration was also identified as a barrier by Respondent 5. Respondent 1 stated that, "*still BMS is a new concept in Sri Lankan context. Therefore knowledge and awareness of technical details may be a problem in our context*." Moreover, Respondent 6 demonstrated "*we faced various issues in utilizing BMS or maintaining BMS due to lack of knowledge and skill persons in our organization.*" Accordingly, it was identified that the concept of BMS is still in the growth stage in Sri Lanka and therefore there is a less tendency in applying BMS. Table 6 summarized the barriers for successful introduction of BMS identified through literature survey and expert opinion survey.

Table 5: Barriers of BMS installation

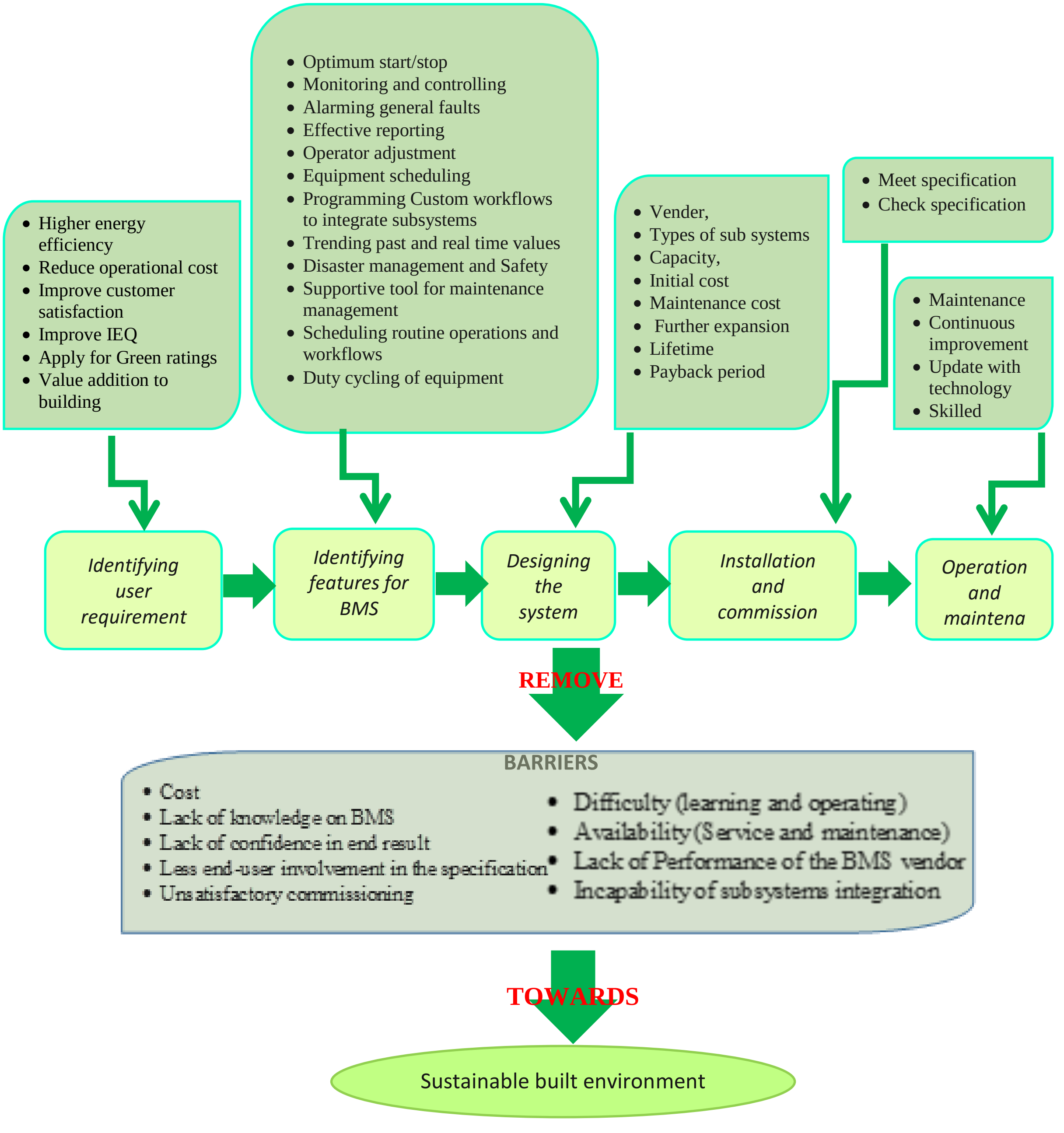
Barriers	Literature review	Additional factors from Expert survey
Cost	√	
Lack of knowledge on BMS		√
Lack of confidence in end result		√
Less end-user involvement in the specification	√	
Unsatisfactory commissioning	√	
Difficulty (learning and operating)	√	
Availability (Service and maintenance)	√	
Lack of Performance of the BMS vendor	√	
Incapability of subsystems integration		√

Discussion

An appropriate step by step procedure is required to utilize a BMS effectively for creating a sustainable built environment. The study identified five sequence steps of BMS implementation process namely; identifying user requirement, identifying BMS features, designing, installation and commission and operating and maintaining as shown in Figure 3. The first step; identifying user requirement describes the purpose of installing a BMS into a building. Mostly, a building owner/facilities manager will decide the user requirements. Higher energy efficiency, reduce operational cost, improve customer satisfaction, improve IEQ, apply for green ratings, value addition to building and maintenance purposes identified as main user requirements. The next step is to select the BMS features. As shown in Figure 3, real time monitoring, controlling every vital point, alarming general faults, effective reporting via short message service (SMS), e-mail, and visual alarms energy saving through optimized operating algorithms highlighted as BMS features. The system will design in next stage. In this stage, user shall think of BMS vendor, sub systems, capacity, initial cost, maintenance cost, further expansion, life time and payback period. It is essential to consider the long term perspectives rather than the short term implementation strategies when designing a BMS. The proposed BMS will install during the installation and commission stage. The BMS installation team and the BMS vendor have the highest responsibility in this stage to develop a proposed system. It is client's duty to check whether the system meets design specifications. Further, the testing and verifying the developed system is important in this stage. Afterward, client or BMS operator is accountable for functioning the system throughout its lifetime. In this stage, a BMS operator shall consider the maintenance schedule, continuous improvement, update with technology, skilled person, and appropriate performance measurement strategy. This stage is the longest stage and proper management is vital to remain in the sustainable built environment.

It is also highlighted that the building owners are confronting various issues in implementing the BMS into their buildings. Cost is one of the prevailing issues among building owners. Other than that, lack of knowledge on BMS, lack of confidence in result and other several issues (as shown in Figure 3) need to be eliminated in achieving a sustainable built environment adopting BMS. The Figure 3 shows the sequence steps and the barriers should be addressed to accomplish a sustainable built environment.

Figure 3: Theoretical model for BMS towards a sustainable built environment



Conclusions and Recommendations

With the pitfalls of continuous consumption of resources in today's world, it's important for architects, engineers and facilities managers to make buildings which are sustainable by its functions and as well as its usage. However, the built environment is facing awkward challenges in accomplishing the concept of sustainability due to their massive impact on the environment. Thus, new technologies such as Building Management System are emerging as a real life solution for the building matters. The study investigates the application of BMS towards a sustainable built environment through an opinion survey. It was revealed identifying user requirement, identifying BMS features, designing, installation and commissioning and operation and maintenance as five sequence key steps to follow when implementing an effective BMS in an organization. Moreover, cost of the operation, lack of skilled persons, lack of knowledge on BMS, and lack of confidence in result are some of the barriers faced by the building sector when implementing and managing BMS in an organization. However, the contribution of BMS towards a sustainable built environment is significant and it is evident that economic, environment and social pillars can be easily achieved through effective and efficient application of BMS.

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