A STUDY OF BUILDING AUTOMATION SYSTEM (BAS): A CASE STUDY AT THE SCHOOL OF CIVIL ENGINEERING, UNIVERSITI SAINS MALAYSIA

FITRI BIN MAHAMAD MUDZRABI

SCHOOL OF CIVIL ENGINEERING
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By

FITRI BIN MAHAMAD MUDZRABI

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Name of Student: Fitri Bin Mahamad Mudzrabi

I hereby declare that all corrections and comments made by the supervisor(s) and examiner have been taken into consideration and rectified accordingly.

Signature: Approved by:

_____ _____

(Signature of Supervisor)

Date : Name of Supervisor :

Date :

Approved by:

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(Signature of Examiner)

Name of Examiner :

Date :

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ABSTRAK

Peningkatan gaya hidup mewah telah meningkatkan permintaan BAS kerana meningkatnya kesedaran tentang teknologi ini yang telah mengubah teknologi bangunan serta peningkatan keselamatan dan keselesaan kepada pengguna. Perubahan ketara ini telah membawa banyak perubahan kepada struktur bangunan, sistem, perkhidmatan dan pengurusan. Gabungan faktor-faktor ini telah membawa kepada era bangunan automatik dan pintar. Teknologi yang lebih maju telah diwujudkan untuk mewujudkan satu sistem penggunaan tenaga yang cekap dan aspek ini digunakan sebagai satu kunci utama untuk banyak negara.

Objektif disertasi ini adalah untuk mengkaji konsep Sistem Automasi Bangunan (BAS), menentukan trend, dan faktor-faktor yang mempengaruhi keperluan dan pertumbuhan automasi bangunan di Pusat Pengajian Kejuruteraan Awam, USM. Selain itu, untuk mengukur tahap statistic pengetahuan mengenai teknologi BAS dalam kalangan pelajar di Pusat Pengajian Kejuruteraan Awam, USM.

Kajian tertumpu kepada aspek BAS yang boleh didapati di Pusat Pengajian Kejuruteraan Awam, Universiti Sains Malaysia (USM) dengan mengambil kira khusus kepada lima aspek Sistem Automasi Bangunan iaitu pemanasan pengudaraan dan penghawa dingin (HVAC), sistem kawalan lampu, kawalan kebakaran dan keselamatan hidup, akses kawalan dan keselamatan, dan sistem pengurusan bangunan.

Hasil kajian mendapati bahawa faktor utama yang mempengaruhi trend Sistem Automasi Bangunan (BAS) di Pusat Pengajian Kejuruteraan Awam, USM adalah factor kecekapan tenaga, trend semasa BAS di Pusat Pengajian Kejuruteraan Awam, USM adalah dalam trend sederhana, jadi peningkatan dalam penggunaan BAS adalah penting untuk mengurangkan masalah sumber tenaga yang menghadapi tekanan yang besar kerana permintaan tenaga meningkat lebih tinggi dari hari ke hari.

ABSTRACT

The increase of luxury lifestyle has increased the demand of BAS due to increasing awareness about this technology that has transformed the building technology as well as the increase of safety and comfort to users. These significant changes have brought many changes to the structure of the building, systems, services, and management. The combination of these factors has led to the era of automatic and intelligent buildings. The advanced technology was created to establish a system of efficient energy usage and this aspect is basically used as a key objective for many countries.

This dissertation's objective is to review the concepts of Building Automation System (BAS), determine the trends, and the factors that influence the need for and the growth of building automation at the School of Civil Engineering, USM. Besides, to statistically measure the extent of knowledge about BAS technology among the students at the School of Civil Engineering, USM.

The study focussed on the aspects of BASs that are available at the School of Civil Engineering, Universiti Sains Malaysia (USM) with specific regard to the five aspects of Building Automation System that is heating ventilation and air conditioning (HVAC), lighting control system, fire and life safety control, security and access control, and building management system.

The result shows that main factor that influences the trends of Building Automation System (BAS) at the School of Civil Engineering, USM is energy efficiency, As the current trends of BAS at the School of Civil Engineering, USM is in moderate trend, so the increases in adoption of BAS are important to reduce the problem of energy sources that facing great pressure due to energy demand is scaling higher from day to day.

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LIST OF ABBREVIATIONS

BAS	**B**uilding **A**utomation **S**ystem
USM	**U**niversiti **S**ains **M**alaysia
OECD	**O**rganisation for **E**conomic **C**ooperation and **D**evelopment
HVAC	**H**eating **V**entilation and **A**ir **C**onditioning
BMS	**B**uilding **M**anagement **S**ystem
ASHRAE	**A**merican **S**ociety of **H**eating, **R**efrigerating and **A**ir-**C**onditioning **E**ngineers
IBI	**I**ntelligent **B**uilding **I**nstitute
IB	**I**ntelligent **B**uilding
AI	**A**rtificial **I**ntelligence
EMS	**E**nergy **M**anagement **S**ystem
LED	**L**ight-**E**mitting **D**iode
PIR	**P**assive **I**nfrared **S**ensor
CCTV	**C**losed **C**ircuit **T**elevision **C**amera
IoT	**I**nternet **o**f **T**hings
GHG	**G**reen **H**ouse **G**as
BEMS	**B**uilding **E**nergy **M**anagement **S**ystems
KBS	**K**nowledge **B**ased **S**ystem
GBE	**G**reen **B**uilding **E**nvironment

CHAPTER 1

INTRODUCTION

1.1 Background of thesis

Building Automation System (BAS) is the latest technology that has been implemented at the School of Civil Engineering, USM. There are a lot of Building Automation System (BAS) that may be noticed at the School of Civil Engineering, USM but only some part of the device that can be well known, some of them is new especially about the details, the function and the effects of this technology to the School of Civil Engineering, USM. Therefore, a study was carried out to determine the current state of BAS at the School of Civil Engineering. This is in line with USM requirements outlined by The Organisation for Economic Cooperation and Development (OECD, 2007) suggested the institution of higher learning should contribute towards sustainable development by demonstrating good practice through on-campus management and development activities, strategic planning, building design, waste minimisation, and water and energy efficiency practice, responsible purchasing programmes and pursuing good citizen type initiatives like the "green campus" concept (USM, 2008).

Innovation of the building has changed from a conventional building that has been used in the old days that separates the functions or the system of building such as security, fire, energy management and temperature control to the automated building. There are a few factors that drive the increase of the usage of Building automated systems (BAS) such as the demands of the intelligent buildings continue to evolve due to users starting to realize the potential economic, sustainability, and the business benefits that can be gained from investing in this type of building. Building Automation Systems use advanced sensors that play a main role in transforming facilities into intelligent buildings.

Most of this intelligent devices contain sensing devices that deliver a digital output and are networked via wired or wireless configurations to support actionable judgement that can improve building performance.

BAS have many functions which ensure ease of operating performance without ignoring the important features such as comfort and safety of building occupants. BAS is also suitable for all stages of the building, whether in new building constructions, refurbishment and renovation of old building to the new building control system. A building that is controlled by the building automation system is often referred to as intelligent building or smart house.

This dissertation focussed on the aspects of BAS at the School of Civil Engineering, University Sains Malaysia with specific focus on the five aspects i.e. heating ventilation and air conditioning (HVAC), lighting control system, fire and life safety control, security and access control, and building management systems.

A Building Automation System (BAS) is a system of network integrated computer components that automatically control a wide range of building operations such as lighting, smoke detector, security, access control, card reader, heating ventilation and air conditioning (HVAC), fire and life safety, Building Management Services (BMS), audio-visual systems and more .

1.2 Problem Statements

The future of power generation depends largely on what can be saved than what can be produced. With the high rate of population increase, energy sources are facing great pressure since energy demand is scaling higher and higher each day, with the uses of BAS it can be seen as the effective way solution for conservation of energy at the

School of Civil Engineering, USM to achieve the target of future trends in architecture and design that is moving towards zero energy consumption in homes and building.

The building of School of Civil Engineering, USM also have a problem with the number of occupants in and out without knowing who is accessing the building. So, the uses of BAS technology is an effective way to enhance the safety of building occupants and protecting assets by allowing only those with required credentials access. This system has an electronic control access system that provides controls access to non-public areas where authentication is required. Access control is concerned with determining only the allowed activities of legitimate users by requiring mechanism such as a card authentication which reflects the clearance level of personnel in the building.

1.3 Importance and benefits of thesis

The importance of this research is to study the trends and what are the factors that influence the use of this technology at the School of Civil Engineering and finally find out the main factors that influence the need for and the growth of building automation at the School of Civil Engineering. This is an important aspect that needs to be studied to make valid conclusions that top management can rely upon due to the various benefits it provides to the occupants of School of Civil Engineering and to make this building as an example for Smart Building in Malaysia in the future.

1.4 Aims

This dissertations objective is to review the concepts of Building Automation System, determine the trends, and the factors that influence the need for and the growth of building automation at the School of Civil Engineering. Besides, to investigate the

extent of knowledge about BAS technology among the students at the School of Civil Engineering, USM.

1.5 Objectives

1) To review the concepts of Building Automation Systems.
2) To determine the trends and factors that influence the needs for and the growth of Building Automation System at the School of Civil Engineering, USM.
3) To statistically measure, the extent of knowledge on BAS technology among the students at the School of Civil Engineering, USM.

1.6 Scope of work

This study uses questionnaire as a case study approach that was limited to 40 students. The target respondents are students of the School of Civil Engineering, USM. Students have been chosen as target respondents as students can be classified as clients of the School of Civil Engineering, USM for 4 years and the data obtained may not be biased to the School of Civil Engineering, USM. The questionnaires were distributed to determine the response of the students towards the technology of BAS that are available at the School of Civil Engineering, USM. The data obtained were used for the analysis to produce a comprehensive database on the study on BAS and top management team can rely upon in their appreciation of the real purpose and advantages of BAS and comprehensive range of benefits available to occupants at the School of Civil Engineering, USM.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Building Automation Systems, (BAS) can be considered as a tool in the hands of building operations personnel that provides a more effective and efficient control over all the building systems. Today, BAS is a widely accepted and adopted technology through homes, buildings, residential and industrial complexes. BAS is concerned with improving the interaction among integrated systems and the habitants or users of the buildings.

Historically, BAS was developed from automatic control of heating, ventilation, and air-conditioning systems, (HVAC) simultaneously improving human comfort and reducing energy costs (Figueiredo and Martins, 2010). BAS increases the interaction of mechanical sub-systems within a building and reduces energy consumption as well as allowing for off-site building control which ensures occupants' comfort and ease in property and facilities management. Currently, there are numerous building subsystems controlled by BAS, among them are lighting control systems, air conditioning and heating, alarms and security systems, audio-visual systems, water systems of heating and cooling and shading, amongst others. BAS uses computer-based monitoring to coordinate, organize, and optimize the above-mentioned building control sub-systems.

For a BAS to attain its intended purpose of maximum user control, emphasis should be put on the proper functioning of computer hardware's and software's by identifying the potential benefits and practical or technical limitations early. The intended operator of the system should then be identified, implying that building designers,

contractors, property managers and end users should work hand in hand for the success of BAS.

Building automation control has come a long way in recent years, dating back from proprietary systems and protocols to standard-compliant architecture that is backward and forward compatible. Modern BAS provides remote monitoring and alerting capabilities that can warn operators of a system of component failure, any abnormal condition or an increase in system energy consumption within a building. Such alerts are not restricted by geographical boundaries and this allows for off-site monitoring beyond borders or after hours ensuring timely response and correction.

2.2 Definition of key terms

There are several key words that are used in this research and a brief definition is required to fully understand their meaning. The terms include: - Conventional Buildings, Building Automation System (BAS), Smart Buildings, and Intelligent Building (IB).

2.2.1 Conventional Building

Conventional building, or simply Conventional refers to a building built according to the common practice of a specific country in a specific period (Sartori and Hestnes, 2007). A conventional building is easily understood as a traditional house that separates building systems or functions such as temperature control, energy management, fire and security.

2.2.2 Building Automation System (BAS)

BAS refers to a system of network integrated computer components that automatically control a wide range of building operations such as lighting, access control,

HVAC, fire protection, audio-visual systems security and more. It has centralized, interlinked networks that have hardware's and software's, which monitor and control the environment in all types of facilities. The automation system conserves energy, lightens loads, ensures that the facilities operate efficiently and make sure building occupants are comfortable and safe, providing comprehensive, customized solutions that bring out a building's top performance while keeping the people inside safe, comfortable, and productive. Basically, building automation begins with control of mechanical, electrical, and plumbing systems. A building controlled by a BAS is often referred to as an intelligent building, smart building or a smart home.

The methodology proposes for integrating the data within a BAS using multi-media networking technology and providing the BAS with artificial intelligence (AI) using knowledge-based system (KBS) technology (Clark and Mehta, 1997). The early design of integrated building management system is a system that merely collects the outputs from the various controllers for monitoring purposes. Thus, with the help of AI in BAS, the system can assess, diagnose and suggest the best solution. Energy saving can be achieved by inserting rules, like time schedule, into the system to control the environment within the building for maximum occupant comfort at minimum cost.

2.2.3 Smart Buildings

Smart Buildings 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 to meet the drivers for building progression: energy and efficiency, longevity, and comfort and satisfaction. The increased amount of information available from this wider range of sources will allow these systems to

become adaptable, and enable a Smart Building to prepare itself for context and change over all timescales.

This is the integration of building technology and energy systems in buildings. Smart buildings reflect technological advancements and convergence of building systems. They provide information about a building or space that is within a building to allow the owner or occupants of the building to manage it.

2.2.4 Intelligent Building

The term “Intelligent Buildings” was first used in the United States in the early 1980’s and a definition given by the former Intelligent Building Institution in Washington was an intelligent building is one which integrates various systems to effectively manage resources in a coordinated mode to maximise technical performance, investment and operating cost savings, and flexibility (Derek, 1997).

There are four basic elements that have been outlined by the Intelligent Building Institute (IBI) to consider the building as an intelligent building. The four basic elements are structure, systems, services and management, and the interrelationship between them. The European Intelligent Building Group defines an intelligent building as one that "incorporates the best available concepts, materials, systems and technologies; integrating these to achieve a building which meets or exceeds the performance requirements of the stakeholders which include the building owners, managers and users as well as the local and global community (Ben and Margaret, 2014).

This building function is not only for shelter but simply as a basic requirement it is an expression of self, investments, policy and most importantly a safe and comfort place where people can experience ultimate comfort, convenience, safety, security, long-term flexibility and marketability (Ben and Margaret, 2014).

2.3 Subsystems of Building Automation System (BAS)

2.3.1 Lighting Control Systems

BAS allows for all lighting to be controlled centrally and can be switched on, off or dimmed at a pre-defined time, depending on occupancy, daylight availability, and alarm conditions or in relation to the weather/geographic conditions outside the building. The occupied - unoccupied lighting control is a time-based program that schedules the on or off time of lights for a building or zone to coincide with the occupancy schedules. Another way to reduce the costs associated with lighting is to control the level of lighting in a building.

Lighting controls can be either stand-alone, room dependant types, or larger networked systems, where the dimmer units are fitted in an electrical cupboard and operated by a network of external devices like sensors and control panels (Vattano, 2014). The concept behind this controls is to operate lighting automatically according to the function of an area, time of day, ambient light levels, or occupancy. An important aspect of lighting is programmability which is the ability to remember lighting levels as a series of settings. These settings, also known as scenes, can be recalled automatically by the dimmer system or by the central building control system. Intelligent lighting controls have many advantages over manual ones, including convenience, creating ambience, increased design flexibility, energy savings, reduced lamp replacement costs and security.

According to article on "Intelligent Lighting Control Systems" from a book entitled “Intelligent Building Control”, lighting can play an important part in security, deterring intruders whether the property is occupied or not. Low levels of illumination can be programmed to operate at night in certain rooms or hallways. When the building is unoccupied, levels can be selected that copy normal usage. This can be by time clock

or by selecting a vacation mode. Dimmed or selectively switched levels of illumination will save energy and is more effective than leaving lighting on or using simple plug in timers (Robin, 1989).

The market for lighting controls in commercial buildings has expanded and transformed radically in recent years. Demands for local controls, such as occupancy sensors and photo sensors, as well as networked controls are on the rise as adoption rates of light-emitting diode (LED) lighting begin to hike as control technology improves and becomes less expensive. The lighting control techniques have been focussed which could help in energy saving. Lighting not only consumes energy but also generates heats in the building, thus it adds to the cooling loads on the air conditioning system.

Why should Public and Commercial Buildings install intelligent lighting solutions? According to a rapidly growing number of Public and Commercial Building owners/developers/managers and users, open standards convergent building control solutions make business sense, i.e. profits. Electrical lighting loads account for between 25% and 60% of such buildings total demand and fully automated and intelligent dimming lighting can save up to 75% of this.

According to Alton Controls Sdn. Bhd, there are a few reasons why the lamp should be turned off when we not in used. This is because typically up to 40% of a building's electrical usage is from lighting. Sometimes, lighting or HVAC systems for entire floors remain on when only one or no occupant is present. Buildings with uncontrolled lighting will experience a huge energy wastes.

The use of automatic shut off lighting in large commercial buildings helps facility managers and building owners save energy and money. Figure 2.1 below shows an example of an occupancy sensor.

Figure 2.1: Occupancy sensor, (Alton, 2011).

The principle of operation and benefits of occupancy sensors are well understood. By turning off the lights when a space is unoccupied, energy savings can result by eliminating waste. Occupancy sensors can also enhance security and reduce light pollution.

Due to their relative simplicity and high energy savings, coupled with the requirement in prevailing energy codes for automatic lighting shut-off, occupancy sensors are rapidly becoming a standard feature in new buildings and retrofits. Figure 2.2, 2.3, 2.4, and 2.5 illustrate some of the lighting control systems adopted.

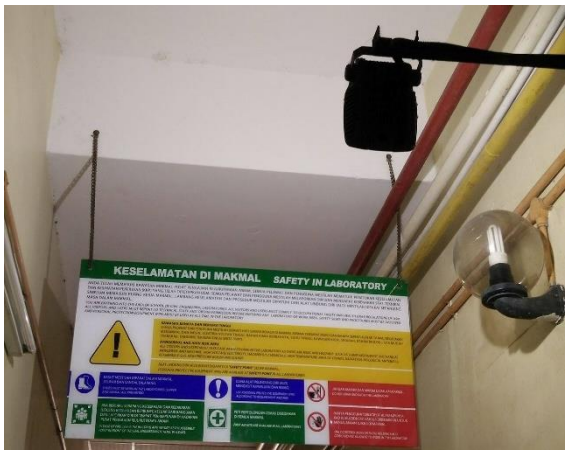

Figure 2.2: LED lighting (in front Geomatics lab)

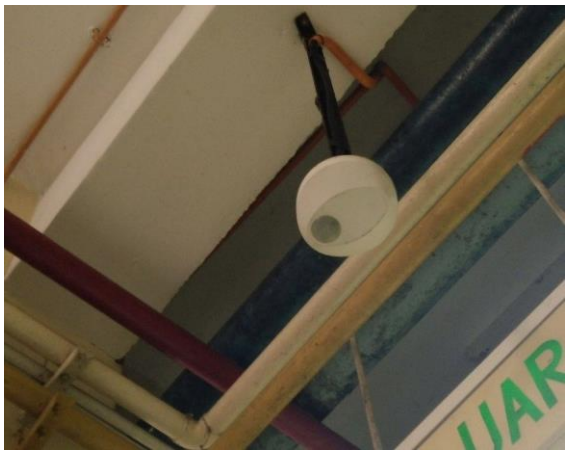
Figure 2.3: Motion detector (in front Geomatics lab)

Figure 2.4: Emergency lamp (at structure lab)

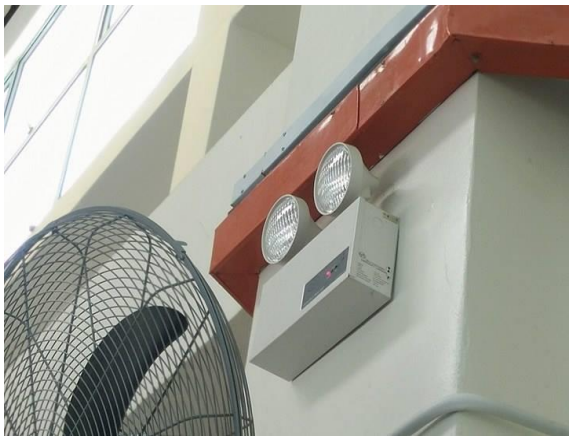

Figure 2.5: Emergency lamp (at hydraulic lab)

2.3.2 Heating Ventilation and Air Conditioning systems (HVAC)

HVAC can consume up to more than half of the total energy of a building and thus energy conserving operation in buildings require control systems for Heating, Ventilating, and Air Conditioning. The HVAC control system should be designed to be able to sustain a comfortable building interior environment, to maintain acceptable indoor air quality, to be as simple and inexpensive as possible and yet to meet HVAC system operation criteria reliably for the system lifetime and to result in efficient HVAC system operation under all conditions. HVAC systems like lighting, respond automatically or manually to various stimuli in the environment like weather, time of day, building occupancy or alarm conditions as in the case of a fire.

No matter where one is in the world the building requires heating, ventilation or air conditioning (HVAC) to provide a comfortable productive environment for its occupants. However, HVAC isn't cheap, it accounts for approximately half of typical buildings total energy consumption. So, making sure that the system is running as efficiently as possible is critical to the buildings operational costs. HVAC controllers form the brain and nerves of a HVAC system, monitoring interior conditions and

responding to load changes in a coordinated fashion providing comfort and energy efficiency.

The HVAC can automatically provide ambient temperature depending on the overall temperature conditions of the room. For example when it is hot, a cooling effect is provided while when it is cold, a warming effect is provided. The HVAC can also be manually set to be within certain ranges of temperature and when it is above or beyond the set temperature range, it automatically sends a message to the property manager about the temperature conditions in a room and they are able to adjust it from the control panel. Figure 2.6 illustrates an extract fan incorporated in one of the buildings.

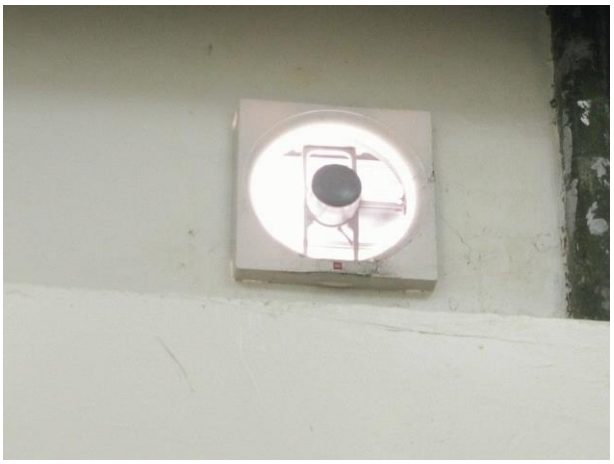

Figure 2.6: Extract Fan (at hydraulics lab)

2.3.3 Security and Access Control Systems

Security systems such as closed circuit television (CCTV) cameras once integrated with building automation systems, can offer building surveillance always with records being simultaneously stored on backup files in a central control room for reference if need be . This technology is one of the important thing now, mostly occupant seeking a building that have this technology for consideration before bought the building. Today, BAS has greatly increased safety in building and this attracts investors in this

market. BAS have access control systems that enhance safety of building occupants by allowing only those with required credentials access. However, this controls system required integration with other systems such as video surveillance and HVAC.

This system has an electronic control access system that provide controls access to non-public areas where authentication is required. They have a system that detects intrusion in such areas and a manual authentication system that is used in case connectivity is unavailable. These systems use access cards or biometric authentication at the entry points of such areas such as doors and windows and this increases the degree of safety in buildings (Delta Controls, 2017).

Access control is concerned with determining only the allowed activities of legitimate users by requiring an authentication mechanism such as a password which reflects the clearance level of personnel in the building. The objectives of an access control system are to protect system resources against inappropriate or undesired user access . There remains the need to protect occupants and assets. Small sites however do not have the luxury of dedicated security teams so the need of automation to lighten the load.

Furthermore, usually occupants will always lose keys or keys can remain with staff who leave. Replacing key is expensive and time consuming as all keys must be replaced, not just one. Alarm systems are constantly ringing and with no idea as to who is in the building and when they arrived. As a solution Access Control System (ACS), can be used to replace keys, with this system can eliminate re-keying because access control can be used to replace keys. Each key is now a credential in ACS and can be individually assigned. If the credential is lost, then it can be disabled in the software and a new credential assigned. No one else is affected and no extra cost is incurred by re-keying the lock (Delta Controls, 2017).

ACS also can make the intrusion system can be integrated with the access control hardware. When the building is locked, the alarm activates thus giving the peace of mind that the building is being actively protected. When the building is unlocked in the morning, the intrusion system deactivates (Delta Controls, 2017).

The ACS can also be integrated with the CCTV system. With reduced staff, CCTV gives managers their eyes and ears on the ground. Each image can be integrated with the access control, so security breaches can immediately bring the correct image to the attention of the manager.

Access control lets the occupants in control of the building, who can allow or deny access at any time. The system can quickly run reports to determine who has accessed the building and thus giving a constant data on the buildings.

The benefits from this technology is that it we can allow the building owner to see who is coming and going into the building, lower the cost and increase security of the building by not issuing keys, allows managers to understand the occupancy patterns of their buildings and lock down your building and activate the intrusion alarm automatically (Delta Controls, 2017).

Security systems incorporated range from CCTV cameras with centralized control and monitoring screens, while access control systems range from biometric card or fingerprint readers and gate barriers. The access control systems only allow permitted persons to access certain spaces by the use of cards or fingerprints and once access has been granted, the BMS is able to monitor their movement, by recording which card was used at what time, to enter what space, and the details of the card owner. Figure 2.7 and Figure 2.8 illustrates the Centralized Access Control System and card reader that are used while, Figure 2.9, 2.10 and 2.11 illustrate the CCTV Control Room, Emergency Door Release and CCTV.

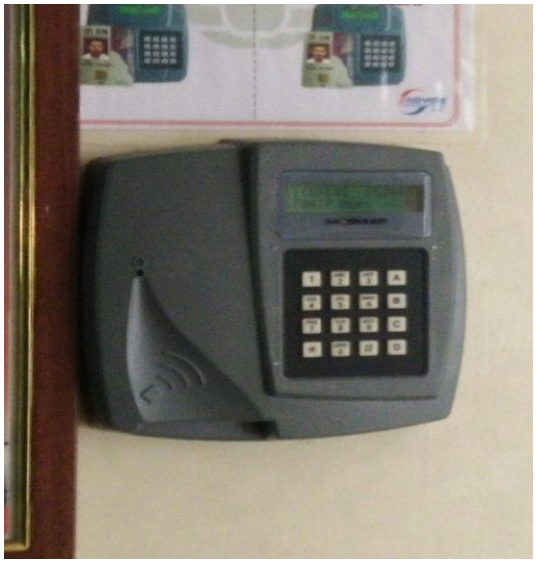

Figure 2.7: Centralized Access Control System (in front of Computer lab)

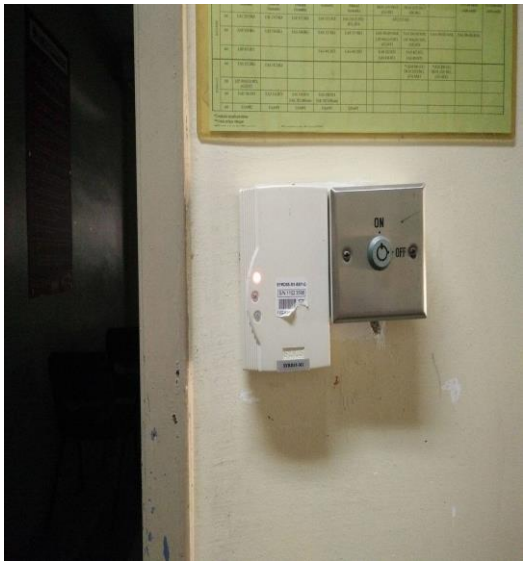

Figure 2.8: Card Reader (at Tutorial Room)

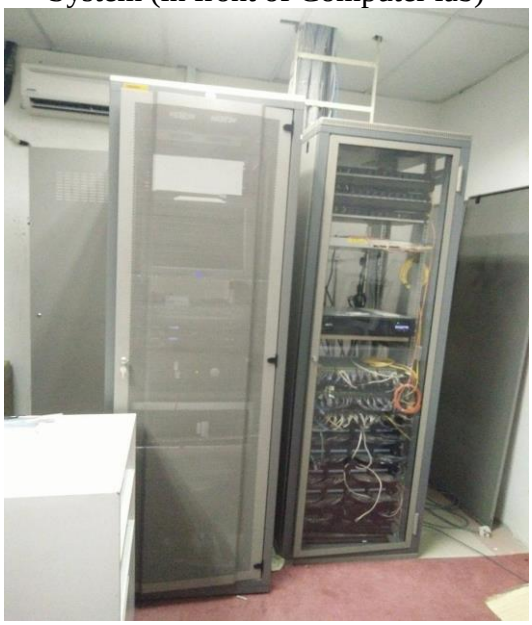

Figure 2.9: CCTV Control Room (inside Computer Lab)

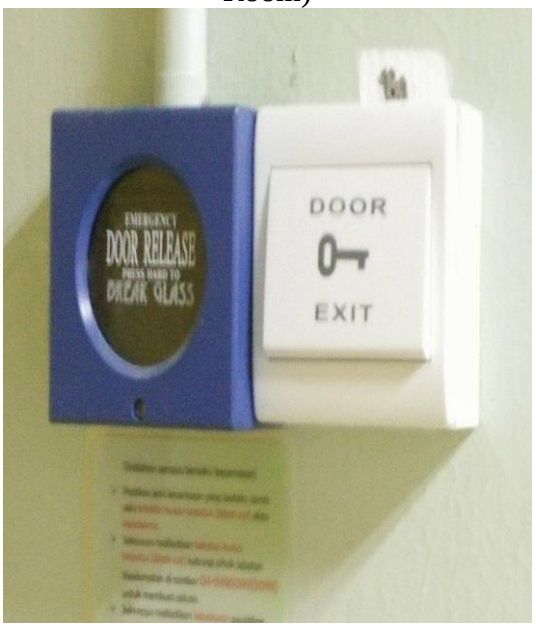

Figure 2.10: Emergency Door Release (inside Tutorial Room)

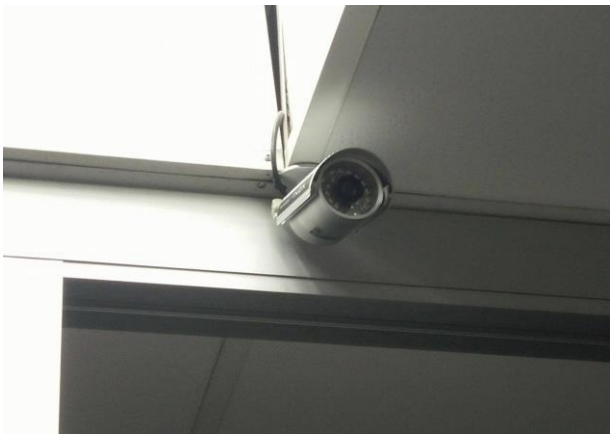

Figure 2.11: CCTV (in Computer Lab)

2.3.4 Fire and Life Safety Systems

There are many reasons for integrating fire alarm systems with other building automation and control systems according to, as in the case of door locks and a fire occurs, it will be easy when all doors are automatic unlocked without the need to use any key or scan any card. Besides that, among the reasons given by include a smoke control, main access to building information will be easier in maintenance, sharing sensor data, obtaining information about the location of people during an emergency, and providing infrastructure for new technology to improve performance and safety.

New sensors are being developed that can recognize various contaminants in the air that can represent a fire signature or a hazardous contaminant that poses a life safety threat. In an integrated system, these sensors could be used by the HVAC control system to control ventilation rates with no adverse impact on their life safety functions. Multiple uses for the same information will make it more cost-effective to implement new sensor technology, for example, in some buildings, access control systems monitor the location of building occupants. Providing access to this information to the life safety systems could be very helpful in an emergency as emergency response personnel would know

where to look for occupants who need to be evacuated. They could also reduce the risk to themselves by avoiding dangerous areas where no people are present.

A research was carried out by the National Institute of Standards and Technology (NIST) to develop a new generation of smart fire alarm panels that can make use of sensor data from an integrated system to calculate heat release rates in a fire. Using this information, a fire model in the panel could predict how the fire will grow and spread. Emergency response personnel then used this prediction to plan a strategy for fighting the fire. It could even be transmitted by the building systems to fire stations or fire trucks so that planning can begin before emergency personnel reach the site. This could significantly improve response time, saving lives and reducing property loss

The detection systems include smoke detectors and the fire alarm which serves as both a detection and control system as it alerts the occupants of the building and fire brigade as well as activate sprinkler systems for basement levels. The sprinkler systems incorporated are served by an automated water pump that monitors the level of water in the tank and automatically starts the pump when a certain level of the tank is reached and stops the pump when the tank is full. This helps in ensuring a constant supply of water for daily use and in the event of a fire as well as minimizes wastage caused by overflowing of the tank. A fire control panel is also located at a central point where one can identify exactly which fire alarm has gone off and take appropriate measures to control the fire. Figure 2.12, 2.13, 2.14, 2.15 and 2.16 illustrate some of the fire and life safety systems that can be adopted.

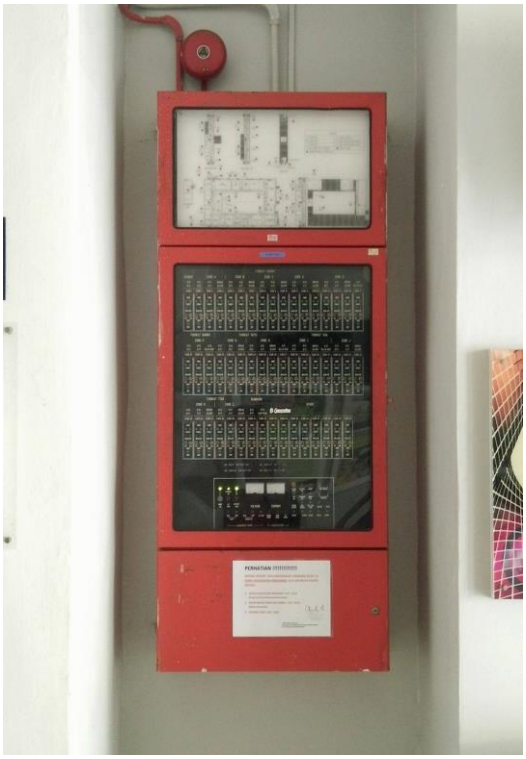

Figure 2.12: Fire Control Panel (in fronts of the School of Civil Engineering, USM)

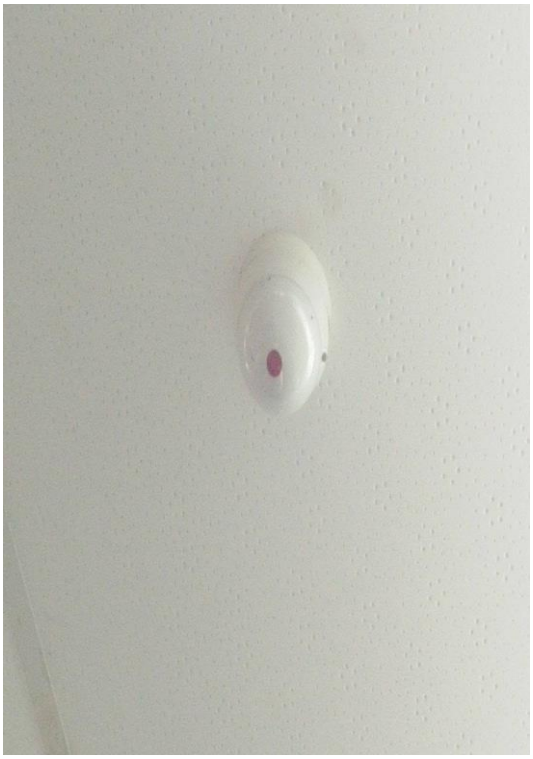

Figure 2.13: Smoke Detector (in Computer Lab)

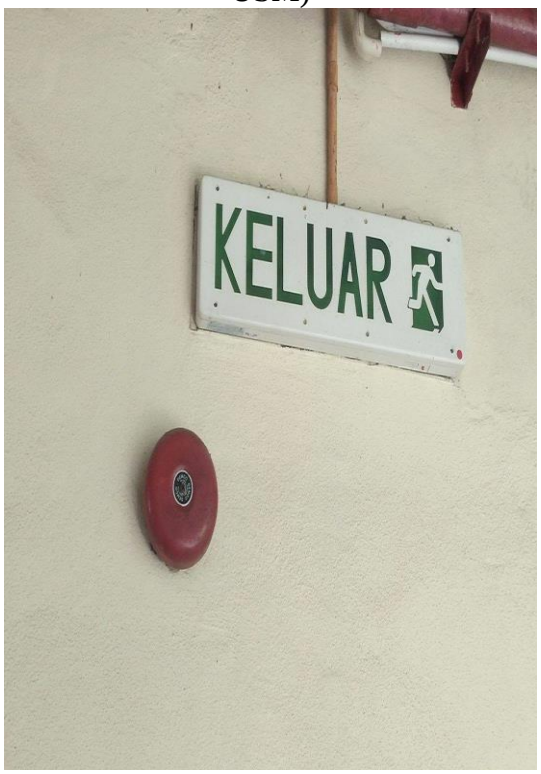

Figure 2.14: Exit Sign (at Structure Lab)

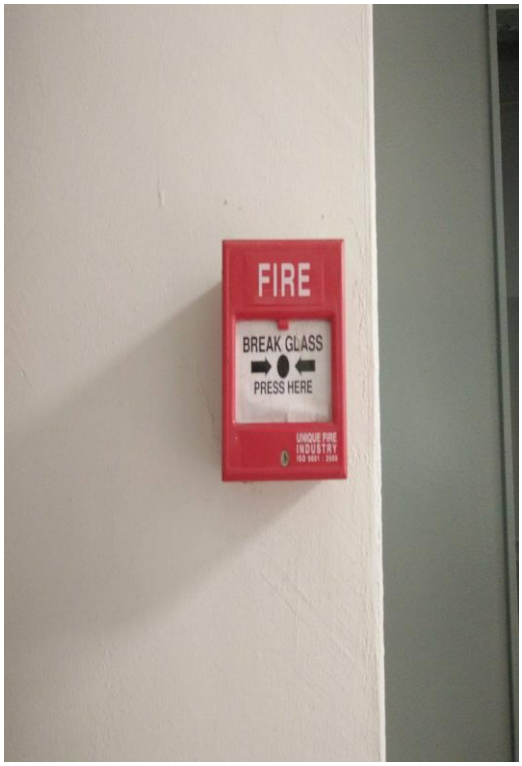

Figure 2.15: Fire Alarm System (at Tutorial Room walkway)

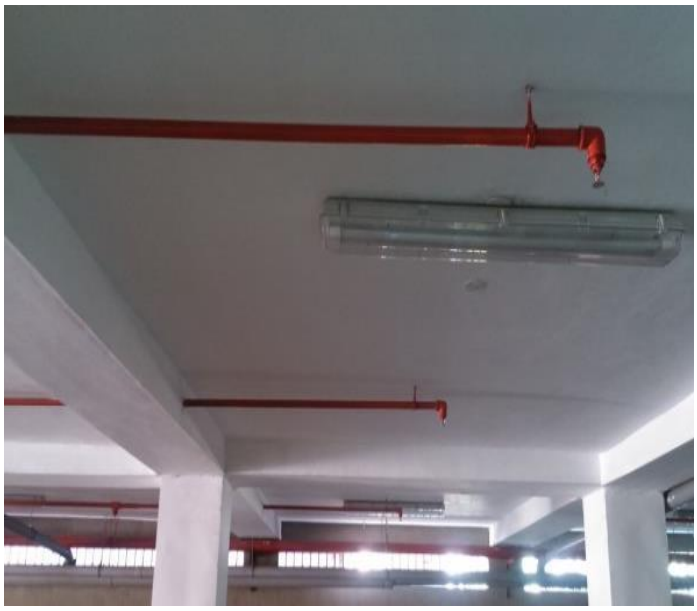

Figure 2.16: Sprinkler System (not available
At the School of Civil Engineering, USM)

2.3.5 Building Management Systems, (BMS)

A Building Management System (BMS) is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems. BMS are most commonly implemented in large projects with extensive mechanical, electrical, and plumbing systems. Systems linked to a BMS typically represent 40% of a building's energy usage, if lighting is included, this number approaches 70%. BMS systems are a critical component to managing energy demand. Improperly configured BMS systems are believed to account for 20% of building energy usage, or approximately 8% of total energy usage in the United States. Fire alarm systems and elevators are also sometimes linked to a BMS, for monitoring. In case a fire is detected then only the fire alarm panel could shut off dampers in the ventilation system to stop smoke spreading and send all the elevators to the ground floor and park them to prevent people from using them in the event of a fire (Fibrecom, 2010).

Building Management Systems, (BMS) are linked to security and access control systems or fire alarm and life safety systems for coordinated response to emergency situations like fires or invasions. About 60% of the buildings had incorporated BMS which enables central monitoring, control and integration of all the building systems such as lighting, HVAC, security and access control and fire systems. BMS also enables offsite monitoring of the building systems through smartphones and tablets where notifications are delivered to the property manager and the maintenance managers of the system in case of a breakdown or malfunction of the system .

The global market for Building Energy Management System (BEMS) continues to grow as technologies reach maturity and customers gain understanding of the business values generated by investment. Across customer segments, the economic impacts of BEMS continue to dominate the decision-making process. As the cost of supplemental monitoring and control devices continues to decrease, BEMS are becoming more cost-effective options for a broader set of customers. Furthermore, these systems generate complementary strategic benefits such as greenhouse gas reductions and sustainability improvements that help support the investment decision (Navigant research, 2015).

The market landscape continues to evolve as trends such as corporate awareness of the Internet of Things (IoT) and demand for data-driven decision support tools facilitate the adoption of BEMS. These systems support customer needs with offerings in four categories: visualization and reporting, fault detection and diagnostics, predictive maintenance and continuous improvement, and optimization. Solutions may span across these offering categories or provide tools for one specific offering, and they vary in technology maturity based on functionality and integration. This variability in solution design and functionality reflects the newness of the market and diverse customer needs.

According to Navigant Research, (2015) the global BEMS market is expected to reach $2.4 billion in 2015 and grow to $10.8 billion by 2024 (Navigant research, 2015).

This Navigant Research Report assessed the global market for BEMS, including the software's, services, and hardware components. The study analyse the current state of the market and provides insight into the future direction of BEMS offerings based on the functionality of emerging technologies, shifting customer demands, and other market dynamics. Global market forecasts, segmented by region, offering type, and customer type, extend through 2024. The report also examines variations in the adoption of BEMS across geographies and customer segments, as well as the competitive landscape (Navigant Research, 2015).

2.4 Building Automation System (BAS) Practice in Malaysia

There are so many buildings in developed countries have adopted the systems and in Malaysia there are a few building that practise this technology. To illustrate the practice, we can use a case study example of Menara Telekom Malaysia Berhad that located at Jalan Pantai Baharu, 50672 Kuala Lumpur, Malaysia.

Menara Telekom Malaysia Berhad has 7.59 Acres (3.07 Hectare) total development area and total gross area is about 256509.51 sq. m, this building has 310 m tower height from ground and 345 m from sea level. Building has 7 sections, first South Wing has 55-storey under the helipad, second North Wing that has 77-storey to the tip, third the core area has lift lobbies, mechanical and electrical services risers, toilet and pantry, forth is Helipad max load is 2 tonne at 59 floor, fifth Sky Garden that has 22 nos. at every 6 floor each wing, sixth is food court that has 16 nos. of stalls at level 3 and lastly Tel. Exchange that has 80K lines at Level Ground 2 (Hanis et. al., 2011).

The design has been influenced by the bamboo shoot, which has a symbolic meaning in the Malaysian culture that represents strength, rapid growth and fertility. It was completed in 2001 at a cost of RM600 million. Its unique curvilinear structure is based on renowned Malaysian sculptor and artist Latiff Mohidin's award-winning masterpiece the “Pucuk Rebung” which depicts a young bamboo shoot with strong foundations at its root and little leaves sprouting. The building is designed by Hijjas Kasturi Associates (Rao and Ezrin, 2006).

The building is rated as a 6-star intelligent building by City Hall, which provides infrastructure for multimedia services with high speed connectivity and features an energy efficient facilities management system. The building is equipped with an Integrated Building Management System (IBMS) concept created by Telekom Malaysia's research and development division to provide a productive and cost-effective environment. The IBMS has the ability to integrate 11 key mechanical and engineering sub-systems within the tower connecting each another from the air conditioning and ventilation system, to the lighting control system, and the security management and lift and escalator systems. Another key feature in the building is the document conveyor system, which transports documents and parcels within the building from three floors underground to the 55th floor that is the highest office floor in the tower (Rao and Ezrin, 2006).

Menara Telekom can be fill with 6,000 occupants and has 22 "Sky Gardens" that located one on every third floor to provide a conducive working environment. The landscaped terraces are calm, private retreats for rest and relaxation. Among the facilities there are a professional performance theatre for an audience of 2,500 and exhibition halls. Occupants of the building can also enjoy sports and recreational activities at the Menara

Telekom Sports Complex and an indoor gymnasium is also available for exercise enthusiasts (Rao and Ezrin, 2006).

2.5 Considerations for a Building Automation System (BAS)

2.5.1 Environmental Consideration

Buildings are large entities and it can give impact upon the environment in various ways due to the uses of large area. In this present day, constructions of building clearly consume large quantities of physical resources such as materials, energy and money in their construction, maintenance and use. Before installing BAS, one should consider the environmental impacts of the building during its entire life cycle.

A Green Building Environment (GBE) is efficient, productive, comfortable, safe and healthy, and supports the business needs of the occupants. Building owners and managers face several challenges in establishing optimum levels for each of these components of GBE. Building owners invest in BAS to automate their buildings. A well-utilized BAS helps operate a building at optimum efficiency, lowers operating costs, enhances comfort levels, increases productivity, improves code compliance, and maintains a GBE (Angloafrican, 2017).

Considerations for environment and energy efficiency need to be part of building design and purchasing criteria and should be balanced appropriately with other important criteria such as product safety, price, performance, and availability.

Energy efficiency and environmental performance should be evaluated using a "system" approach, focusing on how individual components interact within the building system and identifying options with the greatest potential for improving energy efficiency and reducing overall environmental effects. The effectiveness of BAS in terms