PROSPECTS OF INTELLIGENT BUILDING TECHNOLOGIES IN PAKISTAN

By

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DEDICATED

To PAKISTAN

And to all those PAKISTANIS creating awareness and exploring potentials for the betterment of our country.

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The completion of this thesis would not have been possible without the guidance, help, patience and perseverance of a number of people, who in one way or the other extended their valuable assistance in the continuation and completion of this research. Most of all this piece of work would never have been accomplished if it wasn't for the benevolence of one above all of us, the all-pervading Allah, for answering my prayers and for giving me the strength to trudge on despite my resolve wanting to wane and throw in the towel, thank you so much Dear Lord.

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ABSTRACT

Construction industry is one of the major sources of economic growth, development and socio economic advances in a country, naturally accountable for the entire infrastructure in any given place, for generating employment for trained personnel and thousands of unskilled, semi-skilled and skilled workers. Buildings account for 41% of the total energy consumed in any given sector and Pakistan is no exception. With the continuous increase in demand and the increased tariff prices of the available electricity it is becoming increasingly difficult for investors and owners to be able to maintain their facilities to optimal standards. With the advancement in technology, exposure and increased awareness, people have a continual increased demand of maintaining a certain type of lifestyle which is extremely difficult to be provided in the current conditions of the country. The biggest challenge today faced by any building owner in Pakistan is to provide an uninterrupted supply of electricity with minimal billing and proper metering in order to attract maximum clientele and to maintain an up-kept ad safe building environment to satisfy the current strain of occupants. It is important to manage the energy consumption and therefore the energy prices for any building, be it high rise or low rise, residential or office buildings. It is therefore extremely important to cater for such provisions in buildings which would be able to address all the above issues in order to increase the client attraction, and to push Pakistani construction industry forward as far as technological advancements are concerned. Once these basic issues are addressed there will be increased competition paving the way for better standards in construction, increased interest by the foreign investors in the local industry and an overall win-win situation for the local public. For this purpose the topic of intelligent buildings was explored as there is a budding trend towards conserving energy, providing life safety and optimal facility management and improving subsystems in the buildings that are being recently constructed. Although it is only just the very beginning, with the right amount of effort both in the field and in the class room, the implementation of IB technologies in Pakistan will enable us to come to par with other nations like India and China in our building sector. For the purpose of this thesis an extensive literature review was carried out, including books, journals and online publications, furthermore interviews were carried out with the experts on intelligent building technologies to understand and establish the market trends and requirements locally. In order to highlight the benefits in terms of cost savings by employing intelligent building techniques, a comparison between an intelligent building and a conventional one was made. SPSS and excel were used to analyze the responses of the designed questionnaire, and the conclusions obtained were compared to the findings of the literature review. It was safely concluded that in today's challenging environment and growing competition in the industry, using Intelligent building technologies is recommended, as these are not only engrossing for the financers and the clients, but also for engineers, architects, consultants and contractors, along with being comfortable, easily alterable and extremely resource efficient and cost effective. Recommendations were made to incorporate intelligent building technologies in local buildings to make the Pakistani building industry come to par with international standards of construction.

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Chapter 1

INTRODUCTION

1.1 General

In the recent decades there has been an increase in interest in the performance of all buildings, whether high rise or low rise. Today the buildings are about incorporating “intelligence” into the very fabric of design and construction. These do not have a set goal rather they are aimed at providing a number of amenities including maximum comfort, cost effectiveness, ease in management, and ease in future extension and energy/resource management and conservation along with safety and security of both the property and the occupants of the building (Al-Wear, 2005)

Intelligent building (IB) or automated buildings can be categorized by the information and services which are incorporated to serve the needs and demands of the occupants of the building. They incorporate both software and hardware in the fabric of the building namely referred to as the BAS (Building Automation System) or BMS (Building Management System). The study of intelligent buildings and the application of IB technologies is fast becoming a common practice worldwide. It is however a need of time that designers, engineers, owners and contractors break the age old pattern and embrace a team approach to integrate all the functions and systems of a building at the conception stage. The innovative technologies that are being developed today would result in better comfort and efficiency for the end user, energy efficiency, improved security and optimal building maintenance.

1.2 Problem Statement

The current power crisis, lack of security, lack of research and the inability to accept and implement new technologies in the construction sector of Pakistan is a major obstacle in the progression of the building sector in Pakistan. The buildings that are currently made are substandard, constructed with the least attention to detail and without paying any attention to safety precautions and energy management or security of the tenants/occupants. The building contractors and owners alike construct any facility with the sole thought of regaining the invested capital as soon as possible. There is minimal or absolutely no maintenance provided once the building has been occupied. The lack of attention and maintenance results in before time deterioration of all building facilities and does not give the tenants value for money. There is no concept of providing life safety measures in buildings, smoke detectors and automated fire alarms, lighted escape routes and self-closing fire doors are largely unheard of. If these systems are installed, poor maintenance renders them useless and all the initial investment is wasted. Besides the attitudes of the builders and the owners the attitude of the people themselves is a problem in itself. It is common practice in all office buildings for all people at all levels to be least concerned about showing responsible behaviors towards conserving electricity. Unoccupied spaces and offices have all the lights, lamps and air conditioners turned on at all times. People when leaving their offices in the evening cannot be bothered to turn the lights of. And this behavior can be commonly observed in our educational institutes including NUST.

1.3 Research Objectives

The following were the research objectives that present study aimed to achieve;

- To evaluate the awareness of intelligent building technologies in the major cities and industrial hubs of Pakistan
- To identify the hurdles in the implementation of intelligent building technologies in the industry
- To give recommendations to help the implementation of IB technologies in the country

1.4 Limitations of Research

In Pakistan there is a lack of innovative ideas in the construction industry. The industry employs age old methods and processes for construction, there is no proper documentation and most of all there is no team effort or interaction of ideas towards building any facility as a unit. It is merely a collection of subsystems which are basically operating under a single skin, without any linkage or connection. It is this ideology that needs to be changed, people need to sit and think together, and this includes all the stakeholders of the project that is the designers, contractor's owners and engineers. However this process is currently lacking in Pakistan, due to lack of research and lack of interest no such innovative projects exist. The only project that is an intelligent building is that of the FFC towers in Saddar Rawalpindi. The project has integrated and centralized HVAC, plumbing, firefighting, fire detection, fire alarm and security using RFIDs by connecting them to a building management system. The project, surprisingly, has not integrated the lighting systems to the central command. Due to the lack rather sheer absence of other intelligent building projects in Pakistan a relative analysis is not possible for the purpose of this study.

1.5 Proposed Intelligent Building Projects in Pakistan

There is a possibility that intelligent building design and construction will gain popularity in Pakistan. Some projects that are meant to be designed as intelligent buildings are listed as follows (Ansari, 2009)

- Grand Hyatt mixed use development, Karachi.

46 storey, 5 Star premium Grand Hyatt hotel, 384 deluxe rooms, 200 serviced apartments, high end retail space, 2X 26 storey luxury apartments, 46 storey high end office space *Architect/Consultant: Arcop Associates*

- FFC Headquarters, Rawalpindi

12 storey + 3 storey Office space and Data Center *Architect: Meinhardt*

- Center Point Office Tower, Karachi

A 28 storey state-of the-art Office Tower with a Tier 3 Data Center , swimming pool, gym, executive restaurant. *Architect: Arcop Associates*

- MCB Data Center, Lahore

Purpose built IT building with a Tier 3 Data Center *Architect: Arshad Shahid Abdullah*

- HKC Office Tower, Karachi

High end Office space, 8 parking floors, 11 Office floors *Architect: Arcop Associates*

1.6 Organization of the Thesis

This thesis was divided into six chapters, the organization and a brief description of whatever is contained in the thesis is given as follows.

Chapter one gives a general introduction of the topic, describes the problem statement, and highlights the research objectives and the limitations of the research. Examples of existing and potential intelligent building projects in Pakistan are also listed herein. Chapter two describes in detail the intelligent building technologies available in the market, their benefits and the cost savings that can be achieved if these techniques are properly employed and maintained in a building. Chapter three clearly shows that although the price of technology is higher in the start, and that it requires more detailed space analysis and a considerable amount of effort in the building design and execution phase, the efforts are well rewarded. From the calculation in the chapter it is clear that the installation of building management systems and integrated facilities saves up on both material and human resources and pays the owner back in round about five years provided all cost savings are included.

Chapter four shows that this research study uses multiple or mixed research methods. Questionnaire survey is adopted as the main research instrument. In the next chapter, the research method, design, sampling techniques and design of the survey are discussed. Chapter five describes various tests and procedures adopted for data analysis in which normally, reliability and correlation of data was checked and confirmed through SPSS program. Chapter also highlights the important of various factors towards installing building technology in Pakistan between various provinces and categories of respondents. Finally, for better understanding of statistical data, pie chart and groups have also been drawn with the various tests. Chapter six describes in detail the intelligent building technologies available in the market, their benefits and the cost savings that can be achieved if these techniques are properly employed and maintained in a building.

Chapter 2

LITERATURE REVIEW

2.1 What is an Intelligent Building?

An intelligent building (sometimes also referred to as automated buildings) is something that provides an optimal environment for the occupants of that building to both live and work in. An intelligent building maximizes worker efficiency and also employs the resources involved extremely optimally. An intelligent building is essentially a building which is fitted in with intelligent features, like automatically controlled lighting, heating, ventilation, blind control, intelligent facades, controlled water provision in the toilets, efficient plumbing, fire protection, security etc. however it is to be understood that the use of technology is not the only aspect that makes an intelligent building intelligent, it is the integration of all the subsystems that make up the very fabric of the building which is actually the key to the intelligence of any building. (Chen, Clements-Croom et al. 2006)

The concept of intelligent buildings has evolved since the 1980's. According to Wong (2005), an intelligent building is supposed to be receptive, that is it should be able to react to the requirements of the users and the environment and should in turn be able to adapt itself accordingly. An IB provides a productive and cost effective environment by the optimal functioning and utilization of the four basic elements of the building, namely; places (fabrics, structure, facilities, materials), process (automation, control, systems); people (services providers, occupants); and management (maintenance, performance); and the interrelation (Wong, Li et al, 2007)

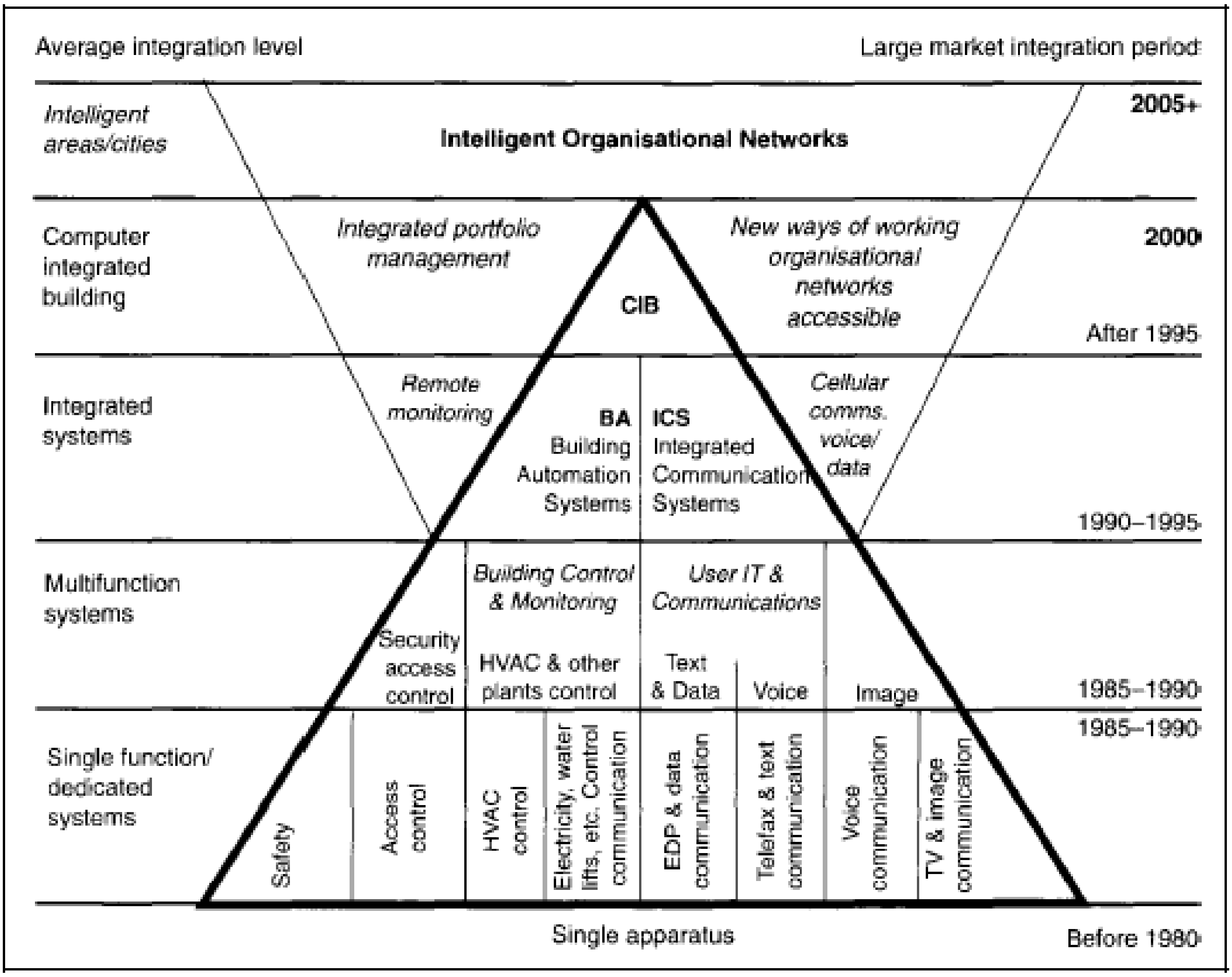


Figure 2.1: The Intelligent Building Pyramid (Lo, 1996)

The hierarchy of system integration in the intelligent buildings since the 1980's till date is shown with the help of figure 2.1. It can be observed that with the passage of time the coexistence of different building systems was promoted. In Pakistan however we are still at the bottom of the triangle where most functions in a building are completely stand alone. Some buildings do employ multifunction controls, by incorporating security access controls, and HVAC and plant controls. However, the Pakistani construction industry is largely ignorant of incorporating new technologies in its buildings. Figure 2.2 shows the taxonomy of intelligent building research.

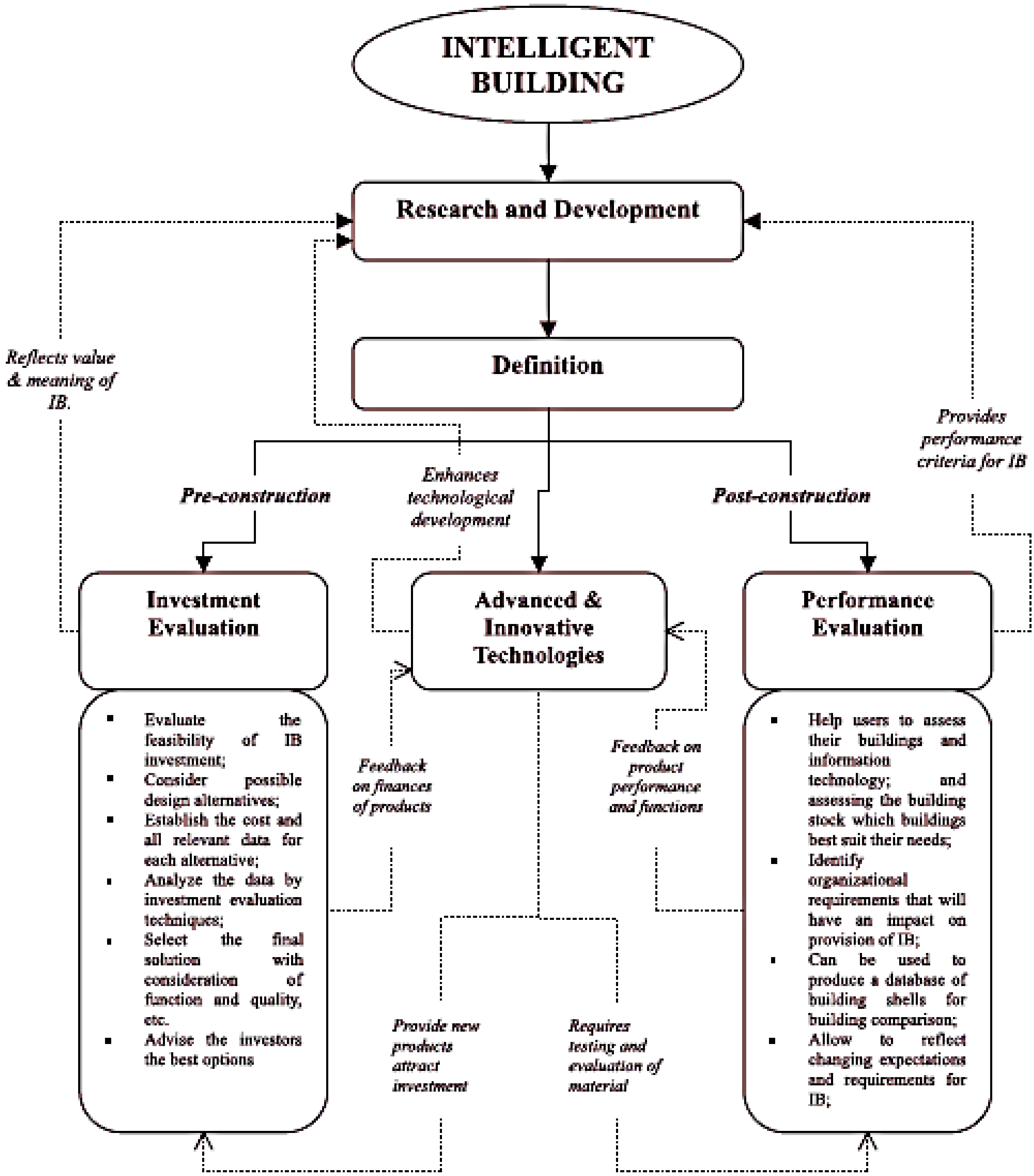


Figure 2.2: Taxonomy of research in intelligent building (Clements-Croome, AL-Wear, 2009)

2.2 Intelligent building definitions

Clements-Croome (2006) gave the following definitions for intelligent buildings;

According to the intelligent building institution in Washington,

"*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; flexibility*." (Clements-Croome, 2006)

The CIB Working Group W98 on Intelligent and Responsive Buildings stated:

"An intelligent building is a dynamic and responsive architecture that provides every occupant with productive, cost effective and environmentally approved conditions through a continuous interaction among its four basic elements: Places (fabric; structure; facilities): Processes (automation, control; systems): People (services; users) and Management (maintenance; performance) and the interrelation between them." (Clements-Croome, AL-Wear, 2009)

From the above definitions it is clear that intelligent buildings basically function in a way that the human body does. Every fiber of the entity is connected with the other in a way that it becomes whole there is inter-dependence of one component of the building on the other component. The highest level of integration achieved is what gives the intelligent building and edge over its counterparts. It was also observed during the course of literature review for this thesis that the definition of intelligent buildings is subject to change depending upon the different geographical locations. Following definitions will elaborate this point further.

2.2.1 Definition of intelligent buildings in USA

According to IBI (Intelligent Building Institute of America) that there is no datum in reference to which it can be stated that a specific building passes or fails the criterion of being an intelligent building, and there is no set of specific characteristics that would characterize an IB. (So, Wong et al 1999). The structure for an IB presented by the IBI is shown in figure 2.3;

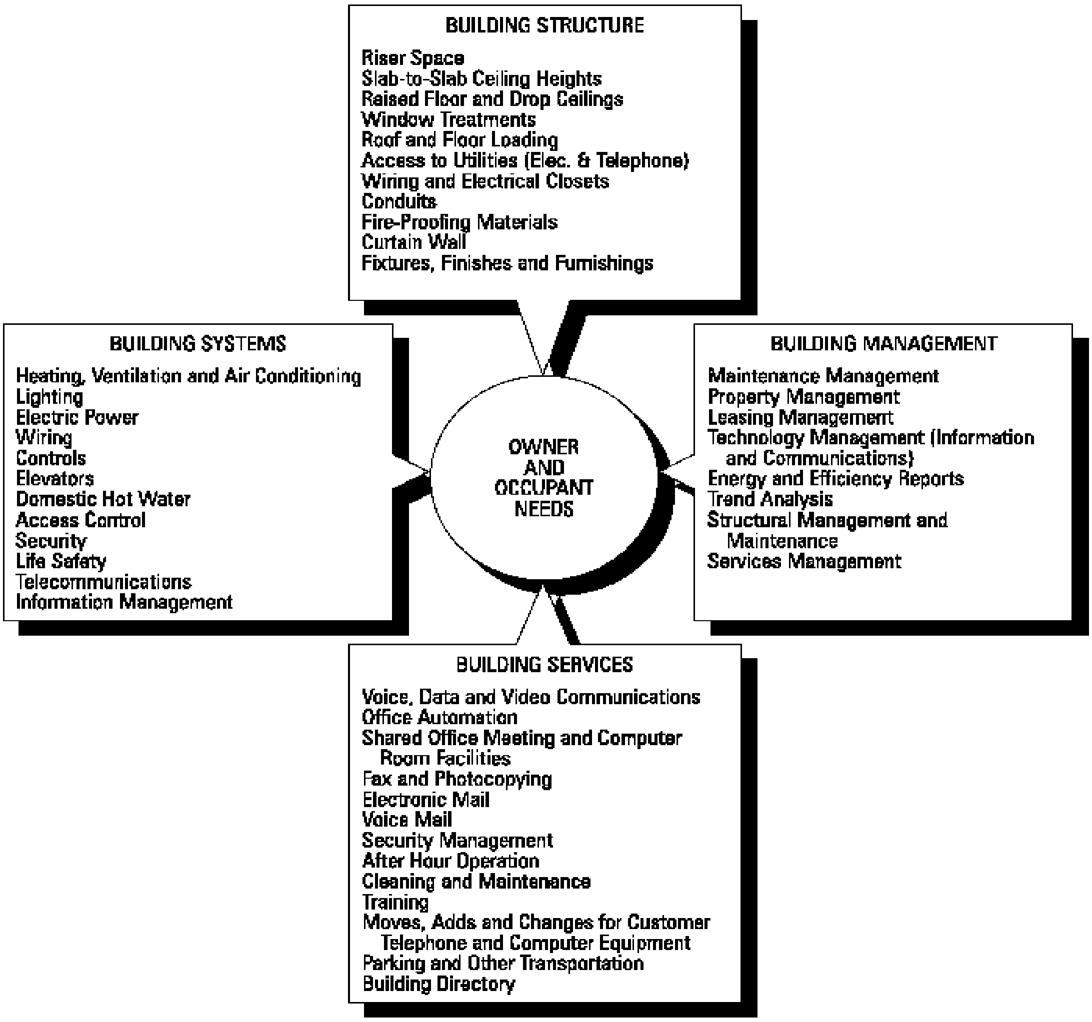


Figure 2.3: Structure of an IB as defined by IBI (So, et al 1999).

An excerpt of the definition of IBs that is accepted by the IBI is given as follows (Arkin & Paciuk, 1997)

"An Intelligent Building is one that provides a productive and cost effective environment through optimization of its, four basic elements: Structures, Systems, Services, Management, and the interrelation between them... the only characteristic that all Intelligent Buildings must have in common is a structure designed to accommodate change in a convenient, cost effective manner."

2.2.2 Definition of intelligent buildings in Europe

Unlike the definition which is provided by the IBI and is wholly technology related, the UK based EIBG, which is European intelligent building group focuses more on the building-human interaction when defining an intelligent building. The definition given by the EIBG is (Arkin & Paciuk, 1997)

"An Intelligent Building creates an environment that allows organizations to achieve their business objectives and maximizes the effectiveness of its occupants while at the same time allowing efficient management of resources with minimum life-time cost."

In order to fully satisfy the criteria set by the above definition, it is important that there be proper understanding of the purpose of the building. The designers need to keep in mind each and every requirement put forth by the client so that the building can best fit the needs of the end user. The information technology suppliers need to understand fully the relationship that would exist between the people occupying the building and the computer systems that they will install in that specific facility. Last but not the least the building owners and tenants need to be effusively aware of the potential of the building automation systems installed in their buildings so that they may be able to reap the maximum benefits out of their investments (Clements-Croome & AL-Wear, 2009)

2.2.3 Definition of Intelligent buildings in Asia

In Asia there are currently three different viewpoints held by three different countries in defining intelligent buildings. Although there has been substantial work on intelligent building technologies in Malaysia, India and Bangladesh as well, there are three countries whose specific definitions are listed here courtesy, (So, et al 1999).

2.2.3.1 Definition of IBs in Singapore

In Singapore, the public works department states that for an IB there are three traits those are indispensable, namely (So et al. 1999).

1. An advanced building automation, monitoring and control system to monitor or look over different building system likes HVAC, plumbing, lighting and firefighting etc.
2. There should be proper cabling throughout the building so as to provide a sound neural network for the flow of data between different floors of the building.
3. Good telecommunication facilities.

2.2.3.2 Definition of IBs in China

There are three categories of intelligent buildings that the Chinese officials specify or label, namely 1A, 3A and 5A. These represent buildings with Communication Automation (CA), Office Automation (OA) and Building Automation (BA). If any other system was to be automated for example the firefighting and alarm system, it would be called Fire Automation (FA) and if maintenance is automated then Maintenance Automation (MA) would lead up to the 5A category (So, et al. 2005)

2.2.3.3 Definition of IBs in Japan

The Japanese IBs are yet again designed and defined to suit the local culture (So et al 1999).

1. *"Serving as a locus for receiving and transmitting information and supporting management efficiency";*
2. *"Ensuring satisfaction and convenience for the people working in them";*
3. *"The rationalisation of building administration to provide more attentive administrative services with lower cost";*
4. *"Fast, flexible and economical responses to changing sociological environments, diverse and complicated office work and active business strategies".*

From all the definitions that have been mentioned earlier, it is clear that the goal of an intelligent building is not merely technological advancement. The sophistication of a building system cannot be overruled when considering the design and construction of an IB but care should be taken so as to not overdo it then what is the requirement of that particular building. There is nothing new in the service systems of an IB in purely technological sense (Arkin & Paciuk, 1997) therefore the sophistication of an IB lies in the integration of different systems that make up the fabric of the building, so that it would be able to achieve its goals both efficiently and economically. The IBI has explained clearly that both optimal use of resources and economy of operation can be achieved by the optimal utilization of four components of the building, namely; structure, systems, service and management (Chen et al. 2006)

2.2.3.4 A new definition for IBs in Asia

According to So et al (1999), all the definitions of intelligent buildings that have been provided earlier are slightly vague and do not really pin down what it is that is required for a building to qualify as an IB. they also argue that these definitions are partial towards technologies that do not fit the culture and environment of Asia, (So, et al 1999) also formulated a new definition for IBS in Asia, the first level comprises of nine "quality environment modules" and the second level includes three areas of key elements that are functional requirements, spaces and technologies (So, et al 1999) Chow (1998) suggested another module to include health and sanitation issues of a building. These modules are given as follows;

- *"M1: environmental friendliness—health and energy conservation;*
- *M2: space utilization and flexibility;*
- *M3: cost effectiveness—operation and maintenance with emphasis on effectiveness;*
- *M4: human comfort;*
- *M5: working efficiency;*
- *M6: safety and security measures—fire, earthquake, disaster and structural damages, etc.*
- *M7: culture;*
- *M8: image of high technology*
- *M9: construction process and structure; and*
- *M10: health and sanitation"*

Each of the above mentioned modules is then assigned any number of key elements in the order of priority (Wong, et al. 2005). These are shown in the table2.1 which is given as follows

Table 2.1: IB modules and key elements (So et al 1999).

Modules	Functional requirements	Technologies	Spaces
Raised floor	Fire fighting	Day lighting	Training
False ceiling	Electrical services	Indoor touring guidance	Shared meeting and conference services
Curtain wall	Plumbing and drainage	Public address	Restaurants
HVAC	Maintenance management	PABX	Entertainment area
Roof and floor loading	Property management	Office automation	Building directory
Floor height	Asset and facilities auditing	Parking and public transportation	Interior design
Rise space	Security control	Voice mail	Emergency escape
Fixtures and furnishings	Indoor air quality	After hour operation	High speed data communication
Vertical transportation	Cleaning	Energy savings and conservation	Satellite conferencing
Building automation	Artificial lighting	Trend logging and analysis	Internet gateway
Fire detection	Structural monitoring	Domestic hot water supply	Gas supply

2.3 System Integration in Intelligent Buildings

System integration is the key to the proper functioning and operation of an intelligent building. This integration is important to exist between the structure of the building and within the systems of the building as well as between the structure and the systems. According to Worthington, (2001), the importance of integration systems started to evolve and make sense in the 1980s, and engineers started to install multifunctional controllers in the building. To check whether how effective and efficient the integration of systems in a building is, it is important to look out for the quality of services that this level of integration is set out to achieve, that is : functionality; security and safety; thermal, acoustical, air-quality and visual comfort; and building integrity.

Intelligent building experts still do not agree upon the legitimacy of building intelligence = systems integration (2.1)

doubtless, integration of systems improves the safety, security and comfort as well as control of the systems installed and simultaneously reduces operation costs.

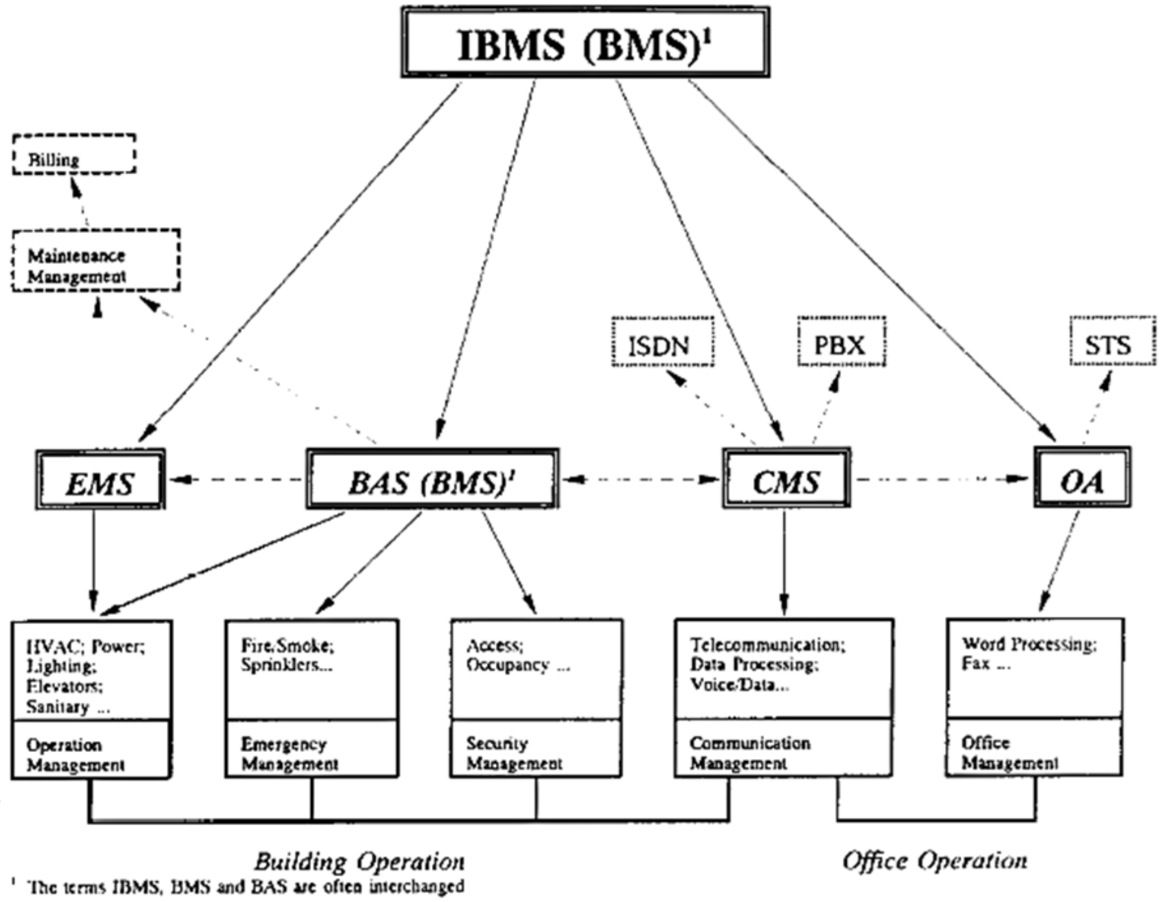


Figure 2.4: Hierarchy of building systems integration (Arkin & Paciuk, 1997)

Therefore it is generally acknowledged that integration is a imperative part of Intelligent buildings. (Arkin & Paciuk, 1997) the figure 2.4 shows the hierarchy of systems integration.

2.3.1 Hierarchy of Systems Integration

According to Arkin and Paciuk (1997), an objective index is required to evaluate the magnitude to which various systems and functions in a building are integrated. This index sums up the various levels of integration that a building is provided with. It is explained with the help of the following figure.

According to the figure 2.4, the functions that need to be provided in a building are broadly divided into two main groups, that is building automation/operation and office automation/operation. The first group that is building operation is concerned with the provisions essential for day to day functions of the building. It contains the Building Automation System, which controls the HVAC, lighting systems, vertical transportation and the EMS providing resource conservation and minimizing operating costs (CABA, 2002). The EMS and the BAS/BMS have provisions to detect and report the resource usage and any fault that might occur in the services that either of these might control, (this later provision is not yet very common around the world and is only implemented in a handful of comparatively smaller buildings.). The information collected through these systems is then stored in respective databases which is available for evaluation and consultation in the future should need arise. These may also be adjusted according to the outside or inside environment of the building, which can be achieved both manually and automatically. The second group consists of a Communication Management System (CMS), and an OA system. The CMS has two responsibilities: the first is related to the systems mentioned earlier, providing communication between sensors and actuators. The second responsibility is concerned with office automation, and traditional communication with the outside, however at a much more advanced technological level. (Arkin & Paciuk, 1997) For the course of this thesis we are not concerned with the OA.

2.3.2 The Scale of Systems Integration

Carlini (2003) explains the three tiers in which building systems can be integrated. At the lowest tier, there is a connection between stand-alone systems like HVAC and fire safety. The second tier tends to bring together the systems possessing common traits, or the systems having the same information base. OA, CMS and EMS are a part of this tier, including the BAS, which supervises a variety of building systems (HVAC, elevators etc. and services (maintenance, administration, billing etc.). Mostly the BMS, the BAS and the EMS are amalgamated or powerfully connected to each other or are in effect a single system. A slightly more detailed hierarchical presentation of systems' integration is shown in figure 2.4 above. The highest level of integration is called Intelligent Building Management Systems (IBMS). The main responsibility or function of the IBMS is to share information on a real time basis to all systems to especially supervise the emergency systems (fire; life safety) that influence all building controls and at the same time balance the requirements for occupant comfort, energy efficiency and operation of HVAC and transportation systems. (Arkin & Paciuk, 1997)

According to Carlini (2003) and Arkin & Paciuk (1997) many intelligent buildings have three tiers of system integration which include (Wong et al. 2007);

- The top tier, it deals with providing different features of normal and emergency building functions and communication management between different systems.
- The intermediate tier, which comprises of the Building Automation System (BAS), Energy Management System (EMS), Communication Management System (CMS) and Office Automation (OA) system. These cope, regulate and supervise the sub systems of the building. BAS would perform the function of energy management system. In certain cases, it also groups together some of the subsystems.
- The bottom tier, which contains subsystems including security system, (HVAC) systems, lighting system, vertical transportation system, communication system and fire protection system.

2.3.3 Examples of Integration

In a common building in order to share and exchange data Arkin & Paciuk (1997) suggested the key to effective operation and maintenance of an intelligent building is not dependant the level of sophistication of the building systems employed in the facility, that is technologically advanced buildings may not necessarily be the ones with the highest IQ, rather it is the connection among various building systems which is responsible for making an IB truly state of the art. Examples of major intelligent building systems and their integration include following examples (Wong, et al. 2007);

- The fire alarm system should be integrated with the vertical transport, lighting and the HVAC system. As soon as a fire alarm goes off the smoke dampers in the area shut down resulting in cutting of the smoke spread. Similarly the fire safety system should also be connected with lighting systems to illuminate the escape routes in case of power failure which may occur in case of a fire.

- The elevators should also be integrated with the fire alarm system and the security system. It should shut down in the advent of a fire, and start functioning again only if there is proof that the threat has been dealt with. Being integrated with the security system, it should define the number of accessible floor levels for every employee or visitor in the building.
- Fire alarm program should be integrated with security in order to unlock certain locked doors under alarm conditions especially the side doors to a building that serve fire escapes and open to smaller roads or alleys.
- Security system should also be integrated with lighting systems, for example the lights turn on whenever someone approaches an entrance or a window, and
- Facility management should be inter connected with BAS.

2.4 Intelligent Building Systems and Building Management

The concept of building management system is the same as that of building automation systems whereby the building managers can manage their resources to improve operation efficiency and control costs from a central control room. Building management system is nothing in itself unless there is a proper integration of all the systems that are present in a building. A building management system or a BMS which can also be called a BAS or EMS basically performs a supervisory role and is responsible for managing and assisting building managers in the following (Croome, 1998)

i. Facility and maintenance management.
ii. Safety management.
iii. Security management.
iv. Energy management.

2.4.1 Facilities and Maintenance Management

The facility management system may be outlined as *"the integral managing and execution of housing, services and other means, which contribute to a better performance of the primary process (in relation to effectiveness flexibility efficiency and creativity) in changing surrounding (primary process, market, social and technological)"* (Mustapa et al. 2008).

A brief over view of what it is that facility management entails is explained through the figure 2.5. It can be observed that what the figure shows is in effect the same as building management or a BMS. As it has been explained in the earlier pages of this document, an IB is all about integration of different systems of a building at various levels according to the user requirements; it is for this reason that sometimes the terminologies FM/BM and EM in a building overlap to a great extent as can be observed in Figure 2.5 (Croome, 1998).

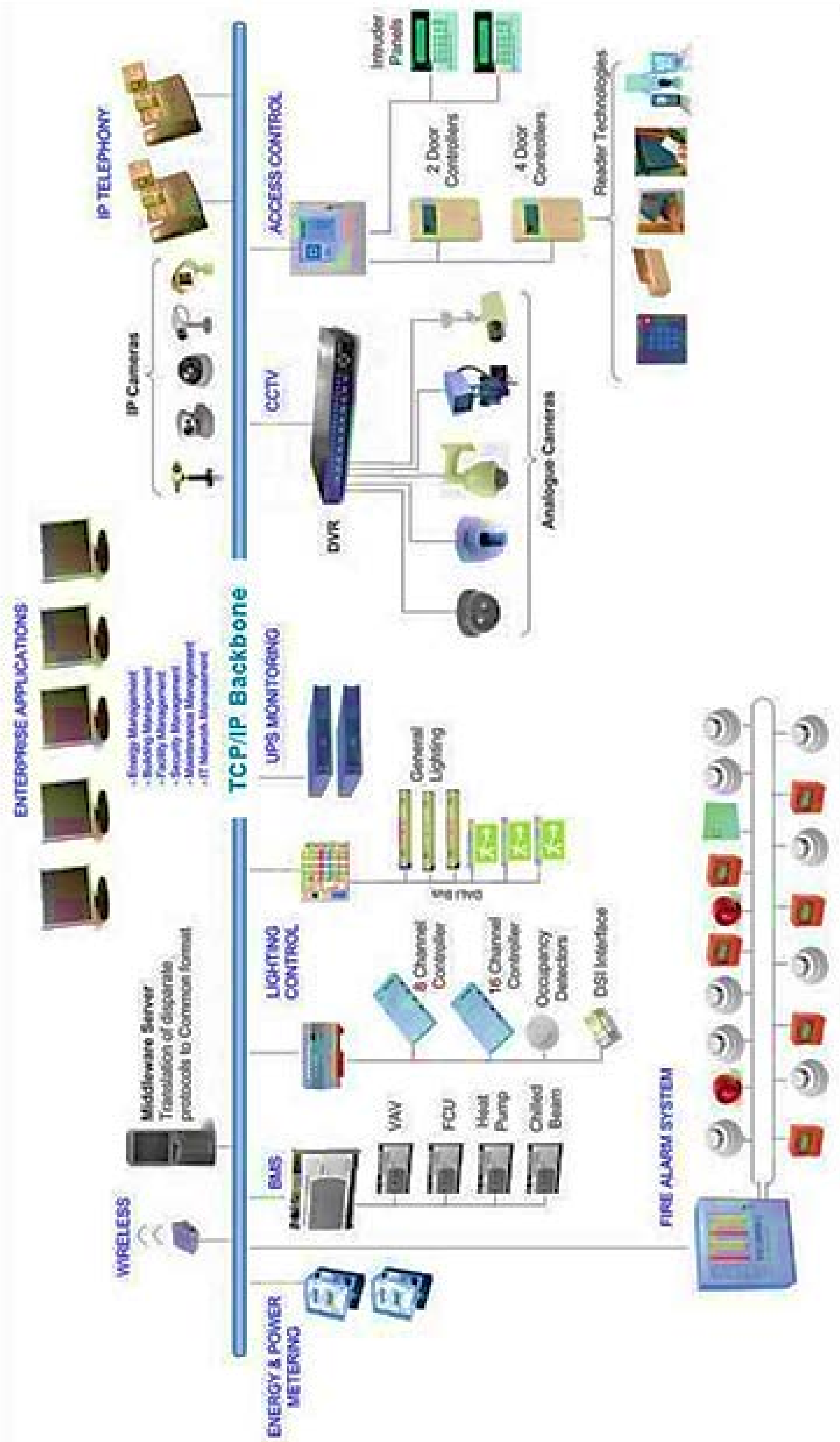


Figure 2.5: Facility management system (Cisco & Johnson Controls, 2008)

The function of facility managers or a facility management system is to control the performance of different systems in a building. These include HVAC, firefighting, plumbing, wiring and other electrical installations, lighting, drainage and security (this list is not exhaustive). The facility management employed in an IB is Computer Aided Facilities Management that is CAFM. It employs a large data base that collects information from all the systems of the building, and enables both the facility manage and the occupants of the building to monitor and track the performance of different building components (Croome, 1998). The CAFM is a highly useful tool for building maintenance. The different maintenance programmes that can be used are; be scheduled maintenance, periodic preventive maintenance, planned repairs or emergency repairs. The system routinely checks for any glitches in the building components and sends out warnings if anything is out of the ordinary. This in turn increases the response efficiency towards any anomalies and hence efficient maintenance, fewer break downs and cost and resource effectiveness (Karatasou & Santamouris, 2005)

A brief explanation of the horizontal layers in the figure 2.6 is given below to better explain the FMS.

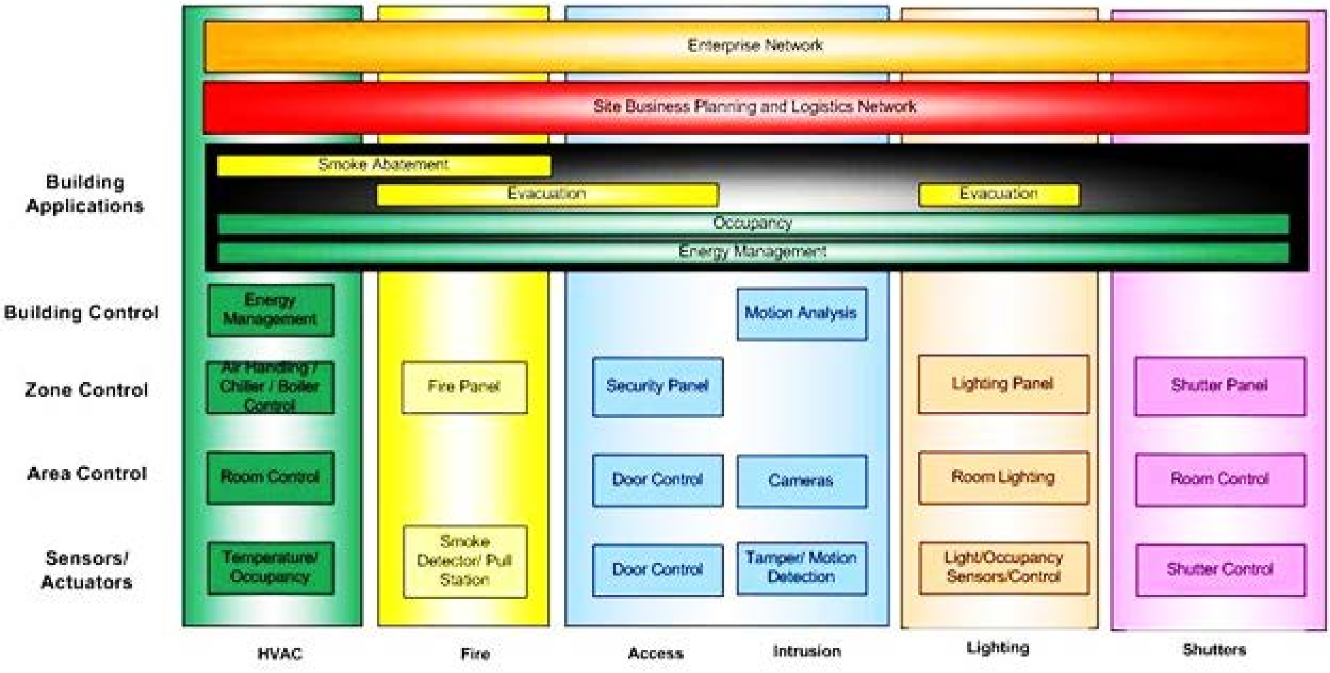


Figure 2.6: Facility management profile (Cisco & Johnson Controls, 2008)

2.4.1.1 Sensors/ Actuators

According to the diagrammatical representation of the FMS (figure 2.6), it is composed of a number of functional columns and rows that are completely integrated and are interoperable at different levels according to the needs and demands of the building and its occupants, as can be observed in the figure 2.6, at the base of every column there is a sensor and an actuator that responds to any changes in the micro environment and sends a signal accordingly to the FMS.

Sensors can be called the nerve endings of the FMS, some types and response times are shown in table 2.2. Sensing any changes in the environments and sending signals to the FMS database. Actuators are the exact opposite and provide a response that is generated as a result of the input data provided by the sensor. Actuators react to the changes in environment, by opening/closing doors, turning lights on/off etc. The interoperability within the different systems and levels of the FMS topology is done with the help of BACnet protocol that is *Building Automation Control network*. In 1995, the BACnet protocol was released by ASHRAE that defined interoperable objects and services within the HVAC silo. It is an international standard now including extensions for Fire, Access, Intrusion and Lighting functions (Cisco & Johnson Controls, 2008)

Table 2.2: Typical sensor types and response time (Cisco & Johnson Controls, 2008)

Sensor Type	Expected Response Ti	Security Policy
Space Temperature	10 minutes	**Heartbeat**
Duct Temperature	1 minute	**Heartbeat**
Smoke Detection	10 seconds	**Supervised**
Occupancy	1 minute	**Heartbeat**
Door Access	1 second	**Supervised**
Static Pressure	100 milliseconds	**Heartbeat**
Air Flow Damper	30 seconds	**Sensor Feedback**
Evacuation	60 seconds	**Supervised**
Admittance	1 second	**Supervised**

Lighting	100 milliseconds	**Optical Sensing**
Smoke Control Dampers	10 seconds	**Supervised**
Smoke Abatement	**60 seconds**	**Supervised**

2.4.1.2 Area Control

A building area is a smaller physical location in a building, which is typically 300 to 500 sq-ft, typically a room (Cisco & Johnson Controls, 2008) Area control is simply about the change in the environment of that particular small area that the sensors and actuators serve. It can more rightly be used in office automation. Commonly, temperature, humidity and occupancy sensors are provided in smaller areas like conference rooms and offices etc. however there are special sensors that are provided in purpose built rooms like labs, operation theaters and kitchens etc. which may include Area controls are fed by sensor inputs that monitor the environmental conditions within the room like air flow, pressure, CO_2 and CO particle sensors (Lombard et al. 2007).

Room temperature controllers are delicate constant apparatuses bringing about ordinarily 60 second control circles. Natural information is furnished to the controller by its sensors in either a surveyed or occasion driven design. The controller then dissects the information and tweaks the actuators appropriately to meet the requisition necessities. Actuators are tweaked every moment to support fitting temperature, wind current and stickiness. Entryway control needs much higher exhibition. Persons dropping in an office will need an idleness of no more than 500msec between swiping the right to gain entrance card and section endorsement. Polaroid container tilt-zoom orders need to execute with less than 250msec idleness. Room lighting control additionally needs ongoing exhibition. Room lights themselves need to have close immediate reaction to a light switch enactment. The lighting admin will want to see some change in the scene inside 500msec after a perplexing lighting order has been executed (CABA, 2002).

2.4.1.3 Zone Control

Building zones are defined by grouping of different areas of the building according to the functions that they serve. Normally zoning is done for HVAC and is characterized by the level of comfort that is to be maintained throughout these zones.

For example, temperature zones in the building are predefined; the temperature in the offices would be lower than in the lobbies, this creates two different temperature zones. Similarly there will be more ambient light in a work space than in a circulation, and there will be two banks of lights separately operable to serve these two separate areas again forming two different zones (Cisco & Johnson Controls, 2008). A zone may be defined as: *"A zone is normally a logical grouping or functional division of a commercial building. A zone may also coincidentally map to a physical locale such as a floor."*

Table 2.3: Examples of zones in buildings (Cisco & Johnson Controls, 2008)

Functional Domain	Zone
HVAC	Air Handler – the area served by a single fan system; Typically a floor or adjacent floors in a building.
Lighting	A bank of lights that all operate consistently
Fire	An area of a facility that will all operate consistently for example fed by the same fan system; covered by the same set smoke detectors or follows the same pressurization and annunciation rules. The zone may also be a functional grouping when a certain area is governed by a set of fire dampers.
Security	A subset of the building operating in a similar fashion for example a logical collection of lockable doors.

Table 2.3 shows the distribution of some building zones. The facility management system when integrated in a building, gives better and more efficient opportunities of controlling these zones and the equipment serving them. Any discrepancy in the equipment itself or its performance is highlighted on the graphic interface which

depicts all building zones that have been pre-defined in that facility, making it easier and faster to pinpoint the exact location of the problem (Flax, 1991)

2.4.1.4 Building Control

Building Control (aka Supervisory Control) provides the overall orchestration of the system. While the sensor, area and zone controllers provide real-time narrow focused applications; the Building Controllers provide broad systemic functionality. The building controllers provide the view ports into the embedded real-time systems for the operator, integrators and enterprise applications. Building controllers will cache and archive important real-time data from the controllers and act as an agent to the Building Servers layer for long-term data archival and retrieval. Building Controllers receive event information for the lower layers and forward the information to all needed devices and systems (Clements-Croome, 2009)

2.4.1.5 Fire and Smoke Abatement

There are different ways that the FMS can work for fire and smoke abatement. At the very basic level these systems can provide display information to the fire marshals or the concerned personnel, much like a CCTV system operates, appropriate actions can then be taken in order to handle the situation the best way possible. In practice however it is better that automatic systems be provided to deal with such emergencies, until the arrival of the firefighting squad. The fire chiefs can then control alarms, evacuation passage way lights and releasing of locks on doors through the designated workstation (Cisco & Johnson Controls, 2008).

Smoke diminution can be achieved through both manual and automatic systems as well. Automatic systems are naturally the best option however manual over rides are recommended to deal with any malfunction in order to maximise functionality. The fire system detects smoke through smoke detectors and then automatically adjusts pressure in the stairwells and exit corridors in order to keep it out of these escape routes (Karatasou & Santamouris, 2005).

The fire detection system does not deal with the smoke abatement process alone. This is where the process of integration of different building systems comes in to play. The fire system gets the information of a fire through one or more of any kind of detectors; it then “informs” the HVAC system of the location of the smoke. It is then up to the air handlers and smoke dampers to then automatically adjust so that the smoke remains localized in one area and does not shift to other areas of the building. It is to be understood that the most loss of life in any confined place in case of a fire occurs due to smoke inhalation and asphyxiation instead of direct burns through fire. Therefore it is important that the FMS prioritize the operations and functioning of the life safety system and the HVAC system such that smoke localization or abatement is the top priority (Cisco & Johnson Controls, 2008).

The system is then programmed to return to the normal functionality once the situation is dealt with. Figure 2.7 shows the details of the system.

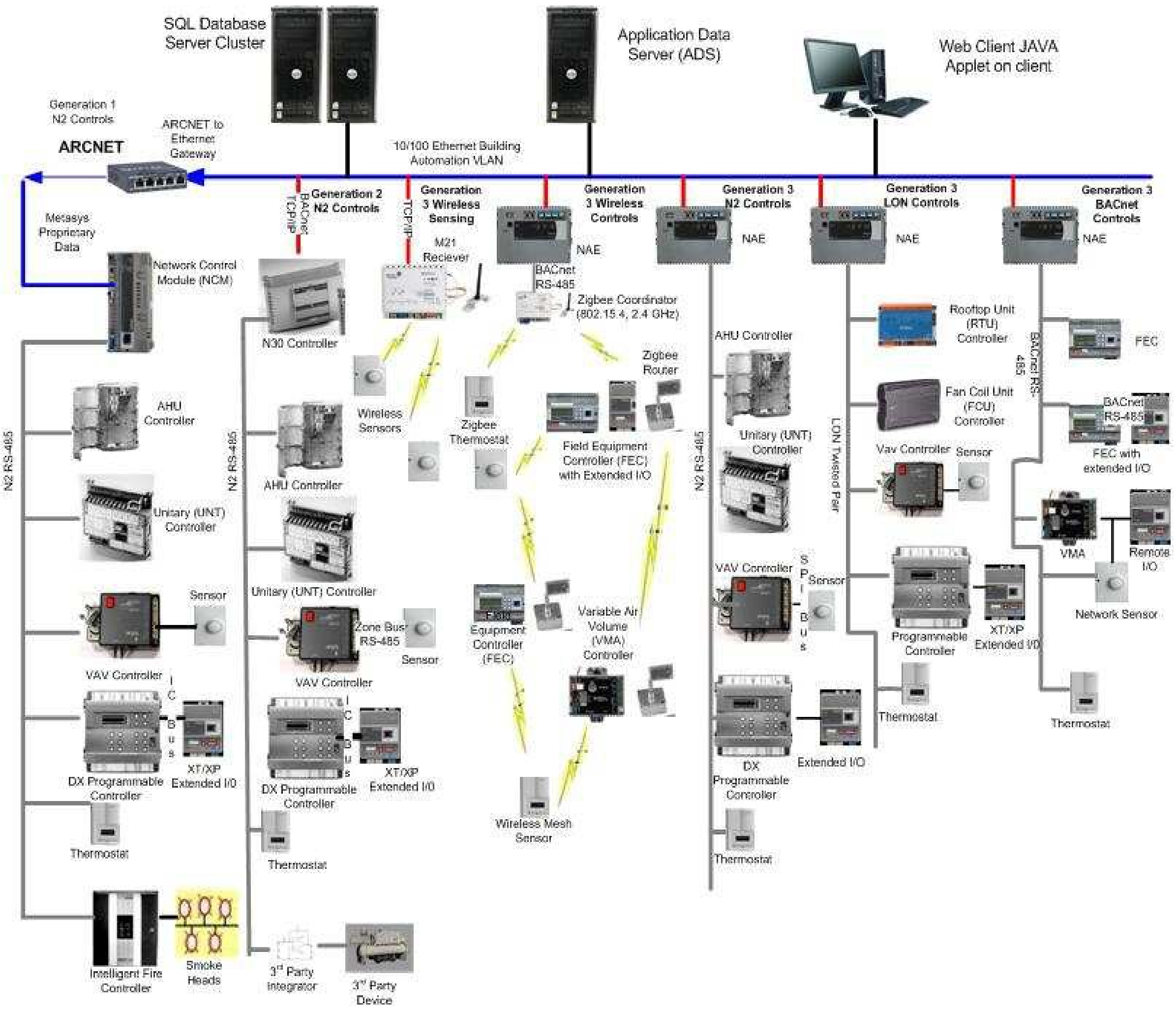


Figure 2.7: Complete set of HVAC controllers (Cisco & Johnson Controls, 2008).

2.4.1.6 Evacuation

Evacuation of people from a facility is a step by step and well-co-ordinated process which is again directed by the sequenced chain of events that is managed, maintained and closely monitored by the FMS. The evacuation procedure may come into practice in case of a fire or in case of an intruder or other such threat (Cisco & Johnson Controls, 2008). The FMS integrates the fire, lighting and security subsystems in order to deal with such situations. In case of a fire, automated warnings are given off which are an integral part of the life safety/fire system. The lighting system which is coordinated with the fire system automatically lights up all the escape routes to aid the evasion, the FMS also monitors and ensures that backup power supply is on standby in case of power failure. Lastly, the security system opens all locked doors in the passageways to aid the egress of all building occupants. If the building has an elevator installed, or a number of them, they are all recalled to the ground floor the instant an emergency is declared, a response which is integrated in the evacuation protocol (CABA, 2002)

2.4.1.7 Occupancy/shutdown

One major technique used to optimize energy in office buildings is to automatically start and stop the HVAC and lighting operations to suit the occupied and unoccupied periods in the building.

Out of all the main building systems, the fire and security systems are the ones that are functional at all times. The HVAC system depends on the time interval for which the building is occupied, the lighting system is also compliant to the HVAC. The HVAC system is usually charged with defining occupied and unoccupied times. The start and stop times for HVAC are pre fed in to the building's operational and management systems, however they can also be adaptively learned integrating the access control operation of the security system with HVAC (Chen et al. 2006) The scheduled timing turns on the ventilation to make sure that the building is at an optimal temperature by the time that it is fully occupied. The system also responds to outdoor air and relative humidity to sequence the start of the ventilation process in order to obtain the best possible results with the most optimal use of resources (Cisco & Johnson Controls, 2008).

As the HVAC tries to determine the latest possible time to start, the same way it tries to find the earliest possible time to shut down. This has to be done while keeping checks and balances to ensure that both the temperature and humidity comply with the pre-set parameters and values. It is far easier to programme the lighting systems in a building, as they can be turned on or off the moment the need arises or ends. The on/off sequencing for lighting is especially good for maintaining a strict time table for housekeeping services, as the staff will be only allowed in the building for as long as the lights are turned on.

Although the systems provided are completely automated, there is never the less an option of manual over ride. The Metasys by Cisco and Johnson Controls offers a telephone interface which will allow the HVAC systems to operate even after hours if a late worker wishes to stay. The lights and fans of that localised vanity also continue to operate (Cisco & Johnson Controls, 2008).

2.4.1.8 Energy Management

The energy management in buildings takes place not only by the lighting and HVAC systems turning on and off at pre-set times, but also during building operation times. This form of "load shedding" occurs in the building when the energy consumption reaches a peak hourly demand. The systems in the building (mainly the FMS) then tend to automatically switch off all unnecessary equipment that are consuming electricity. Another way to cut down energy consumption is peak hours is to reduce the control set point, thereby ensuring that the heavy equipment operates for a shorter period of time that it would otherwise (Flax, 1991).

All this is done keeping in mind that the environment comfort for the occupants of the buildings is not compromised. The FMS continuously monitors the consumption of the building recording data over a period of months, the load shave off points can then be set one the peak demand and peak demand hours have been established. As mentioned earlier, the real effect on energy management is made by controlling the electricity demands of the HVAC system (Croome, 1998).

2.4.2 Safety management

This system comprises smoke control, fire detection and alarm, and gas detection whereby several systems would need to be coordinated. In order to ensure optimal performance and in time reaction in case of an emergency to minimize the loss of both property and life, the use of a completely computer based automatic fire detection and alarm systems is important. Whenever any detector in the building is activated in the advent of a fire, building management system can immediately identify which detector has been activated and correctly show the fire location for firefighting personnel. When the fire safety or life safety system is integrated with other building systems, they perform together to achieve their specific goals aiding the escape efforts for the building occupants, security systems are required to release doors per code constraints under emergency conditions. HVAC systems are involved in smoke extraction, stairwell pressurization and elevator recall, (Which basically means that the elevators are recalled to the ground floor and are automatically shut down until safety clearance is given to the system.) Elevator recall is important as electricity failure in case of a fire can lead to devastating results if lifts in a building are still operational (Clements-Croome, 2009).

The advent of intelligent building technologies facilitates additional functionality. For example, in a fire, in case of electricity in the building, backup lighting will be automatically turned on and the escape routes will be illuminated, not only that, an automatic paging system with pre-recorded messages will broad cast warnings in all parts of the building instead of relying on nervous personnel to give details of the calamity. This will also have provisions for the disabled, like the deaf and the blind by sending automatic warnings on pagers that are provided and maintained for the disabled in these buildings (Suli & Ganlai, 2010).

The alarm system is technically a composition or a network of the following (Suli & Ganlai, 2010)

"Fire alarm control host network-based regional alarm control, local control panel, sound and light alarm (or alarms), manual alarm button, fire extensions, phone jack, intelligent features Photoelectric Smoke detectors, intelligent features of thermal detectors, combustible gas detectors, control and signal module, input module, fire radio host, fire telephone console, cables and central control equipment posed a set of operating fully in line with regulatory requirements and the project The distribution of need intelligent automatic fire alarm and fire control linkage system. Fire alarm control host built-in fire and

fire radio host calls the host. Important places in the set have several sets of fire extinguishers. Accordance with the relevant specifications require the buildings equipped with integrated smart features of the corresponding smoke and thermal detectors, combustible gas detectors; at each and every district to set a manual fire alarm button, sound and light alarm, speaker and phone jack; in the system set up with live status of signal input and control signal output of the various types of electronic modules".

The components of a fire alarm system that are normally provided by vendors to be incorporated in intelligent buildings and are considered intelligent systems may include the following; however this list is not exhaustive (Flax, 1991).

2.4.4.1 Fire Integrators

The fire integrator acts as the "brain" for the neural network of all the life safety systems. It connects any number of systems installed by any number of vendors to a single control point and makes it possible for the facility manager to cope with systems from different manufacturers using a single graphical user interface (Suli & Ganlai, 2010).

2.4.4.2 Fire Annunciators

Fire annunciators are very efficient and intelligent devices that have been announced in the market by Johnson controls (Cisco & Johnson Controls, 2008). These are basically user friendly graphical displays that allow the firefighting personnel to easily and efficiently pin point the exact and most accurate location of fire in the building. "*The information is accessed via a wall-mounted touch-screen that displays the entire floor plan with the location of active alarm system devices, potential hazards, additional access and egress routes, as well as standpipe, stairway, and emergency shut-off locations*" (Suli & Ganlai, 2010).

2.4.4.3 Fire Video

These employ the existing CCTV infrastructure. The benefit of using fire videos is that it allows comparatively faster detection of fire than the older system. It is also a good choice for larger areas/spaces, or remotely located sites where fire and smoke detection are critical (LaSalle, 2002).

2.4.4.4 DVC – Digital Voice Command

The DVC is a multipurpose telephone system that is used for paging, evacuation announcements and a mean of communication for the fire fighters. It has the capability to broadcast a number of messages throughout the facility thus insuring that responsible personnel are alerted in case of an emergency.

2.4.4.5 Fire Alarm Control

Fire alarm controller detects the signal and the alarm, it has a position indicator, regional shows, inspection, fire alarm sound, timing, fault alarm, record and print functions and with signal control, process control, regional control, address control, timing printing control system functions such as automatic control system starts the relevant firefighting equipment, firefighting purposes to achieve rapid and reliable means (Mustapa et al. 2008).

2.4.4.6 Associated Linkage Control System

The linkage controller incorporates the issue of linkage control indicator to the on location module linkage; fire administration control unit; mechanical sprinkler framework control unit; gas fire dousing framework control mechanism; ventilation and ventilating, smoke debilitate damper control gear and electrical instatements; lift control unit; fire radio framework and gear controls; control mechanism (Yang & Peng, 2001). Water supply framework for fire breakout control show Control of fire breakout hydrants, mechanical sprinkler pump start and stop; exhibits the location of the action knob of the pump; show fire hydrants, mechanical sprinkler pump status. The programmed sprinkler framework for the control presentation Control sprinkler framework begin up; show wet alert valves, valve and stream pointer sign working condition;

It additionally incorporates the control of the gas fired breakout quenching framework show indicating the blaze locale's hand / auto status; show gas fire dousing framework operation, issue status. Other blaze supplies, joint control characteristics might be halting the parts of the fan, shutting the damper, and accepting its sentiment indicate; beginning the part of the smoke fumes (counting positive force blower), fatigue valve, and getting the reaction sign; sending control indicates, all the vertical transport then stops at the first level/floor, start shooting lift, and getting the input (Suli & Ganlai, 2010)

2.4.3 Security Management

Security management functions to monitored and controlled by a computerized system where access card are required for entry into the building during or after office hours. Besides that, other sensors such as motion or heat detectors, pressure sensors, door switches and vibration sensors used to detect unauthorized entry. All of these sensors and actuators are connected to field processors and building management control. Security systems are further divided into the following three components (CABA, 2002)

1. Entry/exit control;
2. Disturbance; and
3. Scrutiny.

Effective security systems integrate these three areas, allowing the building mode, function and operation to be pre-scheduled or controlled by individual access requests. A typical system will involve (CABA, 2002);

1. *"Access card;*
2. *Elevator interface;*
3. *Door interface;*
4. *Intrusion detection*
5. *Sensor detection like temperature, moisture, glass breakage etc.*
6. *Guard tours*
7. *Parking controls"*

The leading intelligent building system providers like Johnson controls provide or support the following in their security management solutions (Cisco & Johnson Controls, 2008).

1. Access control and badging
2. Alarm and event monitoring
3. Remote video and surveillance
4. Centralized command and control

5. IP-enabled infrastructure
6. Computer-aided dispatch
7. Case management
8. Pattern analysis and threat identification
9. Visitor, elevator and parking control
10. Perimeter and interior intrusion detection
11. Closed circuit television (CCTV)
12. Analog and digital video recording and management
13. Paging and intercom systems
14. Asset tracking
15. Metal and weapons detection
16. Smart card solutions
17. Biometric solutions
18. Chemical, biological agent detection
19. Network access and alarm controllers
20. Turnstiles, gates and portals
21. Operational command and control centers
22. Emergency response
23. Facility operations continuity

2.4.3.1 Access Control and Intruder Alarms

The access control system basically refers to the authority that is assigned to different personnel to be to access certain or all parts of the building. This is extremely important in all buildings in order to ensure the safety and security of important data, files and even to avoid tampering either the building systems so that different acts of terrorism, foul play and arson etc. can be avoided. Furthermore it is also important to control the entry of people in a building. In an intelligent building, access control is integrated with the building automation system or the facility management system that is the BAS or FMS. Like all the other integrated systems, the sensors and actuators for access control send the information to a designated database and results are generated accordingly. A proper log is maintained to show system performance and for future reference. There is also timely reporting of activities and of any anomaly that may arise in the system (Lonix, 2010)

Access control can be implemented with the help of proximity readers, control nodes, electronic keys and electronic locks (Lonix, 2010). Users can be classified so that they have access only to the spaces they are allowed to enter according to programmed time schedules. They can also be allowed to enter if they have been assigned access card, access keys or if there is a biometric recognition available in the building.

Burglar alert framework might incorporate perimeter security and indoor reconnaissance. Observed entryways and windows might be provided with magnetic connections. Movement indicators utilized as a part of indoor observation might be delicate enough for vicinity location of a lone individual, so they can additionally be utilized for lighting controls and ventilating controls. Burglar/intruder alerts are seamlessly mixed on programming level to gain entrance to control, CCTV/DVR/NVR, lighting control and building mechanization. Allowed access incapacitates the caution zones mechanically. If there should arise an occurrence of robbery the framework gives an alert, which is transferred through BOS to Service Center and/or to specified portable telephones.

The different components for access control are given as follows (Cisco & Johnson Controls, 2008, Lonix, 2010).

2.4.3.2 Network Controllers

System Controllers should interface access control and trespasser alert framework with Management Level utilizing any system order which for instance includes TCP/IP interface or BACnet

2.4.3.3 Interface Panels

The interface panels may include; Door/Reader Interface Panel, Input Monitor, Interface Panel and Output Control Interface Panel.

Door/Reader Interface Panels are fit for showing entryway compelled and entryway held alerts on the FMS level in the central command and in the localized area as well. These also have local alarms to go off for tampering and battery failure (CABA, 2002).

2.4.3.4 Readers

There are different types of readers that may be employed by a system, including plain readers, keypad readers, long-range readers and biometric readers (Lonix, 2010)

2.4.3.5 Video Monitoring

Audio-visual observation could be enabled with Digital Video Recording (DVR) or a completely IP based Network Video Recording (NVR) framework. The Audio-visual observation might be assimilated to the FMS server so the framework begins recording the video stream upon any implication from intruder alert framework, access control, CCTV or whatever available framework reconciled to BMS (Lonix, 2010).

2.4.4 Energy Management

Energy management is one of the most important aspects of building management and IB technologies in the current era. The aim of energy management with in a building is to ensure the optimal use of resources and energy saving while ensuring user comfort. It also ensures maximum energy efficiency which in turn results in cost savings in a building (Ansari, 2009).

The integration of heating ventilation and lighting controls promises a large energy saving potential; 10 to 30% less of total energy consumption when considering only the heating and lighting controllers. Moreover, an improvement of the indoor comfort brings better working conditions, and therefore, well-being and higher productivity. This allows reducing partly the huge economic and social burdens of work related health problems. In USA, for instance, total direct and indirect costs due to these problems have been estimated to be 26 billion dollars per year (Guillemin & Morel, 2001).

Different buildings house different kinds and classes of equipment functioning according to the user requirement; accordingly, each building has its own energy consumption and usage signature. The Hong Kong Polytechnic University led a statistical report about the energy utilization of 16 lodgings in 1998. Consistent with that report, cooling and lighting are significant benefactors of energy utilization. Tshinghua University and Shanghai Tongji University did a comparable review and proposed same conclusion with ventilating and lighting's energy utilization. With proper measures that are taken to improve the efficiency of the HVAC and lighting systems, it is possible to reduce the power consumption of a building by 30%~40% (Ma et al, 2010).

The purpose for the development and installation of a building energy management system or BEMS in a building is to map, monitor and optimize buildings energy consumption, the main target areas for the BAMS are HVAC and lighting. The energy management system is expected to operate such that energy utilization is expected to diminish and better proficiency to be attained.(Ma et al, 2010) as demonstrated in figure 2.8.

Building energy management is the technique of overseeing and regulating the working frameworks inside a building. In spite of the fact that particular segments might vary, the aforementioned working frameworks may be air-conditioning and heating and cooling, ventilation, lighting, power, security, and alert frameworks. Through the BEMS ongoing screening, these effects could be attained (Qela & Mouftah, 2011);

1. Improved building management may be achieved.
2. The unproductive gear can be pin pointed.
3. Identify erratic utilization.
4. Lower peak electrical demand.

The final objective of BEMS is to make the building capable to utilize energy as optimally as possible which in turn leads to the conservation of energy and the maintenance of the quality of environment inside the building.

- **By Optimizing System operational data**

According to Ma et al, (2010) "*BEMS establishes an energy information database and processes the data to perform building energy saving by supervising, analyzing the amount and efficiency. Acquisition of energy data is the key to the energy conservation supervision system*". According to the Guideline of Energy Consumption Data Acquisition in National Office Buildings and Large Public Buildings, as quoted by Ma et al, (2010) the electrical power that is supplied to a building is to be divided in to four different parts. These are given as follows;

1. Air-conditioning
2. Socket power and electrical lights
3. Dynamical power
4. Special power

All of the above are further divisible depending upon the conditions and requirements of the building in question. Any of them can likewise be isolated into numerous sub systems consistent with the actual conditions. System data classification is shown in the figure 2.8.

- **The Use of Optimal System Architecture**

According to Ma et al, (2010) it is best that the system be made such that it has a different set of levels to deal with the information that is coming its way. The system can be divided into separate *"layers"* namely; data acquirement, statistics broadcast, facts elucidation, performance assessment and energy optimization layer.

The first is the data acquirement layer. The operation of gear could be known by getting temperature, dampness, illumination power and the measure of energy utilization (Chen et al. 2006). Sensor and metering appliances are in this layer. The second is the information transmission layer. There are more often than not, two sorts of transmission media: link and remote. For a recently built assembling a link system for example Ethernet, field transport or even a RS485 is favored for simple pre-installation and more solid transmission. Then again, there are challenges to instate another conveyance wires through different parts of a built assembly. Remote transmission is the first attention for adaptability and association. Remote sensor system for example Zigbee frameworks is a new and useful choice. The WSN framework can even be utilized for a short time for local monitoring (Ma et al, 2010).

The data interpretation layer comes on number three. Data interpretation layer will be a preparatory process the field information, and safeguard it to energy information database for the upper utilization. Second last, there is the performance evaluation tier. Consistent with the field information, it makes an appraisal of the level of energy utilization and discovers the deformity of the energy utilization framework (Croome, 1998).

The fifth tier is dedicated to energy optimization. It enhances the vigor utilization framework and upgrades the operation of the apparatus's that the utilization is lessened and the proficiency is raised. Enhancement measures incorporating optimal start/stop administration, alterable optimal settings of operation parameters, the control of peak demand, etc. for system analysis and evaluation it is extremely essential to build a building environment and energy consumption model heretofore. (Flax, 1991).

➢ **Performance Units**

There are four different units incorporated in the BEMS, namely' the analysis system, the control system, metering and monitoring systems. These are shown in the figure 2.8.

1. Monitoring System. Procure temperature, moistness, the intensity of lighting/illumination and so on, showing the indoor nature of the air and the impact of vigor use.
2. Metering System. Metering cooling power, lighting and attachment control, dynamical power, exceptional power; reflect the measure of energy utilization.
3. Control System. Through the building automation framework, it optimizes the function of incorporated equipment.
4. Analysis System. Give energy examination or assessment report; furnish the exhortation for energy recovering methodologies (Ma et al, 2010).

2.4.4.1 Lighting Management

Lighting needs are different for every different building, the purpose of providing intelligent lighting in IBs is to effectively manage the consumption of electricity and provide effective task lighting to allow people to be able to comfortably perform their work. According to CABA, the lighting systems may include (CABA, 2002);

1. Automatically turn on and off lights by photocell or computer schedule; modify lighting levels through the use of photo chromatic windows;

2. Allow individuals to adjust their lighting through computer or telephone interfaces;

3. Link the lighting controller to a graphic user interface with icons, for centralized control;

4. Turn circuits on and off through computer control; and

5. Manage energy consumption by monitoring room occupancy and adjusting lighting to suit.

2.5 Applications of Intelligent Building Technologies

2.5.1 Building Automation

Many physical as well as electrical methods are monitored and controlled through smart handle nodes. Air conditioning (heating) system maintains the temperatures with set point, taking into account the setting from the building and residency info, therefore changing the actual set factors accordingly. Air handling control brings fresh air into dwelling whenever thus needed, taking into consideration the actual setting of the building and existing conditions, for example CO_2 degree as well as residency (Croome, 1998).

2.5.2 Envelope Controls and Lighting

Following aspects affect the envelope/curtain controls and lighting:

- Manual controls having push buttons (on/off, on/off/up/down, lighting scenes),
- Movement recognition,
- The level of light at a particular time
- Pre-set time timetables
- The operations carried out in different zones of the building.

2.5.3 Consumption Measurements

Utilizations of water, power and cooling energy are measured for every building and for every framework. Meters are associated straightforwardly to control arrange or they could be provided with pulse output results, which are joined with counter modules which are associated with control grid. Utilizations are drifted into BOS's SQL database (Croome, 1998).

2.5.4 Access Control

Access control is achieved with control junctions, electronic keys, proximity readers and electronic locks. Clients could be characterized for the purpose that they have access just to the spaces they are permitted to enter as per modified time zones. The access control framework is associated with BOS for full control and reporting, and joined into GUI as choice access control can likewise have sufficient time and participation and information provisions (CABA, 2002).

2.5.5 Video Monitoring

Camera scrutiny is enabled with ordinary computerized and new IP cameras. Camera observation might be outfitted with Digital Video Recording (DVR) server. Framework ought to be incorporated with the BOS server. Utilization can happen both by means of DVR frameworks own User Interface Client and the combined GUI. The point when provided with DVR, the system should record advanced pictures of occasions initiated by intruders, caution framework, access control, CCTV or any possible office administration framework (Croome, 1998).

2.5.6 Fire Alarms

The fire alarm system can be implemented in the following ways; 1.) Separate systems (towers, work places, and what not) as per the common defense necessities or as 2.) Standalone systems, (for example villas), where indicators are associated straight to control junctions (in Control Layer). In both cases alarms are transferred to BOS and indicated in the graphical client interfaces. Ventilation is closed down in the region concerned and its location is demonstrated (Croome, 1998).

2.5.7 Intruder Alarms

Burglar alarms are an important part of the intelligent incorporated building management system. Burglar alert is easily incorporated on software level to accessibility management, CCTV/DVR, lighting management and building automation. Granted accessibility disarms the alert areas instantly. Supplying the areas change instantly the method of the developing into away method. Intruder alarm system includes cover protection and inside monitoring. Doors are monitored with magnetic contacts. Movement recognition with presence indicators are used for inside monitoring. In case of robbery the program gives an alert, which is relayed through BOS to Service Center and to specified cell phones (CABA, 2002)

2.5.8 Leakage Alarms

In case of leaks or moisture, the system gives an alert, which is relayed through BOS to the Control room and to specified cellular phones. Assistance Middle assessments the alert and sends a demand to a servicing company, if necessary (CABA, 2002).

2.5.9 Energy Savings

The integrated solution optimizes energy consumption through the following features (Lasalle, 2002)

- Need based control of all systems
- Situation based control of all systems
- Schedule based control of all systems
- System / device monitoring, consumption measurement and trending
- Electricity consumptions per building / building part
- Water consumptions per building / building part
- Cooling (heating) energy consumptions per building / building part

2.6 Barriers to promotion of intelligent buildings

The implementation of IB technologies faces a lot of barriers not only in developing countries like Pakistan but all over the world. Some of the basic issues that present themselves as challenges to most people in accepting or turning to intelligent building technologies are as follows (Kua & Lee, 2002);

1) Lack of resources or finances that prevents people from implementing untested technology.

2) A lack of able and well learned professionals in this field

3) A lack of skilled workers in his area

4) Lack of knowledge of all stakeholders of the environmental impact (that is both micro and macro environment) of IB technologies.

5) Lack of information about the benefits of IB technologies

6) Lack of institutes like legislative bodies and communities that focus on IB technologies.

It can be observed from the above discussion and that the root problem or the biggest hurdle in the popularity and acceptance of IB technologies in the industry is the lack of knowledge or information in this field (Gonzalez, 2006). To be able to overcome this lack of knowledge it is important that proper research be carried out in the field and be spread out. It is most important that it be shared among the building stakeholders that is;

- architects;
- building scientists;
- engineers;
- conservators;
- material and equipment suppliers

2.7 Benefits of Building Automation Systems

The immediate benefits are…

2.7.1 Lowers utility costs:

Building Automation Systems typically saves 15% of the operating costs of the equipment. For most structures this outcomes in benefits that variety from $0.20 to $0.40/square feet (LaSalle, 2002).

2.7.2 Maintains measured comfort:

Automated controls help to maintain even temperature ranges and level of lighting within the service to provide calculated comfort. Maintaining controlled temperature and lighting style stages reduces down on lost energy (LaSalle, 2002).

2.7.3 Enhances property value

The worth of most commercial buildings is related to the total operating earnings. Decreasing application expenses improves the networking earnings on money for money basis. Every $0.10/square feet stored in power could improve the market value of the property by $0.80/square feet. A 100,000 sq. ft. building could improve in value by$120,000 by decreasing power expenses $0.15/square feet (LaSalle, 2002).

2.7.4 Reduces occupant complaints

The more comfort the building environment offers, the lesser occupant complaints there are to be faced. This in turn results in a more efficient work group and a more productive team.

2.7.5 Increased Productivity

Better ventilation and air quality improve greater worker productivity and less sick time. The value benefits average $25.00/ square foot. With decreased sick days translated into a net impact of about $5.00/square foot and increased in productivity translated into a net impact of about $20.00/square foot (ABB, 2010).

2.7.6 Simplifies Building Operation

Computerized controls and real time graphical displays let you see exactly what is happening with the equipment in the building without having to go up on the roof or crawl up into the ceilings. This saves on costly problem determination visits, and simplifies operations (LaSalle, 2002).

2.7.7 Reduces Maintenance Costs

Operating the devices less and managing it better decreases wear-and-tear and keeps servicing expenses down, and expands devices life.

2.7.8 Avoids Business Interruptions

Break downs and repairs in nay building are very costly and make up for a considerable amount of budget that is expended in a building. These costs may be 50 to 100 times the total cost required to operate a building. (Smith, 1997).

Computerized controls monitor equipment status and help you head-off unexpected problems. Is a great investment –Most systems will pay for themselves in less than two years. Typical numbers for an owner-occupied 100,000 square foot building would be as follows:

Total system cost $200,000 ($2/sq. ft)

Utility Company rebate $30,000 (15% rebate)

Annual energy savings* $15,000 (15% savings)

Annual productivity loss avoidance * $50,000 (1% savings)

Annual O & M cost avoidance* $10,000 (10% savings)

Simple payback 1.3 years

*Annual cost avoidance year after year.

The future benefits may include;

2.7.9 Makes Quantum Improvements Possible

There is a connection between working cost, ecological top quality, and success. Software is the key to handling features and expenses effectively. Without better tools, the current employees cannot keep up with increasing requirements. There may be increase in expenditures in varied areas (like shortened services, utility expenses, or personnel) or the quality deteriorates (Smith, 1997).

2.7.10 Manages Direct and Hidden costs

Acknowledging the real expenses (both immediate and hidden) and how they are managed impacts an company's ability to contend. The following expenses can be considerably decreased using service automated technology (Croome, 1998)

2.7.11 Personnel

Operating personnel need the tools that technology provides to leverage their expertise and time. Without better systems, quality will degrade and overall costs will rise (Flax, 1991).

2.7.12 Utilities

The cost of energy makes a large chunk of the budget that can actually be controlled in any building. the integration of equipment, systems, and the automation of buildings makes these savings possible.

2.7.13 Equipment Repair and Replacement

Repair and replacement of aging building equipment is a fact of life. Newer technology equipment is generally less expensive to purchase, install, operate, and service. Every significant equipment repair or replacement should be evaluated against the cost of upgrading to the newest technology.

2.7.14 Lost Productivity

There is a direct correlation between comfort and the productivity, receptiveness and efficiency of conducting business. Even small percentage losses due to equipment breakdowns or comfort problems represent huge costs and can easily justify providing a proper building environment.

2.7.15 HVAC and Lighting Controls

Standalone computerized controllers are installed to take over the control of building HVAC (heating, ventilation, and air conditioning) systems and lighting. The building is not only scheduled more closely but it is also operated more intelligently and efficiently (Flax, 1991)

2.7.16 Outside Air Optimization

Proper control of outside air provides necessary inside air changes for occupant comfort and health, minimizes energy costs by space pre-conditioning, allows for enthalpy-based free cooling, and reduces the use of outside air when it is not needed.

2.7.17 Coordinating Equipment

Orchestrating the operation of building systems, so that equipment works together, saves energy and improves comfort. Individual control systems that are not centrally monitored and coordinated can fight each other or malfunction, causing comfort problems and wasting considerable energy. BACnet based BAS can interface to existing or planned systems so that the building will run smoothly and at peak efficiency without expensive duplication of controls or unnecessary complexity (Flax, 1991)

2.7.18 Graphical Operation

Simplifying facility operation and integrating data from various systems in a "seamless" manner is best accomplished with a graphical user interface. This eliminates the need to memorize commands or point numbers, and allows the operator to take a walking tour of the facility from the console. Existing systems can be easily upgraded to add this powerful operational tool. Point and click graphics empowers management by letting everyone see what is going on and taking the mystery out of proper operations.

2.7.19 Direct Digital Controls (DDC)

Upgrade older existing equipment to DDC to match new equipment functionality. These controllers come standard on most new mechanical equipment and are more reliable, require less maintenance, provide more sophisticated control, and are less expensive to purchase and operate (Croome, 1998).

2.7.20 Tighter Scheduling

Conventional controls, such as time clocks, are inaccurate and are typically setup to run equipment longer than the actual need. By automating this function with computerized controls, the computer can predict the optimum time to start/stop equipment and eliminate waste caused by excessive runtime.

2.7.21 Smarter Control

HVAC equipment is typically sized to handle the building load under worst case conditions. Most conventional controls are set up to meet these design criteria at all times. With the automation system, control set points and strategies can be adjusted to meet only the actual load, eliminating unnecessary waste (Benefits of Building Automation Systems (Croome, 1998).

2.8 Intelligent Structures

Intelligent structures (sometimes also referred to as smart structures) incorporate sensors and actuators in the building fabric in such a way that the building is able to sense when it in a need of repair, that is like the other building subsystems, it is also able to sense the changes that are happening and then adapt to them accordingly. The use of intelligent structures in the building industry is so far limited to just that, that is the sensing of development of cracks, or leakages to intimate the building maintenance management that it is time for repairs, before the situation or the problem gets out of hands. However, some commercial buildings also contain such provisions which protect the buildings against earthquakes by damping the ground's vibrations (Strong & Jensen, 2010).

The intelligent structure incorporates within itself an ANN or an Artificial Neural Network which enables it to sense environmental data and then form a memory and sometimes act accordingly. The sensory devices used in intelligent structures also form the basis for the categorization of these structures. A brief over view of different sensory network is given as follows.

2.8.1 Piezo Electric Devices

These devices turn mechanical signals into mechanical signals and vice versa. On experiencing a mechanical signal, for example vibrations, they create electrical impulses which tend to vibrate the structure in such a way that the incoming vibrations are damped. Similarly on receiving voltage differences or any other electrical impulses their shapes change hence altering the structures shape on a microscopic level (Strong & Jensen, 2010).

2.8.2 Fibre Optics

Fiber optics used in intelligent structures are the same as fiber optics used for transmitting signals and telecommunication. These devices also change their shapes in accordance with the signals that they receive from the environment. These can change in diameter or length in relation to the movement or vibration of the structural element and also due to changes in temperature, pressure, rotation, acceleration, acoustics, chemical composition, radiation, fluid flow, and liquid level (Strong & Jensen, 2010).

2.8.3 Shape Memory Alloys

There are certain materials, (normally metals) which experience a transition or a phase change in their basic structure in the event of extreme environmental changes. For instance, a metal might switch back and forth between crystal structures, such as between a martensitic phase when cooled and an austenitic phase when heated. This allows the metal to remember the shape it had when it was cool (or hot) even when it is subjected to the other conditions. So basically a material is naturally inclined to change phase at a change of temperature, if however, it is stopped from doing so, it will exert a remarkable force on whatever is hindering its natural inclination. These forces can be used to sense and change the configuration of the assembly in which such a material is placed. These materials are, therefore, used as actuators in smart structure applications, that is they respond by bringing about changes in the structures as a result of changes in the environment. Most of the shape memory alloys are titanium-based although other materials can also possess these properties (Strong & Jensen, 2010).

2.9 Conclusion

Chapter 2 described in detail all the intelligent building technologies that are currently available and are being employed all over the world. All the building systems including the building envelope, curtain control, vertical transport, firefighting system, HVAC, plumbing, lighting systems and even structural systems can be controlled and monitored by a centrally located master control system known as the BMS the Building Management System. However during the literature review it was found that all these technologies are currently unavailable in the Pakistani construction industry. There is no research on the subject of Intelligent Buildings currently available in Pakistan, and although there is implementation of these technologies, the systems, subsystems and the expertise are all imported. A list of intelligent buildings (which is not exhaustive) is given in the appendix III.

2.10 Summary

Chapter 2 describes in detail the intelligent building technologies available in the market, their benefits and the cost savings that can be achieved if these techniques are properly employed and maintained in a building. The chapter also sheds light on integration and the levels of integration that can be achieved, the cost savings, initial expenditures and the benefits of integration. It describes in detail the different types of sensors applied in the buildings and the application of intelligent building technologies.

Chapter 3

CASE STUDY

3.1 Introduction

The main purpose of this chapter is to compare and contrast between intelligent and conventional buildings. The main, basic provisions in both kinds of construction are listed side by side in order to make the comparison easier. All the main systems of the buildings including safety, security, HVAC and lighting are listed, along with facility management. An assessment has been made, and the results mentioned at the end of the chapter.

3.2 General Traits of The Pakistani Building Industry

The building sector in Pakistan faces the following problems (Enercon, 2011);

1. Nonprofessional and ill designed
2. A penchant towards plazas and high rises
3. Box like structures
4. Low roofs
5. No insulation
6. Minimal air circulation
7. Bad livability due to buildup of full space
8. The buildings are non-indigenous
9. Irrelevant to local weather conditions
10. Inferior in service provision and content

These are the list of characteristics that the conventional Pakistani building industry possesses in the present. (Enercon, 2011). Although it is obvious that the current building trends have been prevalent for quite some time, with the general trend of selling up as much covered are as possible to get the payback as soon as the owner can. This trend tends to deteriorate building quality and pays no attention to the thought process that should go into the erection of a facility which consumes so many resources not only at the time of its inception and construction, but also during operation.

3.3 Emerging Trends and Awareness

The current professionals, academics and owners (less than the professionals and academics) are becoming increasingly aware of the benefits they may obtain by incorporating the latest and more environment friendly building systems in their facilities (Enercon, 2011). The fact that resource conservation and maintaining future costs of their business is possible through the integration and automation of buildings and thinking smartly is slowly but steadily dawning in. reduced costs augmented with increased marketability of a state of the art facility are strong attractors for the stakeholders in the building industry. Following are some of the regulations and policy clauses that are being put forward;

1. Buildings should be made so that they automatically adapt to the internal and external climate conditions
2. Buildings should me more efficient and capable to be able to manage themselves
3. Increasing the use of VFDs, VAVs and frequency convertors for fans to reduce energy consumption and equipping the facility with appropriate sensors to do so (Jami, 2010).
4. Integrating the lighting system with the HVAC (Jami, 2010)

These trends are therefore making the stakeholders rethink their current policies and prompting them to learn more about the latest technologies available.

3.4 Practical Implementation of Intelligent Building Technologies

The list of current and proposed buildings with a BMS/BAS is given as follows, this list however is not exhaustive (Ansari, 2009),

- Grand Hyatt mixed use development Karachi (proposed)
- FFC Headquarters, Rawalpindi (existing)
- Center Point Office Tower, Karachi (proposed)
- MCB Data Center, Lahore (proposed)
- HKC Office Tower, Karachi (proposed)
- KRL Hospital extension, Islamabad (proposed)

In order to understand and practically observe the benefits, a building comparison was carried out between a conventional and an intelligent building. It is however to be kept in mind that the building under scrutiny is not fully integrated and does not possess that level of technology as is employed in the more developed countries.

3.5 Building Comparison

For the purpose of comparison, two office buildings were chosen in the Rawalpindi/Islamabad area. Both buildings are located in central business hubs of the twin cities, are state of the art, modern, well maintained, well-staffed and recently constructed. It was requested by the concerned personnel at both buildings to maintain anonymity for security purposes. Interviews were carried out separately with the building engineers and maintenance managers on both sites in order to obtain facts about the facilities that could then be compared. These are listed in the table 3.1;

Table 3.1; comparison between an Intelligent Building and a Conventional Building

Characteristics	FFCL	Telecom Towers
Location	Rawalpindi Central business district	Islamabad Central business district
Year built	2012	2009
Building nature	Intelligent	Conventional
Total floor area	311,400 sq-ft	562,629 sq ft
Number of storeys	14 + 2 basements	18+2 basements
Total building cost	2 billion	2.2 billion
BMS cost	20 million	Nil
Intelligent Building features:		
BMS	Yes	No
Firefighting system	• Automated response with manual over ride • Smoke detectors • Automatic sprinklers • Smoke dampers • Integrated with the building management system • Integrated with the HVAC system • Pressurized stairwells • Response time:	• Automated response with manual over ride • Smoke detectors • Automatic sprinklers
HVAC systems	• VAV control • AHU optimization • Integrated with BMS • Integrated with firefighting system • Daily time	• Central air conditioning system • Manually controlled dampers to set air volume and cycle change in different

	scheduling for switching the system on and off • Gas fired chillers saving electricity cost • Backup power supply • Pre-set temperatures after which AHUs automatically shut of chillers saving both resources and energy • Absorption type chillers with heat exchanger, eliminating the need for boilers.	areas • Temperature is manually set in each room • Gas fired chillers • Centrifugal chillers
Lighting control	Not integrated with BMS, conventional lighting system	Conventional lighting system
Security system	• Integrated with BMS • Personnel identification using access cards • Car parking management using RFID • Time cards • CCTV	CCTV
Facility management	Computerized facility management (CAFM) 70 people specified for facility management. So per person serves 4447.5 sq-ft	Facility management is carried out in a conventional manner employing a staff of 140 people, which includes both in house and out sourced staff, , which means per person serves, 4018.77 sq-ft
Tonnage	2000 ton	2600 ton
Building electricity consumption	1 megawatt	2 megawatt
Electricity bills per month	800,000 approx.	14,00,000 approx.
Electricity bills per annum	9.6 million	16.8 million
Energy savings	25% per annum	Nil
Cost savings	2.4 million per annum	Nil
Gas bills per month	140,000 to 150,000 per month (approx.)	225,000 to 250,000 per month (approx.)

Gas bills per month	1800000 (approx.)	2700000 (approx.)

3.6 Discussion

Table 3.1 is a comparison between two state of the art buildings in the very central districts of the twin cities. Both office buildings are well maintained, well supervised and have been recently constructed. While going through the above comparison table the number of amenities that have been provided in the intelligent building become clear. Here it is important to discuss all the important factors, step wise.

Telecom Tower is almost double the size of FFCL as far as the total floor area is concerned, that is 562,629 sq-ft as opposed to 311,400 sq-ft, however, it can be observed that the building FFCL costs 2 billion as compared to the 2.2 billion rupees of Telecom Towers. The difference in the costs can be explained by the installation of a BMS in the building, which as has been explained earlier is the heart and soul of the modern intelligent facility, integrating and maintaining all the important systems and functions in the facility.

The cost of the BMS or intelligent features are the main put off for building stake holders, through tis comparison the author hopes to alleviate these fears and show that the extra cost spent can be reimbursed through savings in a relatively short period of time.

Total building cost of FFCL Building	= 2.7 billion rupees
BMS cost = 10% of total cost	= 250 million
Building electricity consumption	=1 megawatt
Electricity bills per annum	= 9.6 million
Energy savings	= 25% per annum

The energy savings per annum in building FFCL are mainly due to the installation of a better HVAC system with properly timed and regulated responses. As has been mentioned earlier in this document, HVAC is the most cost and energy incurring system in any building, accounting for a whopping 40% of the total energy expenditure in any building anywhere in the world, regardless of the fact whether it is cooling loads or heating loads (Clements-Croome, 2001). The following factors are the intelligent features included in the HVAC system of Telecom Towers.

3.3.1 VAV Control

VAV or Variable Air Volume involves supplying air in accordance to whatever the thermostat is set to. The building chi has been fitted in with occupancy sensors which keep a record of the building occupation and therefore keep the BMS informed about the comfortable limit of temperature that needs to be maintained in different rooms/parts of the building. The VAV control hence supplies just the right amount of conditioned air in the areas where it is required thus saving up on energy (Cisco & Controls, 2008).

3.3.2 AHU optimization and Integration with BMS

The AHU or Air Handling Unit is the heart of any HVAC system. AHU optimization means that it can function or full capacity or reduced capacity depending on whatever the requirements of the building are at that particular time. Actual savings achieved by optimization of AHU depend on many factors (served area, occupancy, AHU type and configuration, building type etc.), but can be generally estimated to be at least 25% of the unit electricity consumption (Ma et al. 2010)

3.3.3 Gas fired chillers saving electricity cost

The chillers are taken off the electric supply and gas is used as the primary fuel, saving massively on electricity costs.

3.3.4 Pre-set temperatures

After reaching a certain minimum temperature (subject to occupant comfort) the AHUs automatically shut of chillers saving both resources and energy.

3.3.5 Absorption type chillers

Absorption type chillers remove the need for boilers by having a heat exchange cycle with in the chillers. In the absorption chiller, the evaporator allows the refrigerant to evaporate and to be absorbed by the absorbent, a process that extracts heat from the building (Qela & Mouftah, 2011). The combined fluids then go to the generator, which is heated by the gas or steam, driving the refrigerant back out of the absorbent. The refrigerant then goes to the condenser to be cooled back down to a liquid, while the absorbent is pumped back to the absorber. The cooled refrigerant is released through an expansion valve into the evaporator, and the cycle repeats. Absorption chillers are either lithium bromide-water (LiBr/H2O) or ammonia-water equipment. The LiBr/H2O system uses lithium bromide as the absorber and water as the refrigerant. The ammonia-water system uses water as the absorber and ammonia as the refrigerant (Qela & Mouftah, 2011).

3.7 Conclusion

So keeping in mind the above and taking into account the gas savings that take pace due to AHU optimization, preset temperatures and absorption type chillers, the energy savings per annum for the building chi are given as follows;

Electricity bills per annum	= 9.6 million rupees
Gas bills per annum	= 1.68 million rupees
Total energy cost per annum	= 11.4 million rupees per year
Energy savings	= 25% of 11.4 million
	= 2.85 million per annum
Total cost of the BMS	= 20 million

The break-even point for the cost of BMS due to energy cost savings

= 20 million /2.85 million

= 7.017 years

It is clear that by using intelligent building technologies and integrating the HVAC system with the BMS, the initial cost of the system will be paid back in 7 years. Further energy saving is possible by integrating the lighting system with the BMS as well, something that the owners of building Omega plan on doing in due time.

Due to the facility management system, 1 person serves 4447.5 sq-ft in building omega as opposed to 4018.77 sq-ft in the conventional building, which means a building the size of building Omega would require 7 people less than it would have in the absence of IB technologies. Assuming each person is paid 10,000 rupees per month;

Monthly saving	= 70,000 rupees
Annual saving	= 840,000
	= 0.84 million
Adding this to energy cost saving	= 3.69
Total cost savings	= 20 million /3.69 million
	= 5.4 years

Clearly, the integration of lighting systems with the BMS will further improve the cost savings and the payback period for the building will reduce, increasing the building's profits and making the building all the more lucrative for all stake holders.

3.8 Summary

This chapter clearly shows that although the price of technology is higher in the start, and that it requires more detailed space analysis and a considerable amount of effort in the building design and execution phase, the efforts are well rewarded. From the calculation in the chapter it is clear that the installation of building management systems and integrated facilities saves up on both material and human resources and pays the owner back in round about five years provided all cost savings are included.

Chapter 4

Research Methodology

4.1 Introduction

This section talks about the analysis procedure that was applied to reach the results presented at the end of this dissertation. The main methods for gathering and generating analysis information are the set of questions study and the meeting with the participants. This information is used to evaluate intelligent building technology and practices in Pakistan and to suggest actions to motivate the public and private industry and banking organizations in facilities development industry. The following segments provide the details of the analysis method applied in this thesis.

4.2Research Design

The research methods generally used in scientific topics are tests, reviews, archival research, discussions, case studies and backgrounds. Furthermore technique implemented for a specific study relies on the amount of investigation already carried, type of the research function (what, how, why) etc., the research focus, the regional circumstances and control over factors. While choosing a suitable means for research, it is compulsory to think through the connections between information selection and the required issues to be resolved through research, as well as the main concerns to be resolved and the results. Therefore, when continuing on a research, it is very important that the link among research questions, the kind of information obtained and the technique of information research approach should be considered.

A set of questions is mostly used as an device in scientific topics and it is also used as the primary analysis means for the objective of this thesis. For rating of aspects, use of a unique 5-point Likert Scale was made, to be able to discover the finish variety of possible responses between "Yes" and "No".

In the data collection phase, an intelligent building interviews and surveys were conducted. A questionnaire used for intelligent building survey was distributed by hand to different personnel, mainly the top management of forms and university professors, while some forms were also emailed to get responses. The population that the questionnaire was distributed to consisted of project directors, project managers, project planners, project analysts, site engineers.

In the data analysis phase, the collected data was entered in the statistical analysis software package SPSS 17.0 and analyzed. Quantitative method was used for analysis of intelligent building survey. For this purpose, literature was reviewed for learning of statistical tools and to interpret the results obtained from SPSS 17.0. Based on the results of data analysis, conclusions and recommendations were made.

In order to understand the trend of intelligent building technologies in Pakistan, literature review was carried out on existing IB technologies in developed and developing countries. Based on this literature review and the results obtained from above phases, recommendations were made for the local market. Figure 4.1 shows the research methodology employed for this thesis.

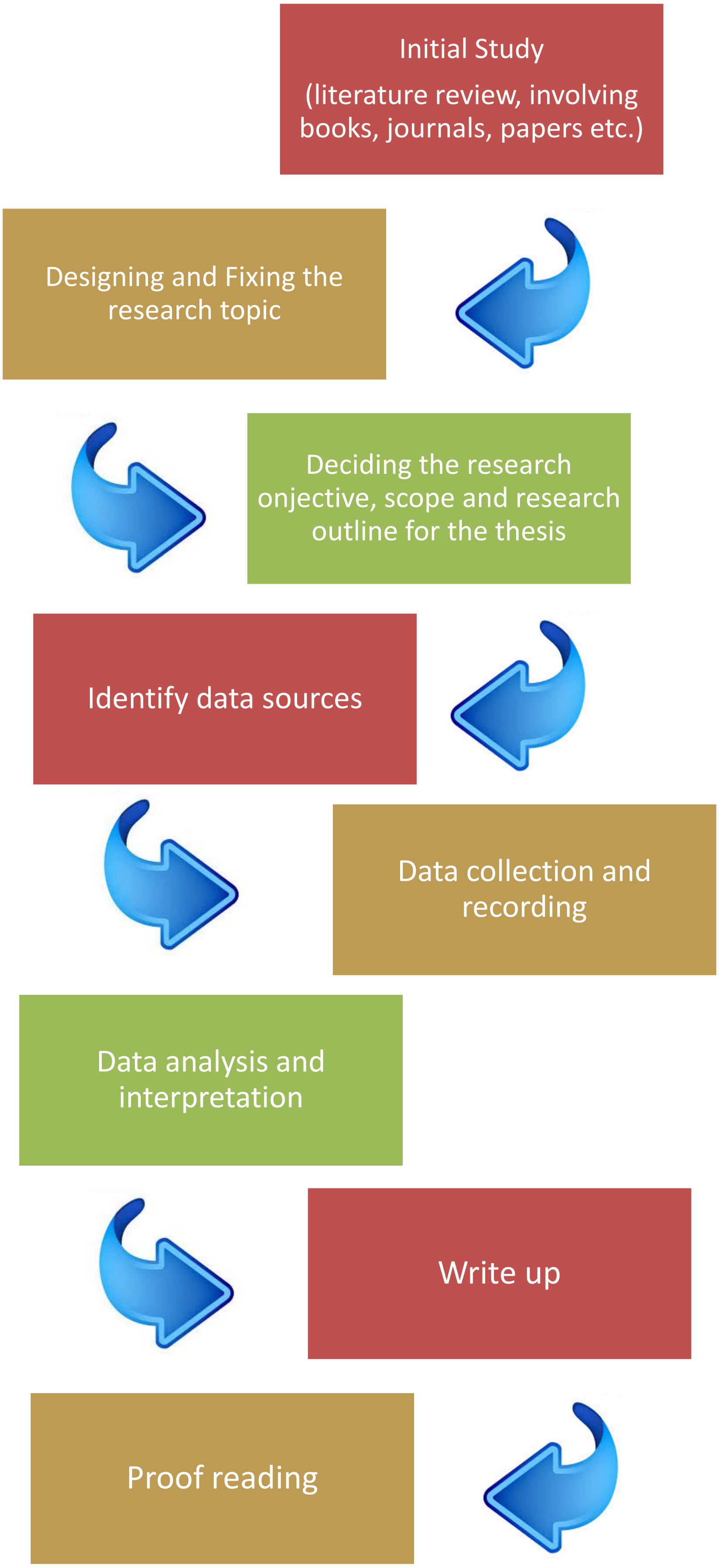


Figure 4.1: Research methodology

4.3 Survey Sample

The purpose of carrying out a statistical analysis is to measure the trend of the population in regard to different factors that are taken for analysis. For this purpose it is essential that the sample which is selected is a very good representative of the population. There can be different methods to select a sample depending upon the particular characteristics of the population which is taken under consideration. These are random, judgmental and non-random samplings (Francis and Hoban, 2002). Judgmental sampling is prone to bias as the sampler uses his judgment to collect the sample. Random sampling is however employed when there is no significant variation in the structure of the population. The techniques employed in random sampling are:

- Systematic sampling
- Stratified sampling
- Cluster sampling.

The Intelligent building ideology is unfamiliar and limited at this stage in Pakistan, therefore only one project is currently implemented, one has been shut down due to poor maintenance of the building management systems and one is has a partially energized BMS, several other projects are still in the planning phase as mentioned in the chapter one of this thesis. It is fairly a small population of intelligent building projects; however the sample selection represented various construction experts including clients, consultants and contractors with different categories and backgrounds. In this research, the judgmental sampling method was used to obtain samples from various categories of construction industry in Pakistan. The intelligent building projects are mainly taken under consideration by foreign investors. Obviously, surveying all these organizations in the privatization sector would yield the most representative results though hardly practicable due to amount of work and time involved. The questionnaire was therefore circulated and dispatched to 160 randomly selected potential respondents. Majority of the respondents were physically visited by the author for interview and discussion purpose as well. These respondents included clients, consultants, developers, financers and academic scholars.

4.4 Sample Size

Following are the factors which should be taken into consideration before determining the appropriate sample size (Dillman 2007),

- Error in sampling
- The size of the population
- Differences in responses
- The level of confidence

According to the Economists (2003) the minimum sample size that should be taken for data analysis is 30. It is extremely difficult to get statistical results if the sample size is smaller than 30 (Saunders et al. 2009). The reason that all these researchers prefer a sample size greater than 30 or equal to it, is because only with this size it is possible to get outputs of data analysis that would be closer to normally distributed data outputs. Therefore keeping in mind the above reasons, it is imperative that a sample size of at least 30be taken for data analysis.

Consistent with Owen and Jones (1994), a normal of 20% of polls returned is recognized to be satisfactory. And in the CI, 30% is considered a good response rate (Black et al. 2000). Accordingly, the reaction rate in this research is highly adequate.

This section describes the background of data collection and gives a perspective view of the research process of how the research plan was executed. The data of this research was collected from the construction sites of Islamabad, Rawalpindi, and Karachi. The questionnaire developed after an extensive literature review, was pilot tested at the start of the data collection period.

4.5 Design of Surveys

Many researchers have highlighted the importance of a questionnaire design for an impelling survey (Giritli, et al. 1990,Kim 2010, Lingard et al. 2010). As needs be, a decently planned questionnaire might as well have such attributes that respondents can effectively handle and can answer without putting in a significant amount of effort and taking investment synchronously and in the mean tie do not waste much of their time. The rate of reaction by respondents is affected by various elements, for example the size of the questionnaire, color and sort of paper utilized, message or plans blanket pages, inquiries request, and also the stamps and envelope used to mail the survey (Memili et al. 2011). In this thesis a mixed mode questionnaire has been adopted which is also favored by a researchers for yielding better results. A large number of respondents were interviewed personally and some questionnaires were mailed in order to receive responses. Samples of the cover letter and the questionnaire used for the purpose of this thesis are showed in appendix I and appendix II respectively.

Summary

This chapter describes that questionnaire survey is adopted as the main research instrument. The minimum sample size and the return rate for the questionnaires have also been discussed and a mix method of study has been adopted. In the next chapter, the research methodology, data analysis and sampling techniques are explained in the next chapter.

Chapter 5

Data Analysis

5.1 Introduction

Great care has been taken while collecting data that the qualification standard of the respondents should be highly educative because of the rather unskilled intelligent building technology atmosphere in Pakistan. Figure 5.1 shows the distribution of respondents as per profession. Keeping the quality of survey, the higher qualification of the respondents and the main objective of determining the suitability for the considered project, it had been kept in mind that all the result analysing process to be carried with extreme measures so that all the sincere efforts put in could be verified and reformed into desired results for the benefit of construction industry of Pakistan. The figure 5.2 describes the experience of respondents in the construction industry.

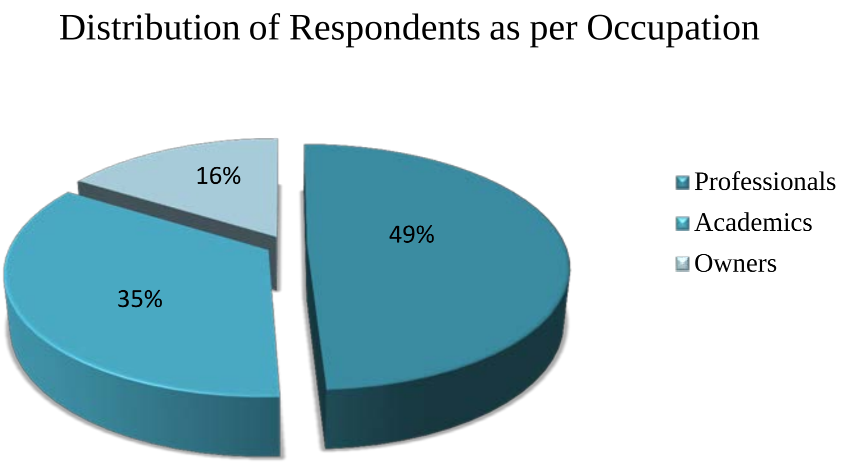


Figure 5.1: Distribution of respondents as per occupation

Table 5.1 and table 5.2 show the responses of the questionnaire respondents. As shows in the questionnaire provided in the appendix II, the respondents were asked if they knew of any intelligent building projects in Pakistan or in any other country abroad. The tables 5.1 and 5.2 state the local and international IB projects respectively.

Table 5.1: Intelligent Buildings in Pakistan as per respondents of the questionnaire

LIST OF INTELLIGENT BUILDINGS IN PAKISTAN	
BUILDINGS NAMED	FREQUENCY OF RESPONDENTS
FFC towers	11
PEC Peshawar building (proposed)	2
Water and sanitation plants in PERRP projects	1
	15

Table 5.2: Intelligent buildings worldwide as per respondents of the questionnaire

LIST OF INTELLIGENT BUILDINGS ABROAD	
BUILDINGS NAMED	**FREQUENCY OF RESPONDENTS**
Adam Joseph Lewis center, USA	3
Techno park Dubai	3
Masdar, Dubai	1
Carrefour, Dubai	1
Burj Marina, Dubai	1
Mascat airport, Muscat	1
Architecture department building Bauhaus university, Germany	1
Burj Khalifa, Dubai	1
U city project, Korea	1
Dockside Green development, British Columbia, Canada	1
Roger Centre, Toronto , Canada	1
	15

5.2 Experience of the Stakeholders in the Construction Industry

Respondents had varied experience in the construction industry as shown in Figure 5.3. Approximately 38% of the respondents had accumulated five years or less of construction experience, 30% had 6 to 10 years of construction experience, whereas only 22% have 11 to 15 years of construction experience. 7 % had between 16 to 20 years and 3% have up till 25 years of experience. Hence all the information provided by these respondents was considered reliable.

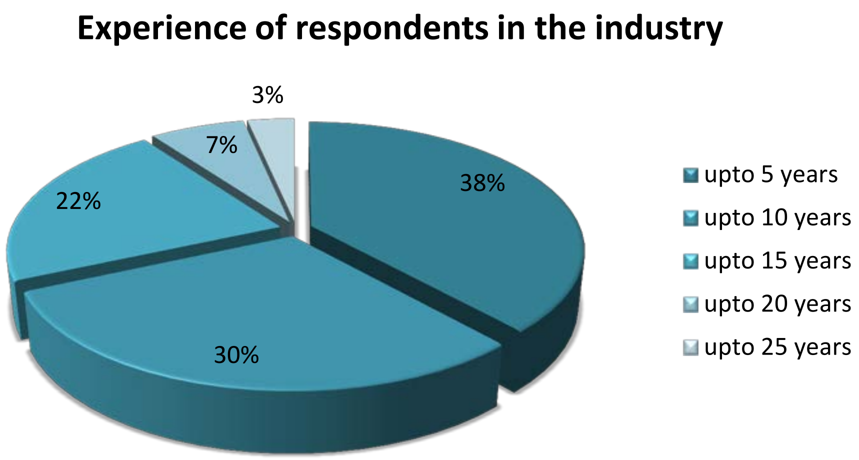


Figure 5.2: Experience of stakeholders in the construction industry

5.3 Construction Companies Included in the Survey

The construction companies who responded to this survey were all registered with PEC in different categories. The survey comprises of the responses from 16 construction companies and 4 local universities. List of the companies/organizations included in the survey is given in the table 5.3

Table 5.3: Firms and respondents of the questionnaire

List of companies	List of companies
CDM Smith Pakistan	G3 architects and consultants
NHA	SATC associates
FWO	KAIST
Bahria Town	Meinheardt
Architects inc.	Carillion
Descon	Al Rajhi Group KSA
Urban Construction	UET, Lahore
SM Associates	NED, Karachi
SMEC international	Baha-ud-Din Zakria University, Multan
Redco interntional	COMSATS, Islamabad

To confirm the reliability, normality and authenticity of surveyed data received from 130 x respondents belonged to ten major cities of Pakistan, the following basic data analysis tests were performed

5.4 Measurement of Normality of Data

The received data obtained through questionnaire was on ordinal scale and in more precise terms it was based on Likert scale measurement involving various categories of respondents i.e. Owners, Professionals (Civil engineering, electrical and mechanical engineering, IT ,architects) and academics (4 x renowned universities). It is essential to measure the normality of data before applying any statistical analysis, Shapiro-Wilk test is generally applied as test of normality and it is used for a sample size which has less than 2000 individuals. To count as sufficiently normal, the significant value should be larger than .05.

The values for all 16 factors came out to be less than .05, which shows the data is not normally distributed; this means that the data under consideration is non-parametric and only non-parametric tests can be applied to it in order to check its credibility.

5.5 Measurement of Reliability of Data (Non-Parametric)

To find out the internal consistency/relationship of scaled data on Likert scale, Cronbach’s Alpha (α) was used to check the reliability or correlation of received data before reaching onto its interpretation and testing. The value of “Cronbach Alpha (α)” ranges from negative infinity to one, where score closer to one shows the strong correlation among data (Cronbach, 1951). By using SPSS, the value of (α) was found out as “0.913” for received data from 130 x respondents, which shows the stronger uniformity and relation among the respondents in ranking out of various factors related with the installing of building automation technologies in Pakistan.

5.6 Measurement of Level of Agreement Among various Groups

To find out the level of agreement between various provinces/federal area in ranking the number of factors given in questionnaire, Kendall coefficient of concordance (W) was used to check the internal relationship because of its characteristics of dealing with more than two groups. In the present study, there were three groups i,e. Punjab, Sindh and Federal area. Therefore it was important to find out the internal relationship/consistency of all these categories in ranking of various factors. The value of “W” extends from -1 to +1. Negative value indicates negative or poor association between various groups; zero value dictates no relationship, whereas positive value shows strong relationship among various groups in ranking of data factors or simply it conveys strong mutual agreement of all groups / provinces.

To find out the level of agreement between various groups in ranking of 16 x factors, values of “Kendall Coefficient of Concordance” were calculated by using the SPSS. The values of “W” came as 0.891, 0.920 and 0.853 as showed in Table 5.4. The result showed the strong agreement / correlation among various groups in ranking of the data.

Table 5.4: Correlation among respondents of Punjab, Federal and Sindh

			Punjab	Sindh	Federal
Kendall’s tau_b	**Punjab**	**Correlation Coefficient**	1.000	0.891**	0.920**
		Sig. (2-tailed)	.000	.000	.000
			16	16	16
	Sindh	**Correlation Coefficient**	0.891**	1.000	0.853**
		Sig. (2-tailed)	.000	.000	.000
		N	16	16	16
	Federal	**Correlation Coefficient**	0.920**	0.853**	1.000
		Sig. (2-tailed)	.000	.000	.000
		N	16	16	16

****. Correlation is significant at the 0.01 level (2-tailed).**

There is strong correlation between respondents from Federal area and Punjab rather than Sindh and Punjab and Sindh and Federal area as shown in the Table 5.4. It can be interpreted that respondents from Karachi and Hyderabad have different ranking perceptions than respondents from Lahore or Islamabad.

5.7 Comparison of Market Analysis Factors for Intelligent Building Technologies in Pakistan

The mean score ranking technique was used to obtain the values of risk probability and impact, which is also a common technique used to analyze the results obtained by questionnaire surveys (Chan et al., 2009). The mean score for each risk factor was calculated separately for risk probability and risk impact factor through the summation of scores given by the respondents according to Likert scale divided by the number of respondents. The formula used was:-

$$Ms = \Sigma s / n \quad (5.1)$$

Where

Ms = Mean score of each risk

s = Score given by respondent as per Likert Scale

n = Number of respondents

Table 5.5 shows the ranking of various important factors associated with market analysis of intelligent building technologies. As per the respondents' feedback, unavailability of required material in the market has been ranked first in Pakistan with the mean score of 4.70. Non availability of technical staff to install the latest automation technologies in the buildings has been considered as second important factor by the respondents from three main provinces of the country with the mean score of 4.66. At number three, the respondents showed concern about the serviceability and warranty of installed automation technology in the building with the mean score of 4.62 as all the equipment has to be imported to the local site which is quite concern for the owners. The respondents ranked "Unavailability of required law or legislation in the country related with installment of intelligent building technologies at fourth position with the mean score of 4.58. Similarly initial higher cost of equipment has ranked at fifth position by the respondents and the inability to achieve agreement among different stakeholders ranked at sixth position. Respondents seems to be less concerned about their unawareness to the latest technologies of building automation, high cost of maintenance of equipment and power breakdown issues and ranked these factors at 7th, 8th and 9th position respectively with the mean score of 350,3.00 and 2.56

Table 5.5: Ranking of hurdles faced in the implementation of intelligent building technologies in Pakistan

Factor	Federal	Punjab	Sindh	Total	Rank
Unavailability of required technology CABA (2002)	4.64	4.86	4.62	4.70	1
Unawareness among people concerned CABA (2002) Clements and Croome (1998)	3.48	3.44	3.58	3.50	7
Non availability of technical staff CABA (2002)	4.62	4.66	4.70	4.66	2
Serviceability / warranty assurance CABA (2002)	4.62	4.56	4.68	4.62	3
Law / legislation CABA (2002)	4.60	4.52	4.62	4.58	4
CostCABA (2002)	4.12	4.08	4.16	4.12	5
Difficulty of achieving agreement among the stakeholders and their interests. CABA (2002)	3.80	3.74	3.86	3.80	6
Power breakdown, restrictions from government CABA (2002)	2.54	2.58	2.56	2.56	9
High cost of maintenance CABA (2002)	2.96	3.12	2.92	3.00	8

Table 5.6 describes the ranking of various factors related with "building technology preferences in Pakistan". The main aim of survey was to find out the people's preference to install modern technologies in their newly constructed building. According to the respondent's feedback, installing of Telecommunication system got highest rank with the mean score of 4.64. Respondents placed "HVAC" at second position with the mean score of 4.60. Placing of Safety related equipment and managing of cables got 4.40 and 4.28 score and were placed at number three and fourth by the respondents. Installing of "Computer aided facility" was ranked at fifth position with the mean score of 4.04. Similarly, in Pakistan, respondents ranked "requirement of energy efficiency in the building and installing of modern monitoring" at sixth and seventh position with mean score of 3.96 and 3.58 respectively.

Table 5.6: Detail of building technology preferences in Pakistan

Description	Federal	Punjab	Sindh	Total	Rank
HVAC AIIB (2001), Armstrong et al. (2002) Clements-Croome (2001)	4.62	4.647	4.66	4.64	2
Energy Management through electrical installations AIIB (2001), Shanghai (2001)	4.00	3.88	4.00	3.96	6
Telecommunication/ LAN AIIB (2001), Armstrong et al. (2002)	4.50	4.58	4.64	4.60	1
Facility management AIIB (2001)	4.04	4.00	4.08	4.04	5
Life safety systems AIIB (2001), Clements-Croome (2001), Chow and Chow (2005), Myers (1997), Shanghai (2001)	4.32	4.44	4.44	4.40	3
Security systems AIIB (2001), Chebrolu et al. (2004)	4.24	4.24	4.36	4.28	4
Lighting systems AIIB (2001), Reffat and Harkness (2001)	3.52	3.56	3.66	3.58	7

The figures 5.3 and 5.4 show the mean values of the respondent's responses and the comparison of responses for the top three factors from different cities of Pakistan

Figure 5.3: Mean value of hurdles faced in the implementation of Intelligent Building technologies

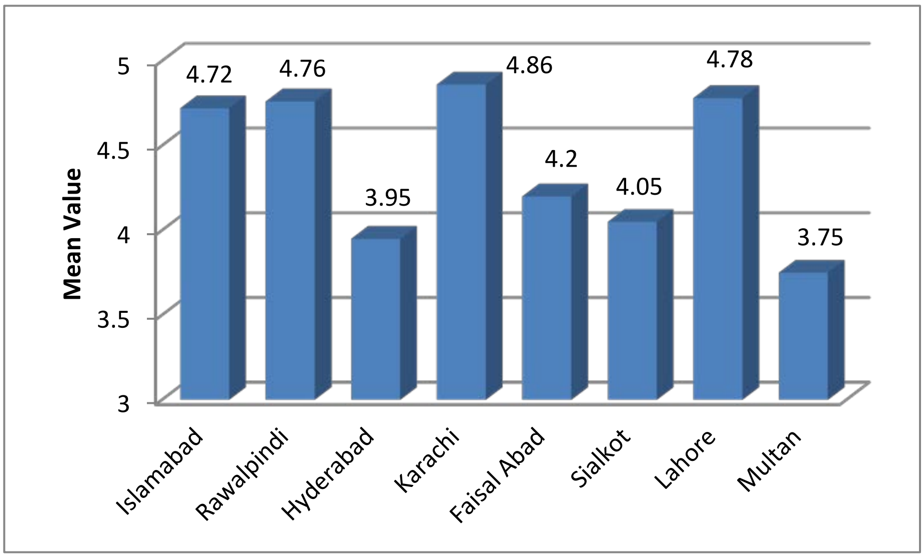
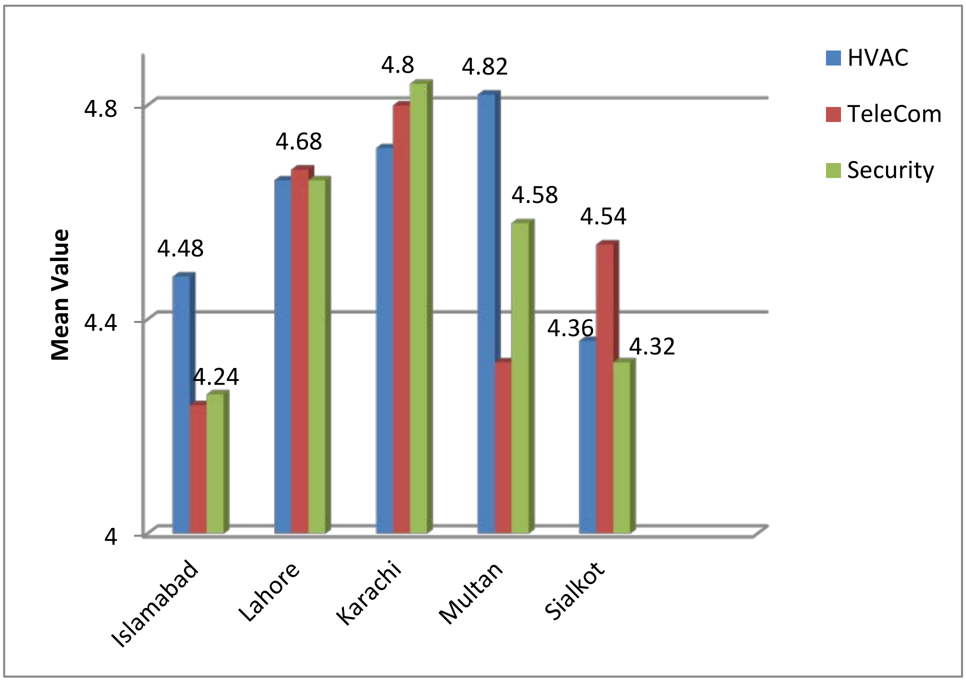


Figure5.4: Comparison of top three hurdles in different cities of Pakistan.



5.8 MANN – WHITNEY U Test

To find out the significant statistical difference between the perceptions of various categories of respondents i.e. educationist, owners and professionals in ranking of various factors associated with "Intelligent Building Technologies" of Pakistan, Mann-Whitney U tests were performed on the received data of respondents as similar technique has been used to compare the perception of various independent respondents in China (Chan, 2011). Mann-Whitney U Test is a non-parametric test and belongs to a version of independent samples t- test and is performed on the ordinal data in a hypothesis testing situation. It tests whether two independent samples represent two populations with different median values (Sheskin, 2007). If the result of Mann Whitney U Test is significant, then it shows that there is significant statistical difference between the medians of two independent samples.

To check the statistical difference in ranking of 9 x factors of market analysis and 7 x factors of "technology preferences" by educationists, owners and professionals, Mann Whitney U test were performed between educationists and owners and professionals and owners as shown in Table 5.7 and 5.8 respectively. The null hypothesis (Ho) was considered as that there would no difference in the ranking/perception of two independent sectors and alternative hypothesis (H1) was considered as that there would be significant difference in the perception of two groups at alpha level (α) equal to 0.05. Z distribution (z) two tail test was used where if "z" was less than -1.96, the null hypothesis would be rejected.

Table 5.7: Detail of Mann Whitney U Test Statistic between Owners and `Professionals

S/No	Factor	Owner (mean rank)	Professional (mean rank)	Z	P-value
1	Unavailability of required technology	4.56	4.68	-0.509	0.610
2	Unawareness among people concerned	4.56	3.80	-0.418	0.034
3	Non availability of technical staff	4.44	4.52	-0.462	0.644
4	Serviceability / warranty assurance	4.24	4.36	-0.178	0.859
5	Law / legislation	4.06	3.98	-0.802	0.422
6	Higher cost of technology	3.72	4.60	-2.466	0.016
7	Difficulty of achieving agreement among the stakeholders and their interests.	4.36	4.42	-0.530	0.008
8	Power breakdown, restrictions from government	4.60	4.52	-0.184	0.524
9	High cost of maintenance	4.28	4.20	-0.634	0.584

Table 5.7 shows that the owners and professionals did not agree on the higher cost of technology. For the owners, putting in extra cost was a big concern whereas for the professionals it was not as they were looking in to the future benefits and the fact that the resource conservation through the implementation of IB technologies would end up not only paying back the initial cost in the first 3-7 years but also cost savings in the future.

Table 5.8: Detail of Mann Whitney U Test Statistic between Owners and `Professionals

S/No	Factor	Owner (mean rank)	Professional (mean rank)	Z	P-value
1	HVAC	4.24	4.30	-0.547	0.124
2	Energy Management	3.80	4.64	-2.177	0.018
3	Telecommunication / LAN	4.54	4.60	-0.214	0.122
4	Facility management	4.24	4.28	-0.841	0.173
5	Life safety systems	4.32	4.44	-0.622	0.111
6	Security systems	4.54	4.58	-0.464	0.229
7	Lighting System	3.62	4.34	-2.108	0.002

Table 5.8 shows that the owners and professionals did not agree on lighting systems. This is primarily because most owners do not realize that as far as resource conservation and cost savings is concerned, HVAC is of prime importance as 40% of the building's energy consumption is due to HVAC systems.

Table 5.9: Detail of Mann Whitney U Test Statistic between Academics & Owners

S/No	Factor	Owner (mean rank)	Academic (mean rank)	Z	P-value
1	Unavailability of required technology	4.52	4.48	-0.509	0.610
2	Unawareness among people concerned	4.32	4.36	-0.118	0.906
3	Non availability of technical staff	4.74	4.68	-0.462	0.644
4	Serviceability / warranty assurance	4.68	4.60	-0.178	0.859
5	Law / legislation	4.20	4.26	-0.802	0.422
6	Higher cost of technology	4.34	3.62	-2.192	0.004
7	Difficulty of achieving agreement among the stakeholders and their interests.	4.36	4.42	-0.602	0.122
8	Power breakdown, restrictions from government	4.14	4.18	-0.324	0.454
9	High cost of maintenance	4.22	4.18	-0.624	0.632

Table 5.9 shows that the owners and academics did not agree on lighting systems as well. This is again, primarily because most owners do not realize that as far as resource conservation and cost savings is concerned, HVAC is of prime importance as 40% of the building's energy consumption is due to HVAC systems.

Table 5.10: Detail of Mann Whitney U Test Statistic between Owners and Academics

S/No	Factor	Owner (mean rank)	Academics (mean rank)	Z	P-value
1	HVAC	4.24	4.20	-0.214	0.238
2	Energy Efficiency	4.20	4.16	-0.424	0.124
3	Telecommunication / LAN	3.54	4.38	-2.018	0.014
4	Facility management	4.54	4.42	-0.624	0.111
5	Life safety systems	4.48	4.40	-0.844	0.229
6	Security systems	3.68	4.42	-2.341	0.008
7	Lighting System	4.24	4.20	-0.214	0.238

Table 5.10 shows that the owners and academics had different ideas about the security system installation and integration as well. While on the priority list for owners, it dropped down to around number four on the list of academics, which is clearly observed in the Mann Whitney test data.

5.9 Summary

Chapter describes various tests and procedures adopted for data analysis in which normally, reliability and correlation of data was checked and confirmed through SPSS program. Chapter also highlights the important of various factors towards installing building technology in Pakistan between various provinces and categories of respondents. Finally, for better understanding of statistical data, pie chart and groups have also been drawn with the various tests.

Chapter 6

Conclusions and Recommendations

6.1 Conclusions

Based on the results of the present study, a set of conclusions was arrived at, which is described as follows;

- There is significant awareness about intelligent building technologies in the country, among all stakeholders, that is owners and professionals in addition to the academics.
- There is a large number of intelligent building technologies available throughout the world, however, as per results of the questionnaire analysis and research it was found that local availability of these technologies is nil and all the provisions for the BMS are imported largely from Johnson controls. .
- It was observed as per questionnaire analysis that BAS reduces cost and increases productivity and comfort.
- In Pakistan, people are not ready to embrace the modern technologies available in the market, they are ready to question, complain and criticize, instead of exploring the benefits and advantages and finding out ways to incorporate the available tools in the local industry.
- People are hesitant to employ intelligent building technologies as there is lack of awareness and lack of knowledge regarding these facilities.
- People misunderstand that the only benefit that an intelligent building has to offer is saving the energy costs. This misconception needs to be addressed and they need to be assured that building management and worker efficiency as well as increased productivity are no small benefits and should be taken in to account.
- There needs to be ample training offered in Pakistan in order to deal with the shortage of trained and skilled people in the field of intelligent building technologies.
- Through this thesis it was concluded that the advancement in IT and development of wireless infrastructures and the common use of and

easy availability of optic fibers has increased the cost effectiveness and application of IB technologies.

- Integration of not only technologies, but expertise as well is the most important tool for the proper application and implementation of IB technologies.
- A properly lay out and well integrated communication network is the back bone of any intelligent building.

6.2 Recommendations

- Written legislation, highlighting quality building construction, making sure that occupant comfort, safety and security is taken care of.
- Increased peak consumption rates for office buildings forcing the stakeholders to take preventive and energy saving measures
- Increased awareness among all stake holders about the benefits of embracing new technologies in the construction industry
- Reward system to increase stakeholders interest in adapting intelligent building technologies
- Educational institutes should upgrade their syllabi and offer relevant majors

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APPENDIX - I

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING (SCEE)

SURVEY QUESTIONNAIRE

To: ____

Subject: **Prospects of Intelligent Building Technologies in Pakistan**

Department of Construction Engineering and Management at School of Civil and Environmental Engineering (NUST) Islamabad is conducting a research survey for "**Prospects of Intelligent Building Technologies in Pakistan**".

The construction industry (CI) is one of the most important industries, participating in our national infrastructure development. An increase in the volume of construction is a positive indicator of national development and economic prosperity. This research is aimed exploring the awareness of intelligent building technologies in Pakistan, the major hurdles in the implementation of IB technologies and the factors in the order of preference that will be included in IBs if they are constructed.

We are interested to find out how you feel about Intelligent Buildings. We are conducting confidential surveys. We would like you to complete the attached questionnaire, for which confidentiality is assured. The questionnaire is relatively simple to complete.

It is important for you to be completely honest about your feelings. All responses will be treated in strict confidence. This will assist us with analysis and interpretation of results.

We thank you for your assistance and cooperation in advance.

Yours sincerely,

Maryam Raza

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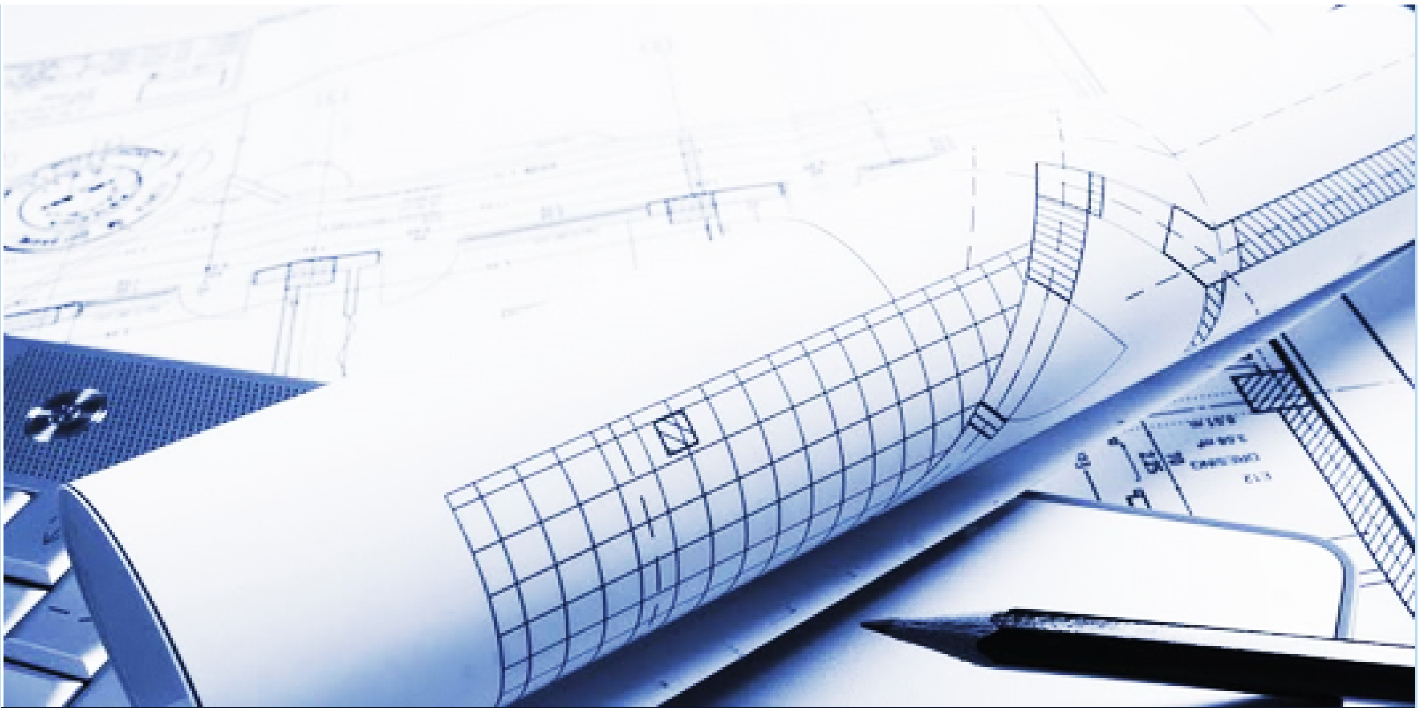
APPENDIX - II

Questionnaire



Questionnaire: Prospects of Intelligent Building Technologies in Pakistan

The purpose of the following exercise is to identify what according to the professionals are the challenges faced in the implementation of Intelligent Buildings in Pakistan, the most attractive intelligent building technologies for the local industry, and the It is ensured that any information provided here in shall be kept private and used for research purposes only.

GENERAL INFORMATION

Name

Occupation

Organization/department

Qualification

Province

Experience (in years) in the field

Contact number (optional)

Email address

Field of experience

- ☐ Professional (contractor/consultancy)
- ☐ Academic (teacher/student)
- ☐ Owner
- ☐ Other:

Category related with construction

- ☐ Government/Public
- ☐ Private
- ☐ Other:

Questionnaire: Prospects of Intelligent Building Technologies in Pakistan

Intelligent buildings:

An Intelligent Buildings is 'one which provides a productive and cost-effective environment through optimization of its four basic elements including structures, systems, services and management and the interrelationships between them'. It can also be defined as 'one that creates an environment which maximizes the effectiveness of the building's occupants, while at the same time enabling efficient management of resources with minimum life-time costs of hardware and facilities'. An intelligent building employs building automation systems (BAS)., for controlling and maintaining all the main systems like HVAC, fire fighting, security, lighting and elevators/escalators automatically, for better efficiency, cost effectiveness and optimal user comfort. This results in better and more effective energy management, facilities management, security management and life safety systems management in the building. The following questionnaire is designed to obtain in put from the Pakistani industry and to gain insight in to their perception of the IB concept and the relative importance of the intelligent systems in the building.

AWARENESS

This section is designed to check how you keep up with Intelligent Building technologies and your awareness about local and international Intelligent Buildings projects

1: Are you familiar with intelligent building technologies?

- ☐ yes
- ☐ no

2: How did you come to know of the Intelligent building concept?

- ☐ seminars
- ☐ journals
- ☐ colleagues
- ☐ university
- ☐ Existing projects
- ☐ other

3: How do you update yourself about intelligent building technologies?

- ☐ seminars
- ☐ journals
- ☐ colleagues
- ☐ university
- ☐ Existing projects
- ☐ other

4: Do you know of any intelligent building projects in Pakistan? please specify names if you answered with a yes.

5: Are you aware of any international intelligent building projects? please specify names if you answer with a yes.

SIGNIFICANCE

This section is designed to find out what according to you is the most important intelligent system and what is the greatest advantage of intelligent buildings

Building technology preferences

Rank the following systems/building components to mark their individual importance in the Intelligent Building

Energy management

1=least important, 5=most important

1	2	3	4	5
○	○	○	○	○

Security management

1=least important, 5=most important

1	2	3	4	5
○	○	○	○	○

Life safety/fire protection systems

1=least important, 5=most important

1	2	3	4	5
○	○	○	○	○

Facility anagement

1=least important, 5=most important

1	2	3	4	5
○	○	○	○	○

Telecom/LAN

1=least important, 5=most important

1	2	3	4	5
○	○	○	○	○

HVAC Systems

1=least important, 5=most important

1	2	3	4	5
○	○	○	○	○

CHALLENGES IN IMPLEMENTING INTELLIGENT BUILDING TECHNOLOGIES IN PAKISTAN

1: Is the high cost of intelligent building technologies is a big hurdle in their implementation?

1=strongly disagree, 3=neutral, 5=strongly agree

1	2	3	4	5
○	○	○	○	○

2: Is the unwillingness to change conventional construction methods a hurdle in implementing intelligent building technologies??

1=strongly disagree, 3=neutral, 5=strongly agree

1	2	3	4	5
○	○	○	○	○

3: Is the requirement of extensive training for a broad spectrum of workers exceptionally hard to achieve?

1=strongly disagree, 3=neutral, 5=strongly agree

1	2	3	4	5
○	○	○	○	○

4: How difficult is it to achieve co-operation and agreement among the stakeholders?

1=strongly disagree, 3=neutral, 5=strongly agree

1	2	3	4	5
○	○	○	○	○

5: Would written legislation and interest by the government increase interest in constructing intelligent buildings?

1=strongly disagree, 3=neutral, 5=strongly agree

1	2	3	4	5
○	○	○	○	○

6: How do you agree that unawareness is one of the major causes of not ccepting or employing IB technologies?

1=strongly disagree, 3=neutral, 5=strongly agree

1	2	3	4	5
○	○	○	○	○

7: Do the power breakdowns and load shedding from the government make your decision for IB technologies harder?

1=strongly disagree, 3=neutral, 5=strongly agree

1	2	3	4	5
○	○	○	○	○

8: Is the unavailibiliy of technology a set back for IB system implementation?

1=strongly disagree, 3=neutral, 5=strongly agree

1	2	3	4	5
○	○	○	○	○

9: are the servisability and warranty issues a major put off?

1=strongly disagree, 3=neutral, 5=strongly agree

1	2	3	4	5
○	○	○	○	○

Do you have any further comments?

APPENDIX - III

List of intelligent building projects over the world

- Anantara Desert Islands Hotel, hotel complex in Sir Baniyas island Abu Dhabi, UAE
- Ontario Tower G+25 in Dubai, UAE
- Mazaya Business Avenue, 3 towers 4B+G+3P+44 in Dubai, UAE
- Avilon Plaza business center in Moscow, Russia
- Kolomenskaya museum in Moscow, Russia
- Krasnaya Rosza business center in Moscow, Russia
- Cardiological Institute power center in St Petersburg, Russia
- PeterburgRegionGaz in St Petersburg, Russia
- SberBank in Nizhnyi-Novgorod, Russia
- Tax inspection center in Moscow, Russia
- Klaipedos Smelte refrigerator terminal, Lithuania
- Business center in Astana, Kazakhstan
- Karolinska Institutet, research institute in Stockholm, Sweden
- Järfälla kommun school complex, Sweden
- Department of Justice in Helsinki, Finland
- Court house of City of Varkaus, Finland
- Technopolis technology center in Vantaa, Finland
- Shopping mall Jumbo in Vantaa, Finland
- Headquarters of Senate Properties in Helsinki, Finland
- Alarm Center of Civil Defence of Turku, Finland
- All phases of Technopolis technology center in Vantaa, Finland
- Headquarters of Senate Properties in Helsinki, Finland
- Headquarters of Sato Rakennuttajat in Helsinki, Finland
- Microteknia technology center in Kuopio, Finland
- Village of 600 smart houses in Brunstad, Norway
- Ocean Heights penthouses, luxurious residential tower in Dubai, UAE
- Lootah Marina Tower, luxurious residential tower in Dubai, UAE
- O2 residential tower G+39, Dubai, UAE
- Waleed Paradise residential tower G+34 in Dubai, UAE
- Damac Signature Residence Showroom in Dubai Media City, UAE
- Dorra Bay residential tower G+21 in Dubai, UAE

- Ontario Tower G+25 in Dubai, UAE
- Palace of President of Uginvest, UAE
- Palace of Chairman of Damac, UAE
- Palace of Chairman of Tameer, UAE
- Villa of Mr. Ibrahim Fahim in Dubai, UAE
- Villa of Mr. Hani Nabulsi in Dubai, UAE
- Mammut Hatta Farmhouse in Dubai, UAE
- Sharqan villa area in Sharjah, UAE
- Kurkino area of blocks of flats in Moscow, Russia
- Sundsberg intelligent residential area in Kirkkonummi, Finland
- Kaskisaari intelligent residential area in Helsinki, Finland
- Paris-Sorbonne University in Abu Dhabi, UAE
- Anantara Desert Islands Hotel, hotel complex in Sir Baniyas island Abu Dhabi, UAE
- Village of 600 smart houses in Brunstad, Norway
- Palace of President of Uginvest, UAE
- Sharqan villa area in Sharjah, UAE
- Kaskisaari residential area in Helsinki, Finland