EVALUATING INTELLIGENCE IN INTELLIGENT BUILDINGS
CASE STUDIES IN TURKEY

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Maryam Farzin Moghaddam

ABSTRACT

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CASE STUDIES IN TURKEY

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Advances in technologies and the idea of incorporating technological solutions into buildings have made it possible to provide more comfortable and secure spaces for living or working. The term “intelligent building” is becoming very popular in terms of attaching prestige to a project and improving its desirability. However too many buildings are claimed to be intelligent and adaptive to change but, without an appropriate understanding of intelligent building concept and also capabilities of assessing an intelligent building, it is not possible to judge such claims. In view of the fact that truly intelligent buildings provide their occupants with efficient facilities and comfortable space, many experts and researchers have discussed the characteristics of intelligent buildings and come up with different definitions and assessment systems, but none agree with each other completely.

The aim of this study was to evaluate intelligence in intelligent buildings and provide responsiveness clues in terms of system efficiency and user convenience to find out whether buildings claimed to be intelligent meet the intelligence requirements or not.

After conducting a literature survey to identify main intelligence characteristics, two buildings both claimed to be intelligent and able to provide occupants with healthy, secure and comfortable space, were selected as the case studies. The intelligent building principals and specific design considerations together with efficient system integration and system requirements were examined in the case studies. It was concluded that, even though case studies were admired in terms of holding commercial value and applying new technologies but there existed a lack in either employing or incorporating that technologies to meet desired responsiveness and dynamism which, are main attributes of intelligent buildings.

Key words: intelligent building, intelligent building indicators, intelligent building systems, intelligent building assessment.

ÖZ

AKILLI BİNALARIN AKIL SEVİYESİNIN DEĞERLENDEİRİLMESİ

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Teknolojik gelişmeler ve binaların içine teknolojik çözümler içeren fikir, yaşamak veya çalışmak için daha rahat ve güvenli mekanlar temin etmeği mümkün kılmıştır. "Akıllı bina" terimi bir proje için prestij ekleme ve cazibe iyileştirilmesi açısından çok popüler hale gelmek üzeredir. Ancak çok sayıda bina, değişim için akıllı ve uyumlu olduğu iddia ediliyor, ama akıllı bina konsepti ve aynı zamanda akıllı bir bina değerlendirme yeteneklerinin uygun bir anlayışı olmadan böyle iddiaları değerlendirmek mümkün değildir. Gerçekçi bir bakış açısından, doğru akıllı binalar, , sakinlerine verimli tesis ve konforlu bir mekan sağlayabilirler ki birçok uzman ve araştırmacı akıllı bina özellikleri üzerinde tartışmış ve farklı tanımları ve değerlendirme sistemlerini ortaya atmaktadırlar ama hiçbiri birbirine tamamen katılmıyorlar.

Bu çalışmanın amacı, akıllı binalarda akıllılığı değerlendirmek ve sistem verimliliği ve kullanım kolaylığı açısından binaların akıllılık ihtiyaçlarını karşılamak olduğu iddiasını, olup olmadığını öğrenmek için yanıt ipuçları sağlamaktır. Bir literatür taramasından sonra, iki binanın akıllı, sağlıklı ve güvenli olduğu ve sakinlerine konfor sağladığı iddia edilen her iki bina, örnek çalışma olarak seçilmiştir. Akıllı bina sorumluları ve etkili bir sistem entegrasyonu ve sistem gereksinimleri ile birlikte özel tasarım konuları örnek çalışmalarda incelenmiştir. Ulaşılan sonuçlara göre, bu örnek çalışmaların ticari değeri tutan ve yeni teknolojiler uygulaması açısından takdirle karşılandığına rağmen, akıllı binaların temel nitelikleri, istenilen tepki ve dinamizmi karşılamak için, bu teknolojilerin bir eksikliği var.

Anahtar kelimeler: akıllı bina, akıllı bina göstergeleri, akıllı bina sistemleri, akıllı bina değerlendirmesi.

To my beloved family

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TABLE OF CONTENT

APPENDIECES

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

LIST OF ABBREVIATIONS

AIIB (Asian Institute of Intelligent Building)

BAS (Building Automation System)

BIAI (Building Intelligent Assessment Index)

CCTV (Closed Circuit Television System)

EIBG (European Intelligent Building Group)

HVAC (Heating, Ventilation and Air-conditioning)

IBI (Intelligent Building Index)

IBRT (Intelligent Building Ranking Tool)

IBS (Intelligent Building System)

JIBI (Japanese Intelligent Building Institute)

QEM (Quality Environment Modules)

CHAPTER 1

INTRODUCTION

This study concerns new technologies and systems integrated into many newly constructed buildings in order to make them responsive and dynamic. In this chapter are presented the argument, primary objectives of the study and a brief overview of the methodology. The chapter concludes with a disposition of the material stated in the remaining chapters.

1.1. Argument

The emergence of intelligent buildings dates back to early 1980s in United States and since then thousands of intelligent buildings has been built. In the late 90's, emergence of industrial Ethernet and IP enabled the production of sensors and actuators to share video, voice and data in a building. Thereafter, advances in electronic and computer technologies led to development of wide variety of building systems. Today constructed buildings are equipped with some degree of advanced technologies and automated components that were not available in the past.

Intelligent buildings claim to provide benefits in terms of several different issues such as:

- Efficiency
- Cost
- Environmental impacts

- Health
- Security

In other words, intelligent buildings claim to apply technology to improve the building environment, functionality and adaptability for occupants while controlling costs.

Any idea to forecast the future of building industry would be deficient regardless of intelligent buildings as almost every newly constructed building includes the simplest intelligence indicators such as automatic lighting or HVAC system. The question that comes to mind is “what are the indicators of intelligence and the related properties of functionality and adaptability?” So, there is a need to define the indicators of building intelligence and their interrelationship together with automatic controllers and installations in intelligent buildings.

In addition, weather buildings claimed to be intelligent are truly intelligent or not, is another issue which requires concern. Regarding the fact that intelligent buildings hold commercial values and cost much more than a normal building for occupants there is a need to determine if the building operates as efficient as claimed or not.

1.2. Aim and Objectives

The aim of the study is to provide clues to what might be called intelligence in intelligent buildings and evaluate intelligence of intelligent buildings. In order to achieve this aim, following are the specific objectives:

- Study the concept of intelligent buildings;
- Identify the indicators of intelligence in an intelligent building;
- Produce a check list for architects that, they can use to design an intelligent building;
- Test the check list on case study buildings in Turkey.

1.3. Procedure

The study was designed to construct a check list for architects considering the most common systems and indicators used in intelligent buildings based on the material given in the literature survey. To do this, the most common indicators which, experts mentioned among different definitions given to intelligent buildings, were summarized in a table and used as a framework to evaluate the case study.
In order to get a better understanding of degree of intelligence in intelligent buildings, two case studies with different functionalities were studied. A residential building was compared to an office one.

1.4. Disposition

The study is presented in four chapters.

Chapter 1 introduces the subject of the study including its argument and objectives; together with a brief procedure of the study and disposition of the subject matter.

Chapter 2 includes the survey of literature and presents: emergence of intelligent buildings, their development and technologic aspects together with their indicators and systems.

In Chapter 3 the method of the study is presented. The case studies are evaluated based on a check list constructed according to the material cited in Chapter 2 and results are given.

Chapter 4 includes the evaluation results of the case studies and discussions. Finally Chapter 5 presents the conclusion derived from literature cited and evaluation results.

CHAPTER 2

LITERATURE SURVEY

In this chapter a survey of literature about intelligent buildings, their definition and historical development together with their indicators and systems are presented.

2.1. The concept and Definitions of Intelligent Building

Emerging and growing of intelligent buildings owes to development and application of technologies in the areas of communication, information, materials and machinery in the construction industry which enabled the production of high efficient devices and systems. Intelligent building is the integration of architectural system, structural system and facilities system within which subjects as sustainable architecture, building structure control, building facility control, computer and network, communication and information, safety and security control, multimedia application, structured cabling and comprehensive electrical system are concerned (Clements-Croome, 2004). In other words, the difference between intelligent buildings and conventional ones lies in the presence of a central computer linked to an integrated network which connects sensors, activators and other installation together. In this way, "the entire building is kept under control since the various installations, from the air conditioning to the security system and computer system, interact by means of the network" (Travi, 2001).

In general intelligent building referres to a building equipped with high-technology devices and computer systems in which, building systems rather than a goal, are means of meeting user requirements (Harrison, Loe & Read, 1998). In other words technology alone does not make a building intelligent, technology works in favor of occupants to make the building responsive to individual, organizational and environmental needs and able to cope with changes (Yang & Peng, 2001).

Many of technical and academic literature discuss the definition of intelligent buildings. However, having one standard definition is not obligatory, the important issue is to have a clear understanding of what different people need and what are their preferences (Wang, 2010). Wigginton and Harris (2002), as the result of a research concerning the intelligent building definitions have mentioned the number of separate definitions to be over 30. One reason is difference in culture or civilization of each country which, require different technologies rather than that in highly developed countries in favor of given priorities in the history and culture of that special country (Clements-Croome, 1997).

Early definitions of intelligent building focused almost entirely on technology and ignored user interaction (Wigginton & Harris, 2002). However, limitations of technological definitions of building intelligence in the mid-1980s could not meet the intelligent building requirements. Some early intelligent building definitions are given as below: Wigginton & Harris (2002), referred to Cardin's (1983) definition of an intelligent building as "one which has fully automated building service control systems". Kroner (1997), cited the definition adapted by the Intelligent Building Institution in Washington definition as "one which integrates various systems to effectively manage resources in a coordinated mode to maximize: technical performance, investment and operating cost savings, flexibility".

Clements-Croome (1997), cited CIB Working Group W98's (1995) definition as: "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 inter action between them".

There are more other definitions but they all commonly have emphasis on flexibility, responsiveness, process and management of business, space and people. Moreover, in a truly intelligent building intelligence should be applied at the concept, construction and operation of a project by clients, designers, contractors and facilities managers (Clements-Croome, 1997).

Wang (2010) categorised intelligent buildings in three groups in order to give clear understanding of the subject as following:

- Performance based definition
- Service based definition
- System based definition

Performance based definition emphasizes demands of users, energy and environmental performance of the building and it's response to internal and external conditions. European Intelligent Building Group (EIBG), located in the United Kingdom, defined intelligent building as one which "give its users the most efficient environment; at the same time, utilizes and manages resources efficiently and minimizes the life costs of hardware and facilities".

In service based definition, services or quality of the services afforded by buildings such as communication and building automation are addressed directly. Japanese Intelligent Building Institute (JIBI) is an example of this definition.

System based definition emphases the technologies and technology systems which intelligent buildings should comprise of, such as: building automation, communication network systems and integration of structure, system, service and management (Wang, 2010).

So & Chan (1999) categorized different definitions for intelligent buildings in USA, Europe and Asia.

- **Definition in U.S.A.**

In definition of intelligent building in U.S.A. the emphasis is put on the availability of technologies. According to the Intelligent building Institute (I.B.I) of U.S.A. an intelligent building provides a cost-effective and productive environment by optimizing its four basic elements: systems, structure, management and services and interrelationship between them. I.B.I also indicated that intelligent building should operate in a cost-effective and convenient manner and accommodate to changes regardless of the characteristics which defines an intelligent building (So & Chan, 1999).

- **Definition in UK**

EIBG, U.K. based, defined intelligent building as one which “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”. In this definition relationship between the building, computer systems and occupiers are concerned; hence, it can be concluded that European definition is based on user’s requirements rather than the technologies (So & Chan, 1999).

- **Definitions in Asia**

Singapore, China and Japan proposed different definition as given bellow:

The definition in Singapore formulated by The Public Works Department of government focused on three elements as given bellow, regarding advance technologies (So & Chan, 1999):

- Advanced automatic control systems
- Good networking infrastructure
- Adequate telecommunication facilities

In China an intelligent building is labelled as “3A” or “5A”, digit indicating number of automatic functions. Communication automation (CA), building management automation (BA) and office automation (OA) systems integrated in a building label the building as 3A while, the addition of fire automation (FA) and maintenance automation (MA) systems make it called 5A (So & Chan, 1999). Communication via advanced technologies is emphasized in Chines definition.

Japanese definition considering flexibility, effective environment, comprehensive automation system and culture focused on four aspects as following:

- Management efficiency
- Occupant's convenience
- Low cost services
- Cope with sociological environment changes and business strategies

Cited definitions are summarized in Table 2.1 and focused aspects of regional definitions are presented.

Table 2.1 Focused aspects of regional definitions

	USA	UK	Singapore	Japan	China
Performance-based		*			
Service-based				*	
System-based	*		*		*

In So & Chan's (1999) point of view, Japanese definition is more suitable to formulate a universal definition, mainly for Asia also extendible to the whole world. The author argued that the existing definitions are either too obscure for detailed design or place imbalanced focus on technologies which do not fit the culture of Asia.

In order to formulate an appropriate definition, So & Chan (1999) suggested a two level strategy. The first level included Quality Environment Modules (QEM) and the second level comprised a number of facilities or key elements which need consideration of designers to specify building systems that should be provided in an intelligent building.

The Asian Institute of Intelligent Building (AIIB) defined nine QEM as given bellow:

- Environmental friendly - energy conservation and health (M1);
- Space utilization and flexibility (M2);

- Human comfort (M3);
- Working efficiency (M4);
- Culture (M5);
- Image of high technology (M6);
- Safety and security – earthquake, fire, structural damages, *etc* (M7);
- Construction process and structure (M8);
- Cost effectiveness – operation and maintenance (M9);

Key elements are defined as functional spaces, functional requirements and technologies; however, more can be added or removed from time to time. Each key module is assigned a number of facilities in an appropriate order of priority and the new intelligent building definition is formulated as the one which "designed and constructed based on an appropriate selection of QEM to meet the user's requirements by mapping with appropriate building facilities to achieve long term building values" (Wong, So & Leung, 2005). In later versions of the AIIB index one more QEM, M10: health and sanitation has been added and M7 and M8 have been modified to M7: safety and structure, M8: management practice and security, respectively.

The integration of two dimensions generates values for the building in terms of productivity, energy conservation and market values that can be measurable. In this case, different building types would have a set of different design criteria in order to call intelligent. Building types could be industrial, commercial (office or retail), residential, educational, transportation terminals, religious and public services (community centers or libraries) *etc*. Afterwards different quality environmental modules in priority manner (P1 the highest priority and P9 the lowest priority) are assigned to each type of building (Wong *et al*, 2005). In Table 2.2 is given some examples of the proper assignment of modules to different types of buildings.

Table 2.2 Priority of Modules assigned to different types of building, (source: Wong *et al*, 2005)

Type of building	P1	P2	P3	P4	P5	P6	P7	P8	P9
Hospitals	M1	M7	M3	M4	M9	M2	M5	M8	M6
Weighting	*9*	*8*	*7*	*6*	*5.5*	*5*	*2*	*1.5*	*1*
Residential buildings	M3	M5	M7	M1	M4	M9	M2	M8	M6
Weighting	*9*	*8*	*7*	*6.5*	*6.5*	*3*	*2*	*1.5*	*1*
commercial (office) buildings	M4	M2	M9	M3	M1	M7	M6	M5	M8
Weighting	*9*	*8.5*	*8*	*7.5*	*7*	*6.5*	*6*	*6*	*3*
Transportation terminals	M7	M3	M1	M6	M4	M9	M8	M2	M5
Weighting	*9*	*8.8*	*8*	*7*	*6*	*6*	*4*	*3*	*2*
Educational institutions	M4	M7	M2	M5	M9	M1	M3	M8	M6
Weighting	*9*	*8.8*	*8.5*	*8.2*	*8*	*7*	*6.5*	*6*	*5*

As discussed above, in this method different combinations of modules regarding priorities are assigned to different building types. After a module is selected, a group of facilities are assigned accordingly; however, it is likely to have one facility assigned to more than one module. Whether the design comprises all facilities depends on priority of the module regarding that type of building and availability of funding (Wong *et al*, 2005).

The latest Asian definition for intelligent buildings includes two dimension; enabling technologies (services and systems) and user needs (deliverable items), gave sufficient details for designers and users in how to design and occupy intelligent buildings. It also provided a fair platform to evaluate the performance of intelligent buildings. Hence, this study focused on new Asian definition prepared by AIIB.

2.2. Historical Development of Intelligent Buildings

United Technology Building Systems Corporation, (UTBS) defendant of intelligent buildings in 1981, was responsible for operation and controlling of the equipment such as air-conditioning, elevator and disaster prevention devices in the world's first intelligent building called City Place Building, built in 1983 in Hartford, Connecticut, U.S.A. Communication services such as local area networks (LAN's), office automation services, computers and digital private automatic branch exchanges (PABXs) were provided by UTBS Corporation to each tenant for the first time (So & Chan, 1999).

Harrison (1998) divided the history of the intelligent buildings into three distinctive periods as: Automated buildings (1981-1985), Responsive buildings (1984-1991) and Effective Buildings (1992-) as illustrated in Figure 2.1.

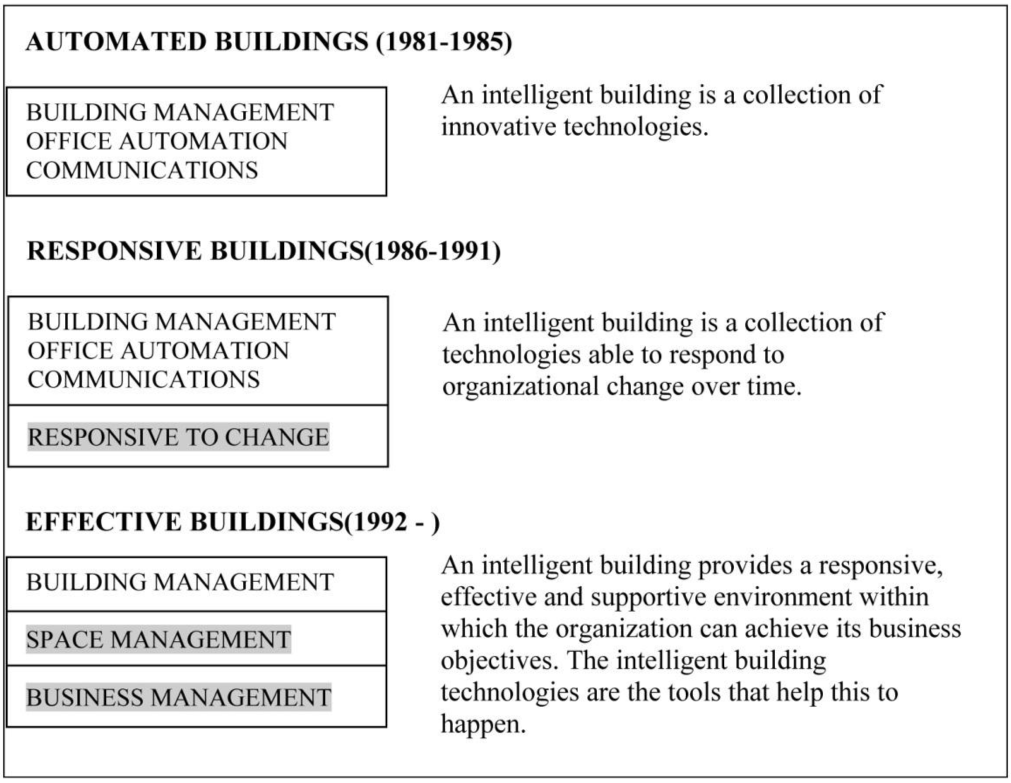


Figure 2.1 Models of Building Intelligence (Source: Harrison *et al*., 1998)

According to Harrison *et al* (1998), automated office buildings were the first generation of intelligent buildings that emerged in 1980s as a result of marketing competition between developers. The author claimed that examples of first generation were not as successful as expected due to deficiencies in integrity of data networking systems and telecommunication.

Purely technological definitions were criticized by many experts later on. In mid-1980s a research conducted by DEGW architects, demonstrated that the intelligent building should be able to deal with changes in the organizations which occupy them or information technology that they use; therefore, responsive buildings era started with the findings of this research and intelligent building definitions were then modified to include responsiveness to change (Harrison *et al*,1998).

From 1992 on it was focused on the environment which intelligent building created and building's occupants rather than on technology and computer systems.
Information technology was acknowledged in favor of user's needs but not as a reason of building intelligence.

Harrison *et al* (1998) stated three main goals of an organization in an intelligent building as: building management, space management and business management and constructed a model that is given in Figure 2.2.

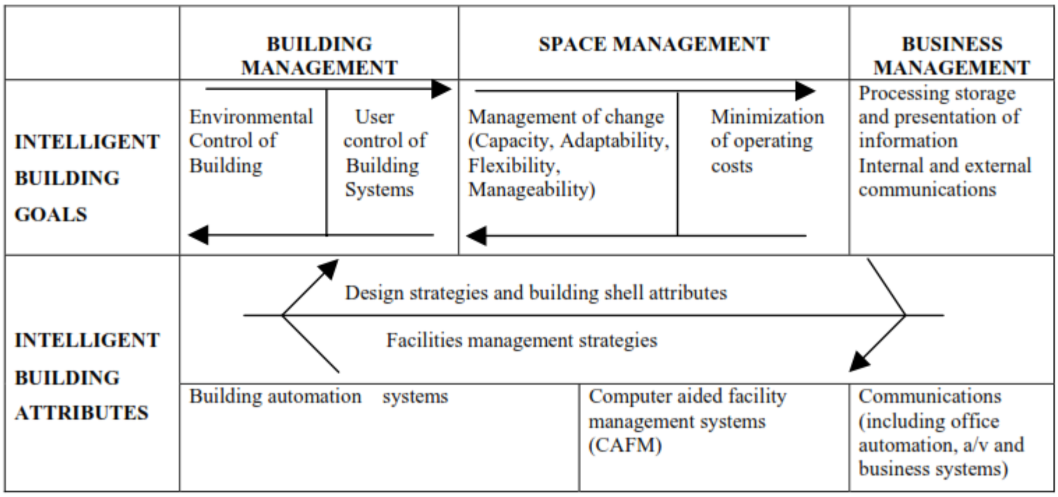


Figure 2.2 Model of building intelligence (Source: Harrison *et al.*, 1998)

- Building management: management of physical environment of the building by utilization of both computer systems (building automation systems) and human systems (facilities management).

- Space management: management of internal space of the building in terms of management of changes and operating cost minimization.
- Business management: management of business activities of the core organization.

The intelligent building pyramid, created by EIBG, given in Figure 2.3 presents the history and progress of systems and technologies integrated in intelligent buildings.

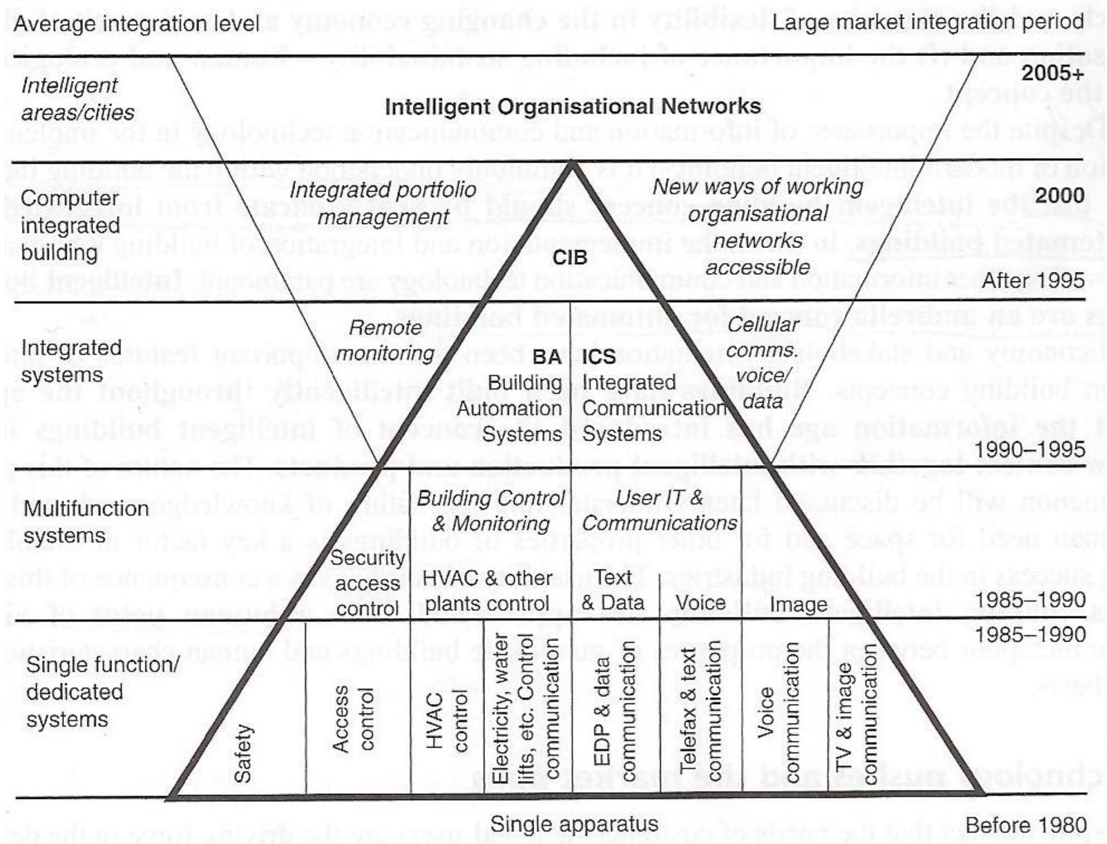


Figure 2.3 The intelligent building pyramid (Source: Harrison *et al.*, 1998)

2.3. Intelligent Building Index

Indicators cannot suggest an absolute measure for the design quality but can affect the qualities felt by users in an intelligent building. The basic criteria in selection of intelligent indicators should consider performance of the building regarding economy, local environment, business and culture. Besides, indicators themselves should be effective, quantifiable, understandable, relevant and usable by practitioners (Ugwu, Kkumaraswamy & Wong, 2006). Alwaer & Clements-Croome (2010), referred to Jefferson's (2007) work in citing the importance of an appropriate indicator system in that it should suggest a measure for current performance of the building, a clear expression about future performance targets and a criterion in order to measure the progress along the way.

Indicators and their related importance vary from one project to other and one culture to the other. Although it is possible to directly transfer the indicators from one index to the other, it might be needed to reformulate, omit or add some indicators depending on specific context of the country. In addition, specific considerations in any project affect the strategies for identifying indicators and related priorities. Finally selection of indicators should consider consequences from micro scales to global scales regarding the scope of the project (Alwaer & Clements-Croome, 2010).

In a research conducted by Wong & Li (2006), three steps for combining appropriate intelligent building components have been suggested:

1. Determination of key attributes,
2. Test critically of selected attributes,
3. Develop a conceptual model from appropriate combination of the selected components and systems for intelligent building project.

In first step the author identified attributes within each intelligent building system in accordance with the literature discussing intelligent building indicators. In second step a scientific questionnaire survey from experts was conducted and the most important indices were selected, finally a conceptual model for combination of building systems and components was constructed (Appendix A). The more significant attributes are given in Table 2.3 below, while the less significant attributes and systems are presented in Table 2.4. The conceptual model is given in Figure 2.4.

Table 2.3 The more significant attributes of Intelligent Building Systems (source: Wong & Li 2006)

BAS	Work efficiency	Reliability
		Ability of integration
		Efficiency (speed)
	Cost effectiveness	Life cycle cost
ICNS [1]	Work efficiency	Reliability
		Allow for further upgrade
		Life span (year)
		Transmission rate/speed
	Cost effectiveness	Life cycle cost
Fire protection	Work efficiency	Compliance with fire protection & fighting code
		Compliance with fire resistance code
		Signal transmission rate
		Allow for further upgrade
		Automatic sensoring and detection system for smoke
		Life span (year)
	Cost effectiveness	Life cycle cost
HVAC	Work efficiency	Life span (year)
		Integrated with BAS
		Frequency of breakdown
		Compatibility with other building systems
	User comfort	Thermal comfort: Predict mean vote (PMV)
		Thermal comfort: Indoor air quality
		Reduce noise
		Amount of fresh air changes
	Work efficiency	Life span (year)
		First cost
	Environmental related	Total energy consumption
	Cost effectiveness	Life cycle cost
Safety & security	Work efficiency	Time needed for public announcement of disaster
		Time needed to report a disastrous event
		Compatibility with other building systems
		Integrated with BAS
		Life span (year)
		Allow for further upgrade
		Time for total egress (minute)
	Cost effectiveness	Life cycle cost
		First cost

[1] Information and Communication Network System

Table 2.4 The less significant attributes of Intelligent Building Systems (source: Wong & Li 2006)

Vertical transportation system	Safety and security	Reliability (mean time between failure (MTBF)/month)
	Work efficiency	Life span (year)
		Waiting time (second)
		Maximum interval time (second)
		Journey time (second)
		Integrated with BAS
		Compatibility with other building systems
		Automatic and remote monitoring
	Environmental related	Energy consumption (kJ/passenger/minute)
	User comfort	Acceleration and deceleration (m/s2)
		Noise (dBA)
		Air change (AC/hr)
		Vibration (m/s2)
	Cost effectiveness	Life cycle cost
Electrical system	Cost effectiveness	Life cycle cost
	Work efficiency	Integrated with BAS
		Compatibility with other building systems
	Safety and security	Compliance with regulations
Lighting system	Cost effectiveness	Life cycle cost
	Work efficiency	Compatibility with other building systems
		Integrated with BAS
		Permanent artificial lighting average power density
		Allow for further upgrade
		Life span (year)
		Automatic control/adjustment of lux level
	User comfort	Ease of control
	Environmental related	Average efficacy of all lamps (lm/W)
H[2]	Work efficiency	Life span (year)
	Cost effectiveness	Life cycle cost
Interior Layout	Cost effectiveness	Life cycle cost
		First cost
	Work efficiency	Life span (year)
Façade system	Cost effectiveness	Life cycle cost
	Work efficiency	Integrated with BAS
		Life span (year)
		Compatibility with other building systems
		Automatic control and monitoring
	User comfort	Automatic response to change in temperature
		Automatic response to sunlight

[2] Hydraulic and drainage

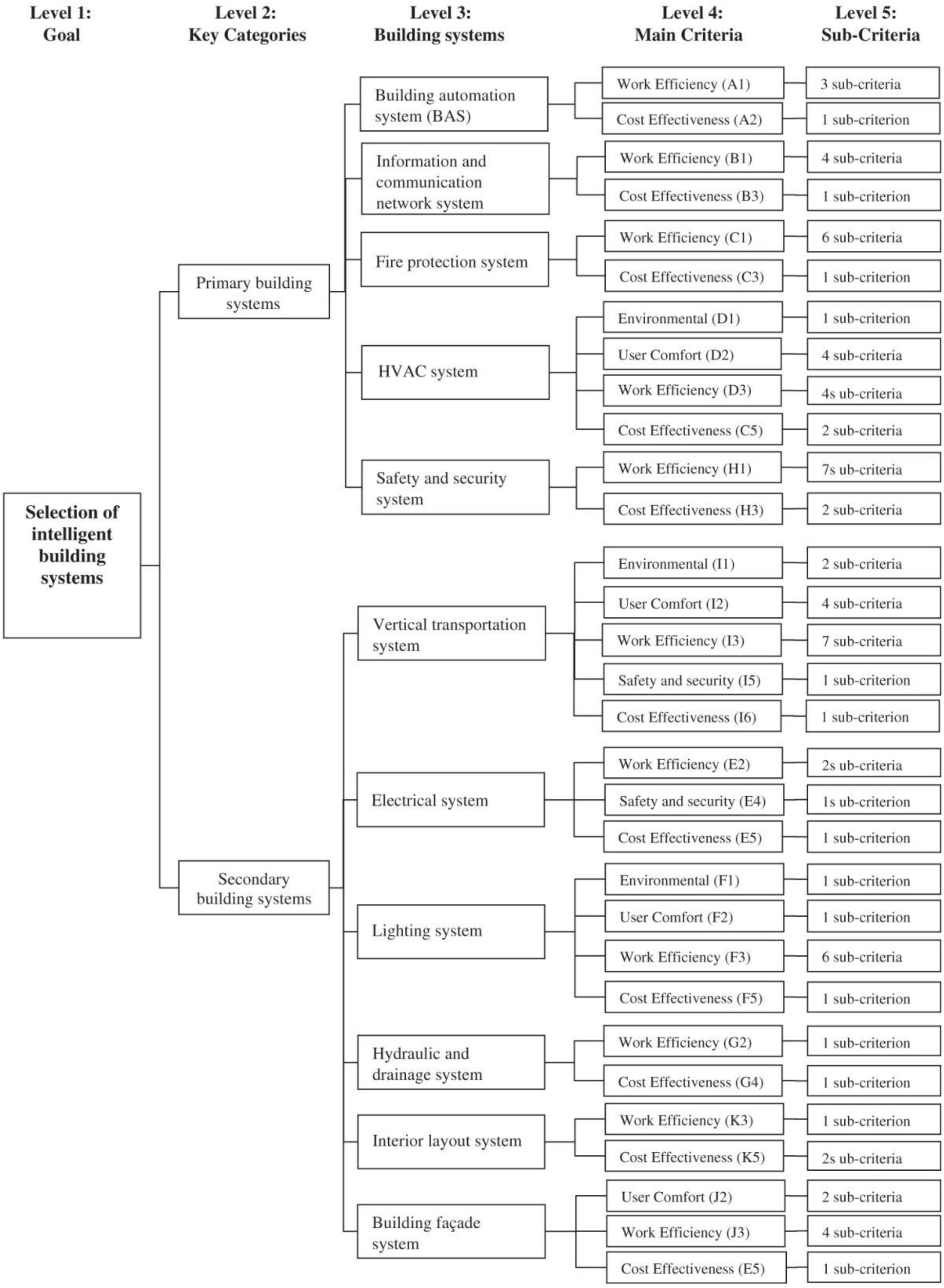


Figure 2.4 Conceptual model for the selection of appropriate combinantion of building systems and components for a particular intelligent building project (source, Wong & Li 2006)

There is no limitation on the number of indicators but a large number can limit comprehension and significance level of each indicator. Adopting widely used indicators ensures the reliability of the results, enabling them to be repeated and compared (Wong, Li & Lai, 2008).

Since there is wide variety of possible indicators to apply in intelligent buildings, experts have been inspired to develop conceptual models to select the most appropriate indicators. Chartered Institution of Building Service Engineers (CIBSE), Intelligent Building Score (IBS), Building Intelligent Assessment Index (BIAI), Intelligent Building Index (IBI) and Asian Institute of Intelligent Building (AIIB) are some of the organizations which provide valuable information regarding intelligent building components (Wong *et al*, 2008).

In intelligent building index prepared by AIIB, specific indicators are assigned to each of the QEMs. Table 2.6 shows QEMs and the number of indicators assigned to each module. Since there is plethora of indicators in the index as given in table below, some of the most important ones that Yiu, Cheng, Cheung, Hui, Lau, Liu, Lo, M.A, Pau, Tang & Yu (2010) presented in the seminar of introduction of IBI in Hong Kong University, are stated in the following section. Full list of indicators is given in Appendix A. It is obvious that cited indicators can vary in any specific project or modify to use in any other region.

Table 2.5 QEMs and number of related indicators (source: Wong *et al*, 2005)

Quality Environment Modules	Indicators
M1: environmental friendly or green index	67
M2: space utilization and flexibility	19
M3: human comfort	50
M4: working efficiency	81
M5: culture	12
M6: image of high technology	38
M7: safety and security	31
M8: construction process and structure	9
M9: cost effectiveness	1
M10: health and sanitation	32
Total	378

In the cited seminar presentation, indicators are grouped regarding three stages of an intelligent building's development:

1. Design,
2. Operation and maintenace,
3. Management;

There exists a number of indicators in each stage; however some sub-indicators might be assigned into upper level indicators. Figure 2.5 shows a hierarchial framework for QEMs and assigned indicators. Details on each QEM and indicators are presented in Table 2.7; in the first column QEMs are presented, in second column each index has been considered within three aforementioned stages and in next columns are stated the ditailed indicators derived from breaking indices.

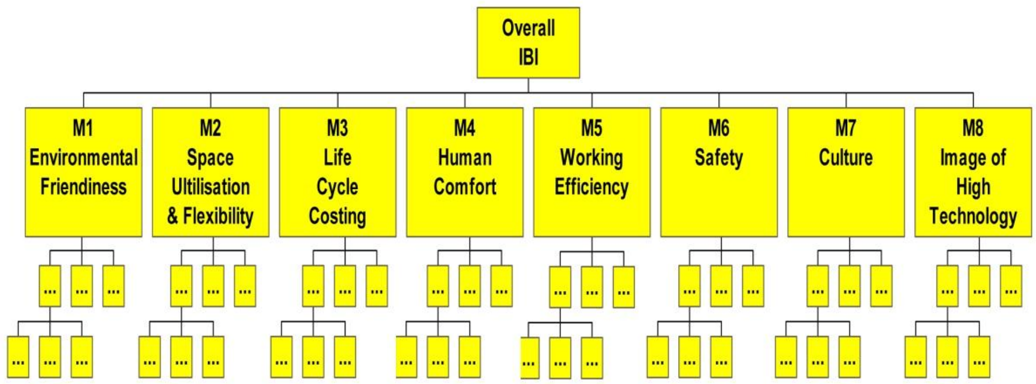


Figure 2.5 Hierarchial framework for QEMs and indicators Source: Yiu *et al*, 2010)

Table 2.6 QEMs and their indicators (source: Yiu *et al*, 2010)

M1: Green index	Design and construction materials	Consumption	Energy	Lifts and escalators
				Thermal comfort
				Electricity
				HVAC
				Lighting
			Water	Flushing system
				Fresh water supply system
			Air	Indoor air quality
			Environment	Indoor environmental quality
				General env. friendliness
		Pollution	Water and waste	
			Air	
			Noise and vibration	
			Lighting	
			General pollution	
	Operation, maintenance and management	Usage and alterations		
		Maintenance and repair		
		Management		
M2: Space utilization index	Design	Space allocation		
		Barrier free access		
		Car parking provisions		
	Operation and maintenance	Flexibility of space reallocation		
		Base of access for maintenance		
	Management	Provision of management office		
		Space management		
		Policy and Audit		

Table 2.6 Continued

M3: Human comfort index	Design	Space allocation		
		Access		
		Building services provision	Lifts and escalators	
			Thermal comfort	
			Ventilation	
			Lighting, color and appearance	
			Lavatory	
			Acoustics	
	Operation, maintenance			
	Management			
M4: Working efficiency index	Design	Space allocation		
		Access		
		Building services provision	Lifts and escalators	
			Thermal comfort	
			Ventilation	
			Lighting, color and appearance	
			Lavatory	
			Acoustics	
	Operation, maintenance			
	Management			

Table 2.6 Continued

M5:	Design	Environment	Feng Shui	
Culture			External landscape	
index			External view	
		Indoor	Privacy	
			Office layout	
			Culturaly based interior design	
			Color and indoor decoration	
			Entertainment facilities	
			Religious facilities	
			Indoor plants	
	Operation, maintenance	Promotion activity		
		Food and beverage supply		
	Management			
M6:	Design	e-services		
Technical		Building services provision		
index		Building design		
	Operation, maintenance	Intelligent building maintenance		
	Management	Building management system		

Table 2.6 Continued

M7: Safety and security index	Design and construction	Structural components	General structural design against natural disasters	
			Large frame and spaecial structures	
		Non-structural components	Finishes, wall tiles	
			Windows, doors	
	Operation, maintenance	Inspection and monitoring structure, fires safety, electricity, lifts		
		Usage and alterations		
		Maintenance and repair		
	Management	Risk management		
		Crowd control		
		Safety management		
M8: Management and security index	Design	Car park		
		Other areas		
	Operation, maintenance	Manitenance management		
		Building intelligence		
	Management	Security and safety		
		Property and facilities		
		Health and hygiene		
		Space		
M9: Cost index	Life cycle cost			
	Income from operations			
	Costs on maintenance and management			

Table 2.6 Continued

M10:	Design	Verification		
Health	Operation, maintenance	Portable water		
and		Flushing water		
sanitation		Drainage		
index		Refuse and cleanliness		
	Management	Health and hygiene		

2.4. Intelligent building systems

Many of the newly constructed buildings are claimed to be intelligent, however their level of intelligence varies corresponding to the operational efficiency and functionality of the installed intelligent components (Wan & Woo, 2004. Armstrong, Brambley, Curtiss & Kapitamula, 2001). Smith (2002) suggested two perspectives of intelligence for IBs. One view is related to building responsiveness while other view concerns adaptability. So, a system is called intelligent if it is able to respond and adapt itself to changing conditions.

Himanen (2004), stated that a building is intelligent if following aspects are implemented in it: environmental friendliness, movable space elements and equipment, flexibility and utilization of space, life cycle costing, convenience, comfort, safety and security, an image of high technology, working efficiency, culture, long term flexibility and marketability, construction process and structure, information intensity, service orientation, adaptability, ability of promoting health, productivity and reliability.

Any failure in operation of building components would lead to dissatisfaction of end users which could result in an overall lack of trust in intelligent technologies, in. Thus, designing and implementing appropriate intelligent building systems which are able to respond intelligently to the changing conditions, require great care (Pati, Park & Augenbroe, 2006).

In practice configuration of IB components, requires a designer's effort in selection and incorporation of the best intelligent building system packages among a vast variety of available alternatives; and incorporate them efficiently to design a truly intelligent building which meets the performance expectations of developers and end users (Wong *et al*, 2008). According to Wan & Woo (2004), satisfying business and commercial needs, user friendliness, meeting international standard protocols, energy saving features, integrating to multiple systems, information technology and flexibility are main perspectives of building intelligence. System designers need to hold a balance between these perspectives in order to meet the expectations of the people intending to occupy the building (Aygun, 2000).

A truly IB responds flexibly to user requirements and changing conditions by interaction between systems; meaning that, all individual systems interrelate with one another (Wong & Li, 2008). Elliot (2009), defined a system to be "a set of parts which, when combined, have qualities that are not present in any of the parts themselves". In an integrated system the parts interact with each other and also with the outside world; those relationships determine the system behavior and that if it is capable of providing desirable environment and meet human needs.

The systematic procedure for a good system design, in most of the literature author has reviewed, starts from a concept (goal) which is broken down to the specifications of the parts which are supposed to be built. Then it brings those separated parts together, tests them against specifications, integrates them and tests again; the procedure is repeated until the whole system meets the requirements.

Elliot (2009), suggested a systematic procedure for a good system design, summarized in a model given in Figure 2.6. The model comprises two types of activity to create a successful system. The left side of the model is analysis and decomposition (capturing the requirements and breaking them into specifications) while the right side is synthesis and integration, both have a common goal of an integrated system design. Integration is both horizontal and vertical. "Horizontal integration is the process of aligning the interests and actions of all of the organizations and people involved currently in the project. Vertical integration considers the total life of a building which starts with concept and ends in adaptation for a new role or demolition.

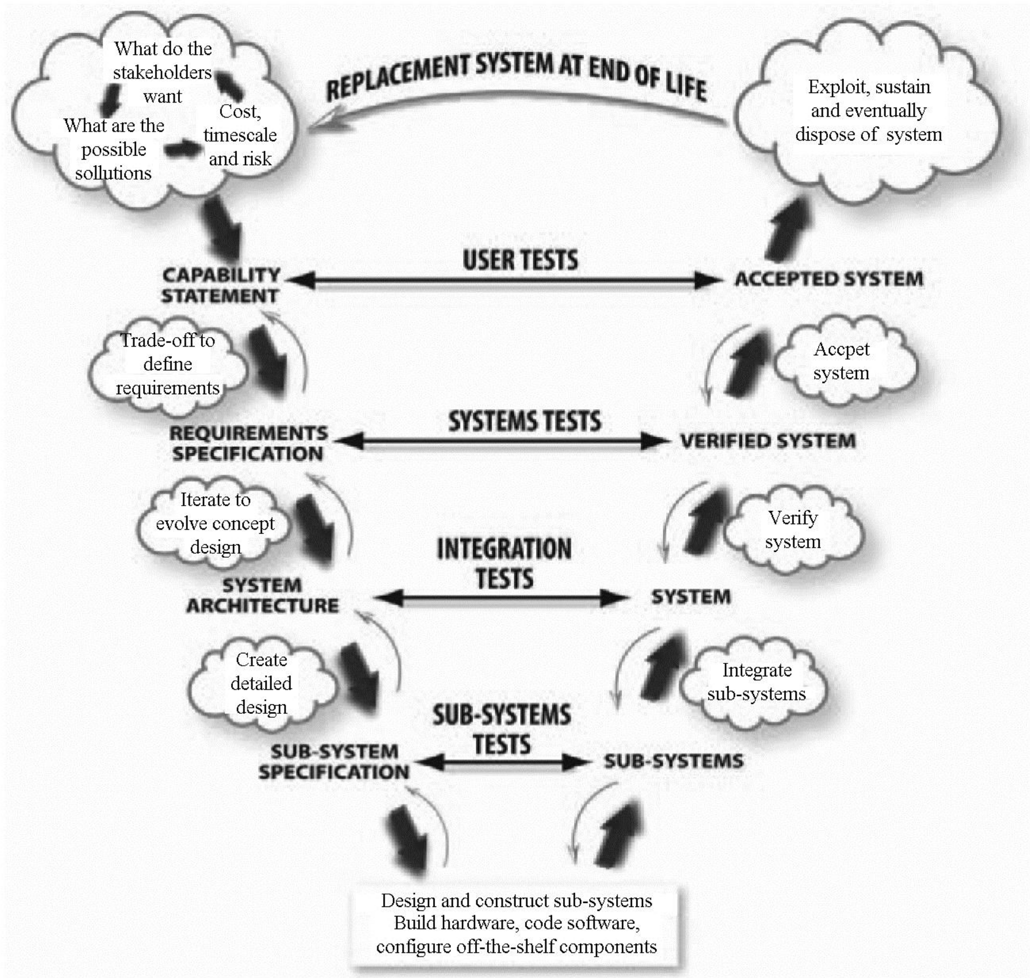


Figure 2.6 Systematic approach for a good system design (source: Elliott, 2009)

Wong & Li (2009), referred to Bien & Yang's (1998) work in determining four key intelligence attributes to construct a machine or system intelligence model. The key attributes are:

- Autonomy
- Man-machine interaction
- Controllability of complicated dynamics
- Bio-inspired behavior

Autonomy refers to machine (system)'s ability to perform self-operatively which means that, during the execution of a task an intelligent system should require the least human interaction as much as possible. The authors also suggested four key elements for autonomous indicators of intelligent systems as:

1. Self-calibration
2. Self-diagnostic
3. Fault-tolerance
4. Self-tuning

Wong & Li (2009) defined man-machine interaction as the ability of an intelligent system to communicate with operators, making them feel more comfortable (emergence of emotion) and make the system user-friendly (ergonomic design).

Controllability of complicated dynamics indicates an intelligent system as the one that is able to perform interactive operative functions and to make a complicated dynamic system controlled well.

Controllability of complicated dynamics indicates an intelligent system as the one that is able to perform interactive operative functions and to make a complicated dynamic system controlled well.

Bio-inspired behavior is related to the system's ability to "interact with the building environment and the services provided". The author pointed out some bio-inspired behavior traits as: biologically motivated behavior, characteristics of neuroscience and cognitive-based behavior which gives a better understanding of human mechanisms and related sensory systems.

The authors stated that, the integration of key intelligence attributes in any intelligent system lead to improved safety, enhanced reliability, high efficiency and economical maintenance. Figure 2.7 shows the summary of Bien's intelligence model.

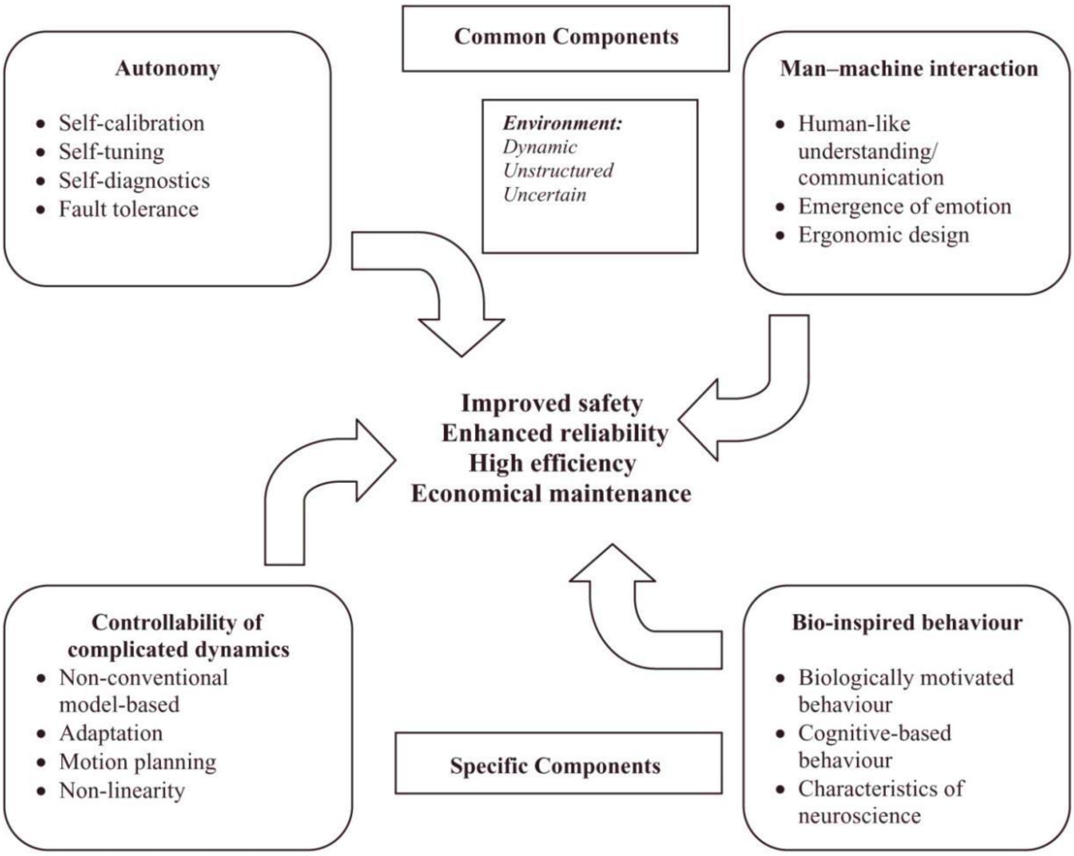


Figure 2.7 Taxonomy of key intelligence attributes in a general intelligent machine or system (source: Wong & Li, 2009)

Embedded technologies in intelligent buildings are being developed to make a close connection between the building and its systems and the occupants. These technologies are specified by a hierarchical presentation of system integration (Lu, Clements-Croome & Vilijanen, 2009). System integration is "the process of connecting systems, devices and programs together in a common architecture to share and exchange data" (Wong *et al*, 2005). The key factor in effective operation of intelligent building is not about sophistication of the building services systems but, is the integration among various systems. According to Arkin & Paciuk (1997) and Carlini (1998), there are three levels of system integration in many of the intelligent buildings as given below:

- In top level: building operation and communication management

- In middle level: Control, supervision and coordination of intelligent building subsystems which is performed by energy management system (EMS), building automation system (BAS), office automation (OA) and communication management system (CMS)
- In bottom level subsystems including: lighting system, vertical transportation system, fire protection system, security system, heating, ventilation and air-conditioning (HVAC) system and communication system

A model of this hierarchical system integration is given in Figure 2.8.

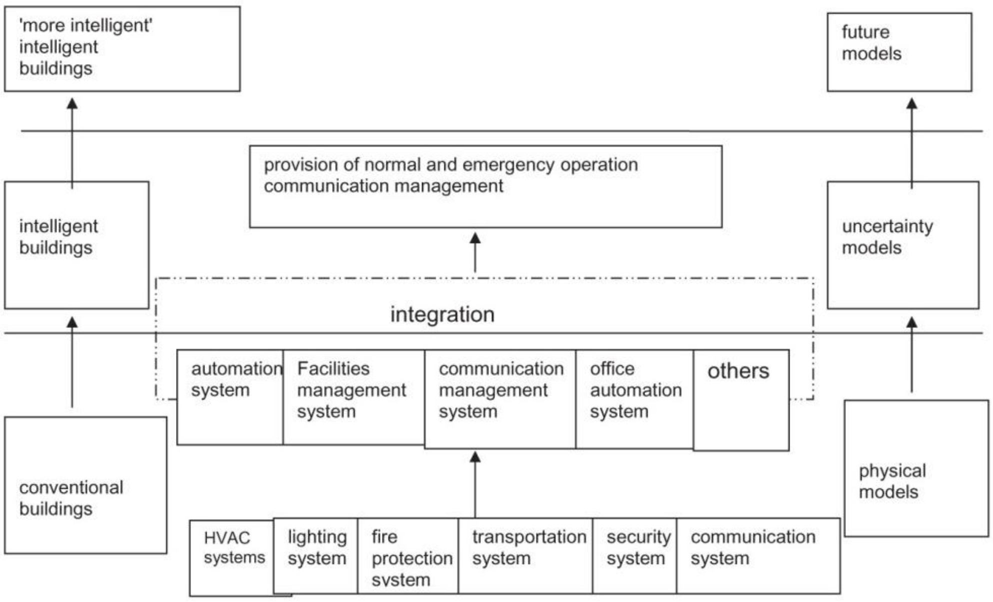


Figure 2.8 Hierarchical system integration in IBs (source: Arkin & Paciuk, 1997)

Hereunder are given some examples of intelligent building system integration as So & Chan (1999) and Wang & Xiu (2002) stated:

- Fire alarm system can be integrated with other building systems, such as HVAC, lighting and security through BAS. HVAC systems can be used to prevent the smoke from spreading by opening exhaust dampers and closing outdoor air intake dampers of the fire floor if there is a fire on one floor of building;

- Vertical transportation system can interact with fire alarm or the security systems in order to define the number of elevators required, the mode of operation and in some instances the accessible floor levels;
- Fire alarm program can be interfaced with security to release specific locked doors under alarm conditions;
- Security system can be interfaced with the lighting and HVAC subsystems to define activation of necessary lighting paths and the specific room occupy mode; and
- Facility management can be integrated with BAS.

Many IB products and deficiency in selection methods of building component methods resulted in difficulties to form an appropriate combination of components to meet the needs of a particular IB project. The existing literature in selecting IB systems consists of case studies or articles only in scientific journals or internal reports which lead to lack of a practical guide in selection of IB systems in any particular project (Wong & Li, 2008).

Analytical methods developed in recent years have facilitated the decision making and evaluation of IB design with focus on classifying IBs in definite categories according to their performance (So & Wong, 2002); however, the major gap is developing "an integrated systematic methodology and techniques in addressing the system intelligence of the IB and its components" (Bien, Bang, Kim & Han, 2002). As discussed by Wong *et al* (2007), system configuration in any particular IB project might not be suitable for another project since building design and project nature varies from one to another. Thus, deficient understanding of system intelligence could result in improper selection of building systems or components.

Intelligent buildings, like any major system, are too complex to be designed, built maintained and operated by one organization. Any incorrect system selection can affect the durability, sustainability, service life and cost of repair or refurbishment of the building, thus Wong & li (2006) were inspired to develop a conceptual model for proper selection of intelligent building systems and their components. To achieve this, following stages were accomplished:

- Determination of key attributes that affect the selection of building systems,
- Testing criticality of selected attributes,
- Developing a conceptual model for the appropriate selection of building systems and components in any intelligent building project.

A common methodology for developing intelligence analytic models that is suggested in the published sources reviewed in this thesis includes following steps: As a first step a review of intelligent building literature is conducted to determine the intelligence indicators and construct general conceptual model of intelligent systems and indicators. In the next step constructed model is tested and refined by means of questionnaire surveys. Finally, the refined conceptual model is modified to a practical model (Wong & Li, 2006; Wong & Li, 2008; Wong *et al*, 2008). To give a better understanding of the procedure, a research conducted by Wong & Li (2008) to develop a conceptual model for the selection of intelligent building systems, is explained in the following section.

In Wong & Li's (2008) research, eleven key systems recommended by several IB experts were selected as:

1. Integrated building management system (IBMS) for overall monitoring and building management function;
2. Energy management system for electrical and power quality monitoring and analysis;
3. HVAC system for heating, ventilation and air-conditioning system for comfort control;
4. Addressable fire detection and alarm system for fire prevention and annunciation;
5. Telecom and data system for communication network backbone;
6. Security monitoring and access system for surveillance and access control;
7. Smart/energy efficient vertical transportation system for multi-floors service;
8. Digital addressable lighting control system for light design and control;

9. Hydraulic and drainage system;
10. Building facade systems;
11. Building layout systems.

In first stage of Wong & Li's research, during a questionnaire, a proposal comprising selected criteria of IB systems were evaluated by experts (academics, design consultants, developers, construction practitioners and quantity surveyors); experts were also invited to add new criteria if necessary. Later on according to relevant importance of criteria given by experts, main criteria group and sub-criteria group were identified and conceptual model for the selection of IB systems was constructed. The procedure is summarized in Figure 2.9.

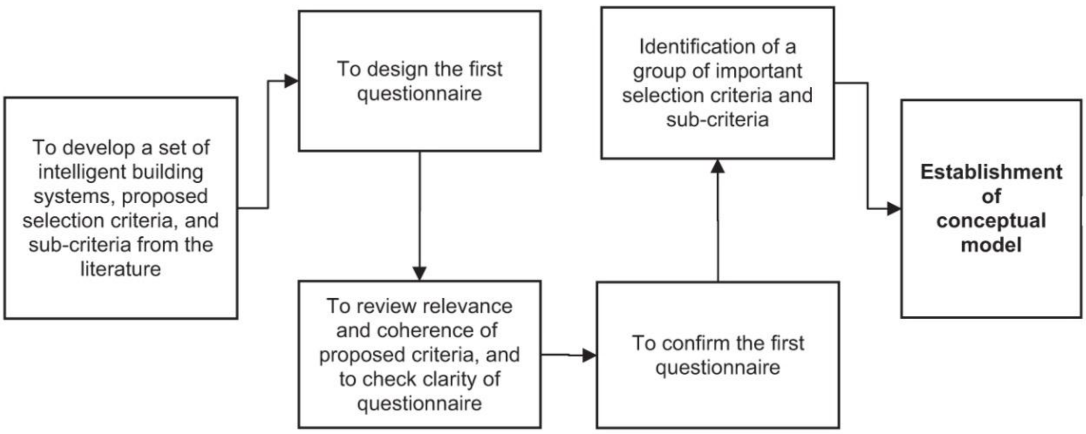
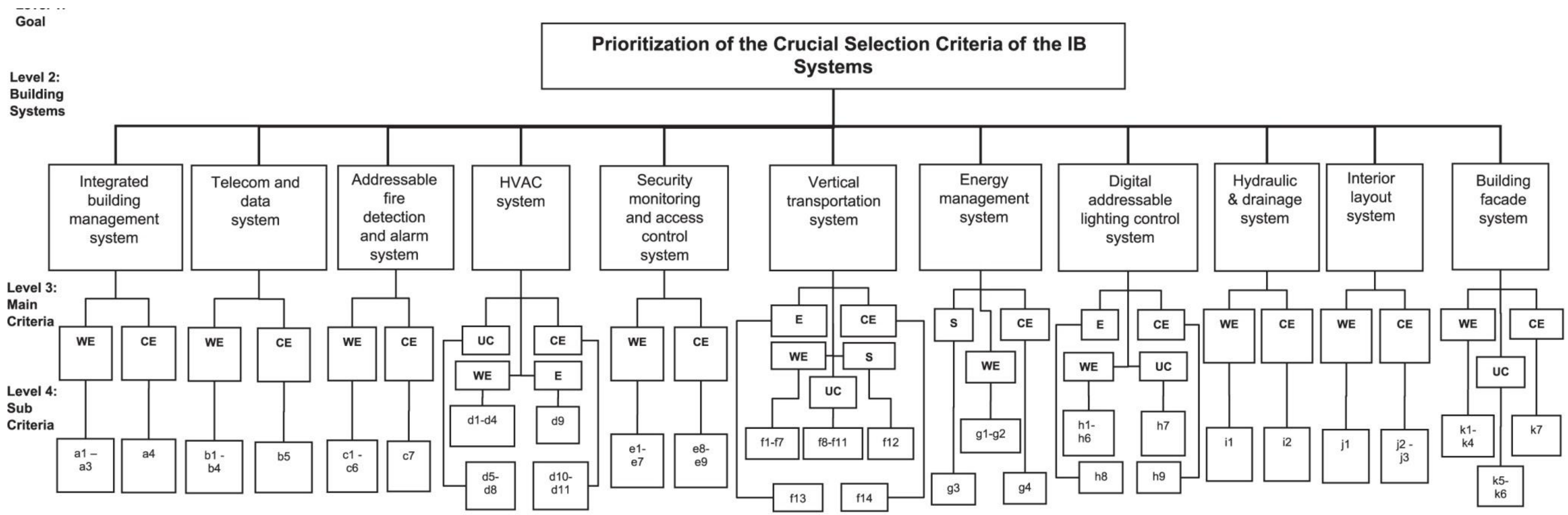


Figure 2.9 Proposed research methodology (source: Wong & Li, 2008)

Finally attributes for selecting IB systems and their related criteria, were presented in a hierarchy model shown in Figure 2.10 as the results of the survey. The model presented by Wong & Li (2008), is comprised of four levels; in the top level is given the goal of the research, in second level building systems of IB are cited, third and fourth level include selection criteria and sub criteria expanded from building systems.



Legend for the Level 3 and 4 attributes:

WE Work efficiency
CE Cost effectiveness
UC User comfort
E Environmental
S Safety
a1 Reliability
a2 Capability for integrating systems
a3 Efficiency
a4 Operating and maintenance costs
b1 Reliability
b2 Further upgrade
b3 Service life
b4 Efficiency
b5 Operating and maintenance costs
c1 Fire detection and fighting code compliance
c2 Fire resistance codecompliance
c3 Efficiency
c4 Further upgrade
c5 Automatic and remote control /monitoring
c6 Service life
c7 Operating and maintenance costs
d1 Service life
d2 Reliability
d3 Connection to BAS
d4 Compatibility
d5 Predict mean vote (PMV)
d6 Indoor air quality (IAQ)
d7 Acoustic comfort
d8 Amount of fresh air
d9 Total energy consumption
d10 Initial costs
d11 Operating and maintenance costs
e1 Time for public announcement
e2 Time for reporting the building management
e3 Compatibility
e4 Connection to BAS
e5 Service life
e6 Further upgrade
e7 Time for total egress
e8 Initial costs
e9 Operating and maintenance costs
f1 Service life
f2 Waiting time
f3 Maximum interval time
f4 Journey time
f5 Connection to BAS
f6 Compatibility
f7 Automatic and remote control /monitoring
8 Acoustic comfort
f9 Acceleration and deceleration
f10 Air change
f11 Vibration level
f12 Safety regulations compliance
f13 Total Energy consumption
f14 Operating and maintenance costs
g1 Connection to BAS
g2 Compatibility
g3 Safety regulations compliance
g4 Operating and maintenance costs
h1 Compatibility
h2 Connection to BAS
h3 Permanent artificial lighting average power density
h4 Further upgrade
h5 Service life
h6 Automatic control/adjustment of lux level
h7 Ease of control
h8 Average efficacy of all lamps
h9 Operating and maintenance costs
i1 Service life
i2 Operating and maintenance costs
j1 Service life
j2 Initial costs
j3 Operating and maintenance costs
k1 Connection to BAS
k2 Service life
k3 Compatibility
k4 Automatic control/ monitoring
k5 Response change in temperature
k6 Response change in sunlight
k7 Operating and maintenance costs

Figure 2.10 Decision hierarchy for selecting IB systems (source: Wong & Li 2008)

Main common systems in the published sources that author has reviewed (So & Chan, 1999; Wang, 2010; Wong, Li & Wang, 2005; Wong & Li, 2006; Wong & Li, 2008; Wong *et al*, 2008) are stated below and a brief explanation of each system is given in the following section.

1. Building automation system (BAS)
2. HVAC system
3. Lighting system
4. Vertical transportation system
5. Fire protection system
6. Security system

2.4.1. Building Automation System

Building Automation System (BAS) includes electronic equipment that performs specific facility functions, automatically. The common definition of a BAS considers the automatic control of one or more building system functions, such as heating, ventilating, and air conditioning (HVAC) system, lifts, lighting, security and fire protection. In short, BAS integrates separate functions of temperature control, fire, lighting, security *etc* under one common operation (Eng Loo, 2006). So & Chan referred to Carlson (1991) in defining building automation system as "a tool in the hands of building operations personnel to provide more effective and efficient control over all building systems".

In other words, BAS employ computer-based monitoring to coordinate, organize and optimize building control sub-systems such as HVAC, security, fire, safety, elevators, *etc*. Common applications of BAS include:

1. Equipment scheduling (turning equipment off and on as required)
2. Optimal start or stop (turning heating and cooling equipment on in advance to the required temperature during occupancy)
3. Operator adjustment (accessing operator set-points that tune system to changing conditions)
4. Monitoring (logging of temperature, energy use, equipment start times)

5. Alarm reporting (notifying the operator of failed equipment, out of limit temperature/pressure conditions or need for maintenance)

2.4.2. HVAC System

Heating, ventilation and air conditioning (HVAC) systems conserve the climate in indoor spaces by controlling the temperature, air flow, humidity and the overall air quality. The operation procedure is to bring the air from outside, mix it with the air that is returned from the system, filter the air, discharge it through a heating or cooling coil and distribute the air to the building sections (Sinopoli, 2010).

As Sinopoli (2010) described, in HVAC system a number of terminal devices and instruments gather data and assist the system in controlling the variable conditions. Input information and data sent by sensors are controlled within the system and based on the input data, actuator devices are controlled.

Doukas, Patlitzianas, Iatropoulos & Psarras (2007), explained the function of HVAC system components as given below:

1. Indoor sensors: sensors which record or measure temperature, air quality and humidity in the building areas.
2. Outdoor sensors: sensors which record or measure outside temperature, air quality and humidity.
3. Controllers: this component includes switches, valves, diaphragms, actuators, *etc*.
4. Decision unit: a decision support unit with following capabilities:
    - Interaction with sensors to diagnose the building’s state,
    - Selection of appropriate interventions
    - Communication with controllers to apply the decision.
5. Database: it includes the knowledge database and database of building characteristics, where all information is recorded.

Sensor systems enable the control of the air quality by measuring CO_2, humidity and temperature. Both of the heating and ventilation systems should be considered within the air quality control to meet thermal comfort of occupants. Figure 2.10

shows the sensor system for indoor air quality.

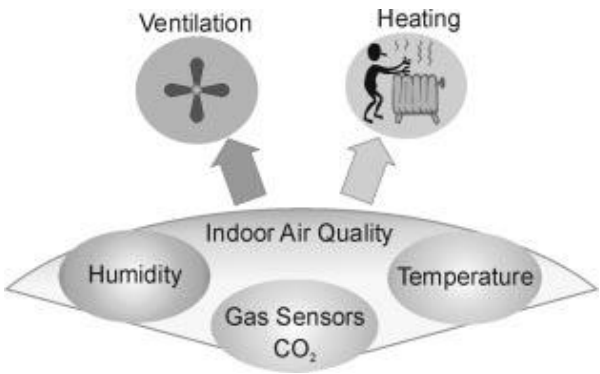


Figure 2.11 sensor system for HVAC (source: Gassmann & Meixner, 2001)

In Figure 2.11 an example of a multifunctional sensor which includes indoor air quality sensors is shown. The module is composed of two optical gas sensors which detect CH_4 and CO_2, a humidity sensor and a temperature sensor; and sensors for presence detection. In this module all sensors are matched to the micro-controller interface, so the signal processing is accomplished within the sensor module. The necessary signals are sent to the related HVAC equipment (Gassmann & Meixner, 2001).

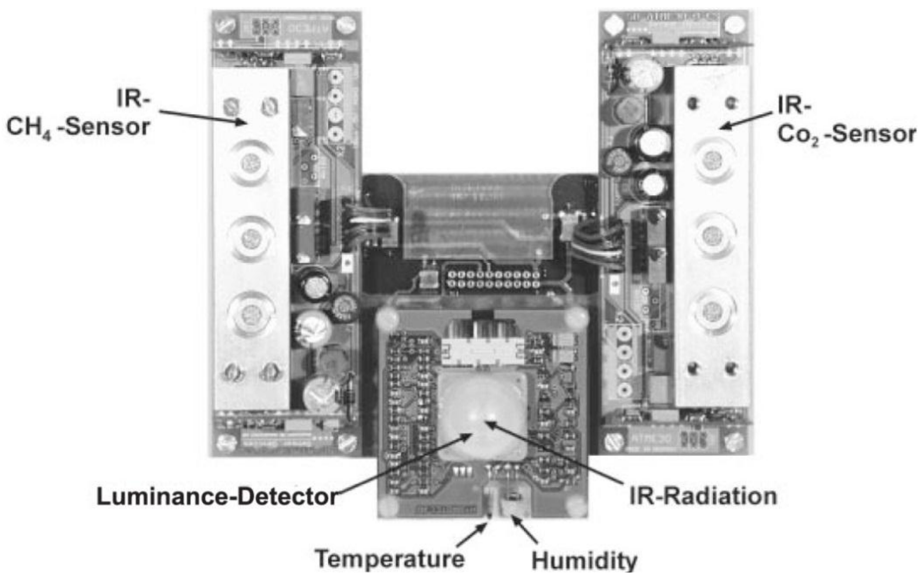


Figure 2.12 Multi-chip module for indoor air quality
(source: Gassmann & Meixner, 2001)

According to Nikolaou, Kolokotsa & G.Stavrakakis (2004), HVAC control system should:

- Be able to create and hold a comfortable building interior environment;
- Maintain acceptable indoor air quality;
- Be as inexpensive and simple as possible but yet meet HVAC system operation criteria;
- Result in efficient HVAC system operation under all conditions.

In addition, according to a research conducted by CABA (2002), HVAC systems should:

- Allow individual occupants to adjust temperatures;
- Monitor temperatures, and adjust it according to input data;
- Adjust indoor air quality based on building standards and room occupancy;
- Adjust temperature, humidity and air flow speeds;
- Use constant volume air or variable air volume distribution design.

2.4.3. Electrical Installations and Illumination

In modern buildings the most important energy source is electricity since almost all building service systems operate with electricity. According to So & Chan (1999), the second highest amount of electrical energy is consumed by lighting system in most buildings. A reduction in energy that is used for lighting systems, could offer great savings in building's total energy consumption.

Illumination technology in IBs includes various lighting types and functions which, vary with each building. Common goal in any lighting system is to furnish the occupants with an appropriate lighting that is required for completing visual tasks productively and effectively (CABA, 2002). To achieve this, several attributes have been cited for an efficient lighting system in IBs.

Sinopoli (2010) cited some of the variables that an efficient lighting system should involve as:

- Scheduling: a predetermined schedule in lighting control system to turn on or turn off the lights;

- Occupancy sensors: sensing occupancy devices turn on or turn off the lights in spaces where occupancy is difficult to predict;
- Daylight: natural light utilization by lighting control system to reduce the cost and need of lighting space, as much as possible.

In addition, CABA (2002) mentioned some of other capabilities of an efficient lighting system as:

- Allow individuals to adjust desired lighting level through telephone or computer interfaces;
- Make a connection between lighting controller and a graphic user interface with icons, for centralized control;
- Turn on or turn off circuits through computer control;
- Manage energy consumption by monitoring room occupancy and adjusting lighting to suit.

Two more characteristics of an efficient lighting system are cited as:

- Adjusting the window shade position corresponding to the angle of the sun's rays;
- A darkness sensor placed outside of a building to switch the lights on or off or modulate the lights (Han, Jeon, Lim, Kim & Chen, 2010).

Lighting system when integrated with security systems, fire alarm systems or emergency power generators, could provide a life safety function by assisting in lighting evacuation pathways of a building. For example, in case of loss of normal power or fire alarm the lighting control system might turn on emergency lighting fixtures (Sinopoli, 2010).

Hereunder are given some examples of lighting occupancy sensors in Figure 2.12:

Figure 2.13 Lighting occupancy sensors (source: http://local.hemagazine.com)

2.4.4. Vertical Transportation

According to So & Chan (1999), any transportation media within the building such as escalators, lifts, passenger conveyors and hydraulic hoists constitute vertical transportation systems. It could be considered as the critical building service system in high-rise buildings.

As cited in CABA (2002), IBs can satisfy occupants with improved elevator service. Elevator control could be quite complex, with multiple elevator groups and traffic patterns incorporated into the system. Some features of an efficient transportation system are given bellow:

- Shut down some elevators part of a day to save energy;
- Communication within the elevator to enable the use of access control cards;
- Permit dynamic changes to user privileges; for instance, deny the access to certain floors even with access control card unless the floors are already occupied.
- Slow down or stop the escalators when no traffic is detected to save energy.

Safety devices, control and monitoring aspects of vertical transportation systems are referred as one of the most important features of elevator systems. The authors discussed benefits of elevator monitoring as increased availability and reliability, increased safety, establishment of condition maintenance program, faster response in the event of breakdowns and 24 hour assistance for trapped passengers.

So & Chan (1999), referred to CIBSE Guide D (1998-1999), in citing the general features of a remote monitoring system as following:

- Indication of lift-in-service status
- Trapped passenger alarms
- Inoperable lift alarms
- Performance alarms
- Early transmission of status and alarms to the monitoring control center of lift maintenance contractor
- Automatic collection of lift performance data
- Two-way voice communication with trapped passengers
- Ability to control on-line investigation and analysis of lift activity
- Data analysis

2.4.5. Fire Protection and Safety

According to Sinopoli (2010), fire alarm system is the basis of life safety system in every kind of building. A proper fire alarm system limits damages caused by fire, heat and smoke and reduces the probability of loss of life or injury. Due to the critically of safety systems, standards, regulations and codes affecting the design and installation of these systems have wide ranging and detailed considerations. CABA (2002) explained code considerations as: the strategies to release or lock the doors per code constraints in emergency conditions.

Reliability and the immediate reaction of fire detectors are crucial. In an efficient fire alarm system, “each sensor can report its individual point address and an analog value to the fire alarm control unit which can communicate with higher level central host computer" (So & Chan 1999). Advanced safety sensors in IBs could detect the presence of persons and also their health situation so that the rescue operations could be easier and more effective. In addition to this, recently developed fire alarm systems comprise gas, temperature and smoke detectors. Figure 2.13 shows the sensor systems for fire detection (Gassmann & Meixner, 2001).

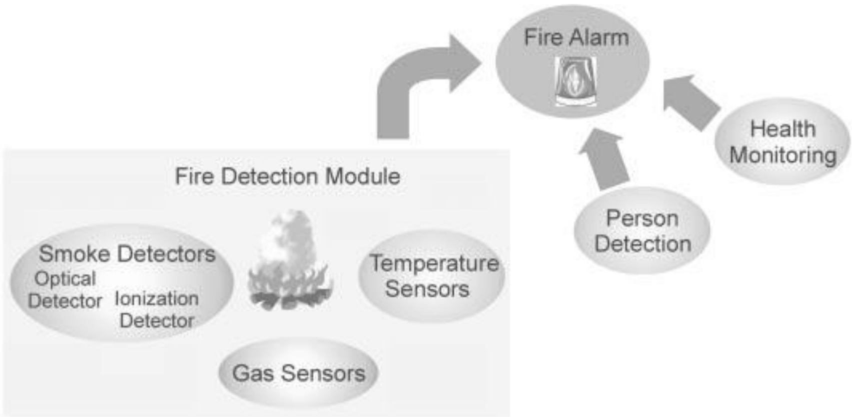


Figure 2.14 Sensor systems for fire detection (source: Gassmann & Meixner, 2001)

Generally when a fire starts, a transformation of matters and energy takes place. During the initial fire phase diffusion of gases are faster than smoke particles so, gas sensors hold an improved and reliable detection speed. Nowadays different gas sensor types are preferred according to different physical principals; common gas sensors detect CO, CO_2 & CH_4 (Gassmann & Meixner, 2001). Figure 2.14 shows a scenario for fire alarm system could be used in a house.

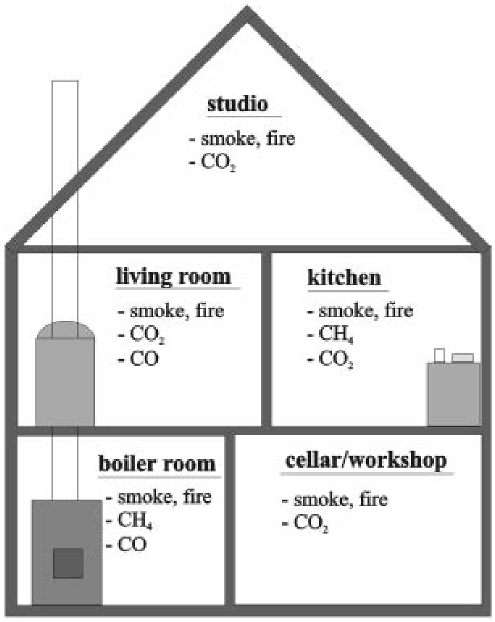


Figure 2.15 Scenario of fire alarm system (source: Gassmann & Meixner, 2001)

In IBs fire alarm systems could be integrated with other systems. Some examples of safety system integrations are given below according to CABA (2002).

- Integration with HVAC system to extract smoke, pressurize stairwell and recall elevators;
- Integration with lighting system to turn on the lights throughout the building;
- Broadcasting emergency messages to individuals by network system.

2.4.6. Security System

So & Chan (1999) defined security as “the anticipation, recognition and appraisal of a crime risk and the initiation of some actions to remove or reduce it”. Stated in CABA (2002), s security system generally includes 3 sub-components:

- access control;
- Intrusion;
- Surveillance

Integration of these 3 areas provides an effective security system which enables building mode, function and operation to be controlled by individual access requests or pre-scheduled programs (CABA, 2002). According to the same research a typical security system includes:

- Access cards;
- Door interface;
- Elevator interface;
- Sensor detection: moisture, temperature, glass breakage, *etc*;
- Intrusion detection;
- Guard tours;
- Parking control.

However a security system can include either all or part of these systems. Another system that can be used in security system is closed circuit television system (CCTV). CCTV system provides a direct link between a monitor and a camera; since CCTV picture signal cannot be transmitted in free space, there must be someone to keep watching the monitor; therefore, this system is applicable during working hours and is not a good solution for night (So & Chan, 1999).

Security system can be integrated with safety system to deactivate parts of the access control system in case of an emergency; or integrated with vertical transportation system to lock the lifts in case of a security alarm (CABA, 2002).

2.5. 2.5. Selected Examples of Intelligent Buildings in the World

The example of intelligent buildings in the USA (Figure 2.16) has been taken from the state of Missouri, (2007) where intelligent building systems were installed in a project that comprised of two buildings, the Truman State Office Building and Wainwright Office Building. The objectives were to be able to remotely and continuously monitor and manage the building systems and the operating conditions, provide diagnostic and fault detection, transform data from building systems into actionable information, and integrate this system with the utility bill payment system and meeting data. To achieve the objectives, this pilot project focused on integration of new and existing systems, the development of the higher levels of information management system and the design and deployment of a statewide communication network to gather data from each facility to achieve the objectives set out.

Figure 2.16 Truman State Office Building
(source: http://oa.mo.gov/ahc/location.html)

In the UK, the City of Manchester Stadium (Figure 2.17) can be taken as an example of an intelligent building that provides effective and efficient building services for people. Some of the key features included housing central plant in the structural and architectural ramp towers; a buried raceway around the stadium which distributed water, electricity, heating and communications. The integrated plant rooms and the services raceway proved to be cost effective. Other attributes of the project were adopting a set of wireless local area networks (WLAN) based information management system including intelligent management system and Radio Frequency Identification (RFID) equipment.

Figure 2.17 The City of Manchester Stadium
(source: http://www.worldstadiums.com)

The example of an intelligent building from Asia is the much celebrated International Commerce Center (ICC) in Hong Kong (Figure 2.18), which has been declared the most intelligent building in Asia in 2011 by the AIIB. The project comprised of commercial space, residential and office units, retail and two hotels. Some main attributes of the building are listed below:

- Double glazed with low E-coating façade to maximize natural daylight,
- Efficient lift strategy,
- Generators for essential chiller back-up, tenants' essential supply and fire services,
- VAV ceiling ducted system with intelligent Direct Digital Control via building management system,
- Wireless aerial provision for mobile phones in premises' ceiling, lifts and common areas,
- Efficient access and security control systems.

Figure 2.18 ICC tower (source: http://www.chinahighlights.com)

CHAPTER 3

MATERIAL AND METHOD

In this chapter is presented the material used in the research and the method of research. Under the material section information related to the two case studies is given. The case studies are an intelligent residential building and an intelligent office building located in Ankara.

3.1. Materials of the Study

Materials related to the two case studies were obtained from the companies incorporated in design and construction of IBs. Detailed information of the residential building was obtained from Teknoboyut Company which is in charge of automation system design and installations in the building complex. Information provided for the telecommunication headquarters building was obtained from Atasarim design group who were the architectural consultants company for the building. The details on these two case studies are presented in the following sections.

3.1.1. Residential Building

The case study is located in Çayyolu, Ankara. It is comprised of 4 villas and a 13 story residential building. At the time that this research was conducted villas were under construction and the residential apartment was almost ready to be occupied; therefore, only the multistoried residential building was studied. The building comprised of a total 26 apartment units; the type of the units were either 3 bedroom apartment with an area of 150 m^2 or 4 bedroom apartment with an area of 190m^2. Each apartment unit included a kitchen, a living room, a bathroom and 1 master bedroom. An exterior view of the building is given in Figure 3.1.

Figure 3.1 Exterior view of the Residential case study
(source: www.google.com/images)

The aim of the project was to create a safe and convenient place to live. In order to meet the user's requirements several safety and comfort considerations were made to satisfy the occupants when either they were inside the house or away. Figure 3.2 shows some of the integrated intelligence attributes in every unit schematically. The details on specific features have been given in the following section.

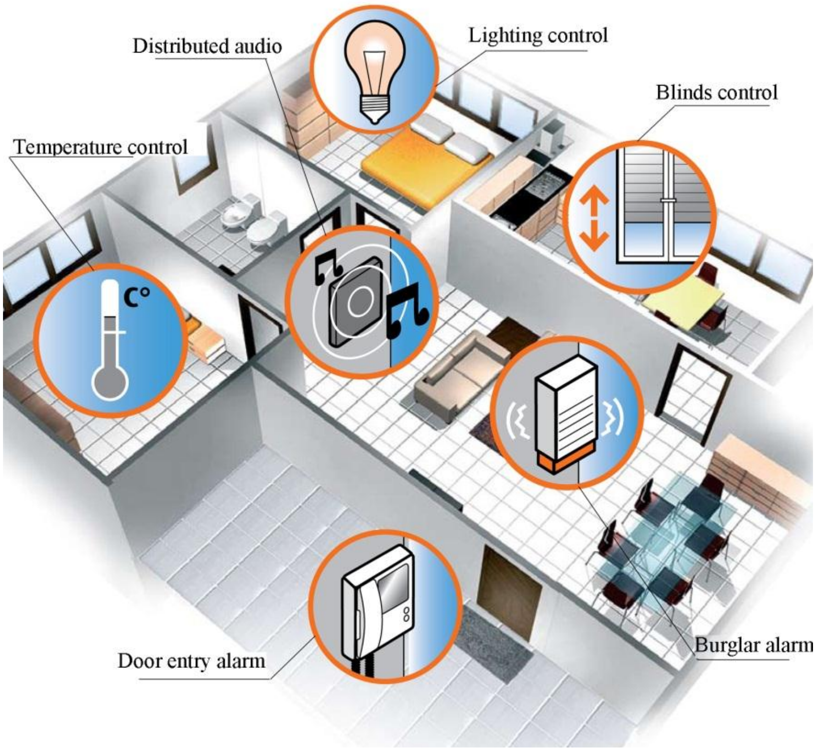


Figure 3.2 General intelligence attributes in the apartment unit
(source: www.bticino.com)

3.1.1.1. HVAC system

The case study does not hold HVAC system; only floor heating system is used within the units. Every room including kitchen and bathroom occupies temperature sensors which activate or deactivate the heating system to keep the temperature on desired level. The project does not have a cooling system however it is possible for the occupants to install cooling system and integrate it to the temperature control system and also control unit.

3.1.1.2. Lighting system

Lighting system in the residential building is composed of illumination system and also blind control system.

- Illumination

In the case study illumination is controlled by switches that have 2 functions; they can either turn on or turn off the light or, adjust the light intense. It is also possible to control the lighting remotely via computer or phone. Lighting occupancy sensors are used in corridors and stairwells. The operation of the key is that each single key can turn or turn off the light, adjust the light by holding the key or adjust another lighting source by double clicking; therefore, the need for several switches is omitted. However, lighting system is not integrated to other systems such as fire alarm to turn on specific lights to exits.

- Blind control

Blinds in the case study are not able to respond dynamically to changing lighting conditions. They can operate either remotely or by direct human interference using switches located in any room possess blinds. Any integration with other systems is not considered in the project. Blind control keys are just like audio control keys.

3.1.1.3. Vertical transportation system

It is planned to install efficient elevators in terms of waiting time, noise, ventilation *etc*; however, vertical transportation system will lack the integration with other systems such as fire alarm system or security system.

3.1.1.4. Fire alarm system

Fire alarm system is composed of smoke and gas detector which is located in the kitchen. It detects unusual smoke amount and also natural gas; however it is not able to detect heat. Detector is integrated with fire alarm system and is also able to inform to mobile phone or PC.

3.1.1.5. Security system

In the case study door entry alarm and burglar alarm are the components of security system.

- Door entry alarm

This device makes a visual connection between outside and inside of an apartment unit; it also enables the video call between several units and also comprises a SOS button alerts the security in case of emergency. The residential building holds 3 door entry alarms in every unit which are connected to each other and placed in entry, kitchen and living room in order to make an easily accessible connection from all parts of the apartment.

- Burglar alarm

Burglar alarm detects any door or window break or opening of any door or window when the active scenario needs them closed; however it lacks the integration with other systems such as: illumination system to turn on the lights when alarm is activated. Burglar alarm when activated informs the security about the situation in the specific unit.

3.1.1.6. Building automation system

The project lacks the existence of BAS but a control unit which has similar operation to BAS is installed in every apartment unit. Control unit in the case study is a 10″ touch pad which enables controlling the illumination, burglar alarm, blinds, temperature, multimedia, scenarios, video entrance, sound diffusion and multimedia systems. It also enables the setting modification of each system. This device is also controllable via PC or mobile phone. It is kind of a simple automation system which includes only the systems within a unit not the whole building. For instance, it is possible to set the multimedia system in children room to operate only in defined specific hours. Figure 3.3 illustrates control unit installed in every unit of residential case study. Examples of all devices and sensors are given in Appendix C.

Figure 3.3 Control unit (source: www.bticino.com)

Hereunder are given brief explanations of scenario keys, sound diffusion control and multimedia system which are controlled by control unit.

1. Scenario key

Scenario key comprises several keys which activate predefined scenarios in the device. Two main default scenarios are on and off keys; on key includes the scenario of *what conditions the occupant prefers when entering into the house.* This includes:

- Activate electricity;
- Preferred lighting system (turn on preferred lights and also illumination level automatically);
- Preferred multimedia system (turn on the radio or TV on predefined frequency or channel);

- Activating heating system to the desired temperature;
- Blinds control (open or close specific or all of the blinds).

In contrast, off scenario deactivates the devices or installations that occupant prefer to shut down when leaving the house, it also activates burglar alarm and fire alarm. This includes:

- Electricity outage and turning off all electric devices except the ones that need to work continuously such as: refrigerator;
- Turn off all or specific lights;
- Stop heating system or put it on standby at a specific temperature;
- Shut all or specific blinds as preferred.

In the residential case study two other scenario keys are open to occupant's preferences; these could be work, party, relax or guest scenarios. All features mentioned above are open to modify in any scenario, however it is preferred to keep burglar alarm and fire alarm on at all times.

2. Sound diffusion control

Music and radio control is possible via audio control keys. These keys are located in the entrance, living room, master bedroom and kitchen. By switching on the key either radio is played on predefined frequency or music from a predefined device is played. Each control key activates and adjusts the volume of the system in that room but, the control of the whole system is feasible by control unit. It is also possible to integrate media players, laptops and mobile phones to the audio system.

3. Multimedia system

Multimedia system enables the management of any video or audio system. This means that PC, MP3 player, TV, video entrance system (indoor and outdoor) could be integrated via multimedia system. For instance MP3 player if connected to multimedia system, is controllable to diffuse the sound from specific speakers; similarly, when a PC is integrated to multimedia system it is possible to watch the same program distributed from one source, by several TVs or other devices. Figure 3.4 shows a multimedia interface which integrates other audio or video devices.

Figure 3.4 Multimedia system (source: www.bticino.com)

3.1.2. Telecommunication Headquarters Tower

The tower located in Altindag, Ankara is under construction in an existing property site of the telecommunication company. The tower occupies an area of 53.000 m^2, comprises 34 floors and reaches the height of 192 m; which will make it the tallest office building in Turkey when it is finished in 2013.

Main goal of the design, as design team discussed, was to provide a comfortable and secure space to work in. At the design stage and primary phases of construction some attributes such as producing electricity by photovoltaic cells and wind turbine, double-skin façade for better energy performance were proposed by the design team; however, for the time being energy performance is planned to be reached via double-skin glass façades and the other proposals could not be actualized. Figures 3.5 and 3.6 show an exterior view and ground floor plan of telecommunication tower, respectively.

Figure 3.5 Telecommunication tower (source: www.atasarim.com)

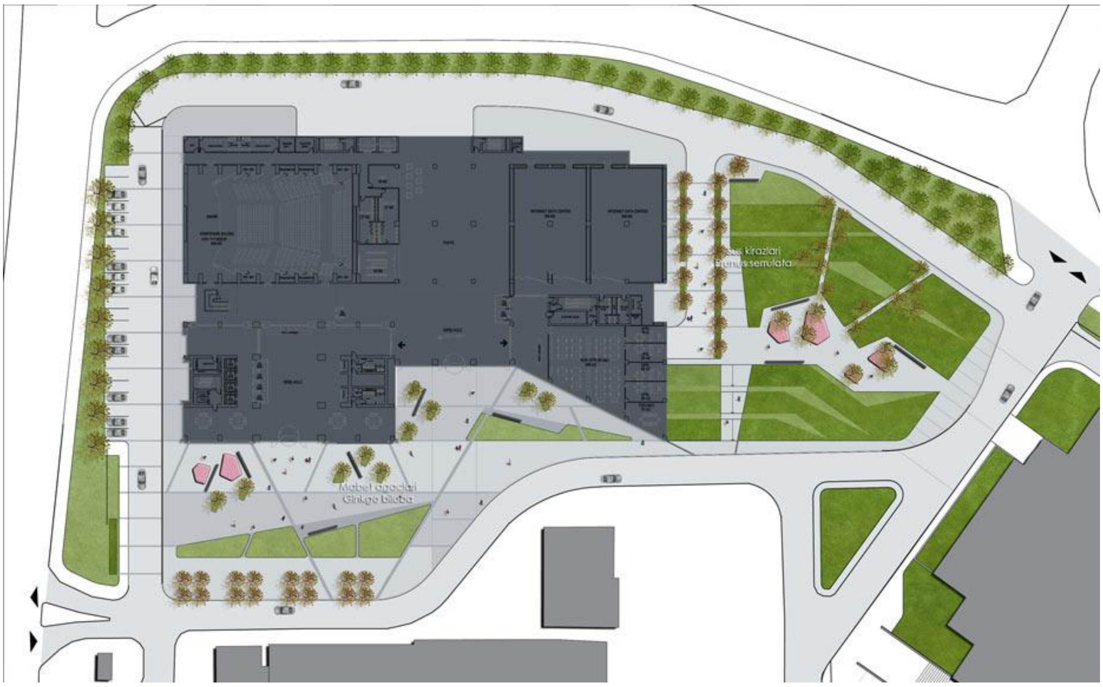


Figure 3.6 Ground floor plan (source: www.atasarim.com)

The tower is claimed to be one of the most intelligent buildings in Turkey, by its design group and telecommunication department. The design team explained main intelligent characteristic is automatic blinds installed between 2 layers of glass façades. Blinds are able to sense desired daylight amount and also the temperature between layers and operate automatically to either be pulled up or down; although, the full automatic operation without any human intervention and a semi-automatic system which enables the users to adjust the blind personally has not yet been decided between design team and the project owner. As designers claimed, integration of blinds to other systems through BAS enables the building to respond dynamically and perform better in terms of energy. To elaborate, the building's facility systems and intelligent attributes are discussed in following sections

3.1.2.1. HVAC system

To provide thermal comfort HVAC system provides favorable temperature and air quality according to a desired working pattern. It is planned to divide the whole space to specific thermal zones and define the comfortable temperature for various zones. In this case HVAC system's operation would be different from one zone to the other.

Temperature sensors located inside the building will enable the adjustment of heating or cooling systems dynamically; however, no outdoor sensors are planned to be incorporate into the HVAC system. In addition, dynamic response has not been designed for air conditioning system, and the HVAC system lacks the existence of air quality sensors so air conditioning system is planned to operate in specific hours for a specific time according to a predefined program; even though, it is possible to define different air conditioning function for different zones.

The HVAC system is designed based on maximum loads so, it is not able to cope with occupancy fluctuations. This means that, if HVAC system in a zone is designed to be efficient for 50 people working in that zone, it cannot be adjusted automatically to lower performance when 20 people occupy the zone. Operating and maintenance costs are planned to be regulated by the efficient performance of the HVAC system and also by the integration of HVAC system and blinds. For instance, when façade blinds are pulled down due to the rise in temperature, cooling system starts operation automatically.

3.1.2.2. Lighting system

Lighting system in working spaces which require continuous lighting is designed based on an occupancy schedule; in other spaces which occupancy is difficult to predict lighting sensors are used. The system would be designed to turn on and turn off the lights automatically according to a predefined schedule; however, incorporation of light intensity sensors is not considered. For example: if the system is programmed to operate between 9am and 6pm, it would operate continuously except human interference occurs but, it will not able to sense light intensity and solar radiation to adjust the amount of lighting.

Similar to HVAC system, lighting system is also designed for maximum loads. If the system could adjust itself with existent light intensity, it could maximize natural day light, turn off unnecessary lights, adjust the intensity of light source and reduce lighting power.

It is planned to integrate the lighting system with façade shades and allocate specific lights to the integration. The operation is to turn on automatically some specific lights when blinds are pulled down and conversely, turn them off when the blinds are pulled up. However the intensity is not controllable in this case either.

3.1.2.3. Vertical transportation system

It has been planned to use efficient lifts in the tower which are compiled with safety regulations and could provide convenient journey in terms of, waiting time, journey time, air change and acoustic comfort. Allocating different lifts for lower and upper, odd or even floors, recall the nearest lift and remote control or monitoring are other aspects of lift strategies.

Lift system will be integrated with BAS so that in case of any accident or emergency condition it would be possible to control the lifts automatically according to a pattern introduced to the system beforehand to lock or recall specific elevators or all. However it is not planned to define different operation scenarios for weekdays, weekends or special events.

3.1.2.4. Fire alarm system

Fire alarm system in the tower includes sensors which detect smoke and activates the fire alarm automatically. The main specification of this system is the integration to HVAC, lighting and vertical transportation systems through BAS.

- Integration to HVAC system is designed to stop the operation of HVAC system and close the air intake ducts in case of fire.
- Integration to lifts includes locking down all standby lifts and lead the active lifts immediately to the ground floor. In addition to the lifts, stairwells are constructed with materials that could resist fire during estimated time for the fully evacuation of the building.

- Integration with lighting system contains lighting up automatically all exit signs or other lighting sources designed to specify exit ways to the stairwells, by building automation system. If the fire occurs during electricity system breakdown, power generators light up the exit signs and ways.

3.1.2.5. Security system

Since the communication tower is one of government departments, information regarding its security systems is not participated with individuals. Just some general security considerations were accessible for the author, as cited below:

- Temporary ID card for visitors;
- Lift operation by verifying ID cards;
- Limited access to specified floors or places;
- Burglar detector and alarm system;
- Integration with BAS.

3.1.2.6. Building automation system

In telecommunication headquarters tower BAS integrates aforementioned systems and enable the interaction between different systems. For instance: integration of HVAC and blinds control, HVAC and fire alarm system, lighting system and blinds, lighting system and fire alarm system, vertical transportation system and fire alarm system, vertical transportation system and security system, are planned for the project.

3.2. Method of the Study

As stated before, two case study buildings were selected; one a residential apartment and the other an office block. Information on the two buildings was obtained from the architecture and engineering firms.

First of all a check list compiled from the various definitions of intelligence in intelligent buildings and from the criteria cited there in. Furthermore, this check list also included the systems and indicators that are commonly repeated and evaluated by the various assessment tools (AIIB, EIBG, IBRT) being used in the world. Finally since existence of indicators and also priority of them differs regarding building type, the check list was developed into two separate check lists for residential building and office tower. The main check list from which the two separate check lists are derived is presented in table form in Appendix D.

The check lists are constructed based on assessment models by AIIB (2001); Wong & Li (2006), (2008); Wong *et al* (2008); and priority of various indicators in each system regarding building type as cited by AIIB (Table 2.2). This means that in residential buildings, indicators of human comfort, culture, safety and security, environmental friendliness, working efficiency, cost effectiveness, space utilization and flexibility, construction process and structure and image of high technology indices occupy the highest and lowest priorities, in descending order of importance. Similarly, in office buildings indicators of each system are selected based on the priorities of working efficiency, space utilization and flexibility, cost effectiveness, human comfort, environmental friendliness, safety and security, image of high technology, culture and construction process and structure indices as given in Table 2.2.

Both of the check lists are composed of six main intelligent building systems as HVAC, BAS, fire alarm, security, vertical transportation and lighting system but, they alter in terms of some of the indicators. For instance, since working efficiency in office buildings holds the highest priority, indicators concerning that criterion are entered into the check list; while some of the indicators concerning construction process could be omitted. In addition, scale of the projects affected the number and also existence of some indicators in that, some indicators are needed to be applied only in large scale projects. The other consideration in selecting the indicators was different system requirements of the case studies; for example, fire alarm system needs more concern in residential buildings because of cooking and ironing are activities particular to homes. Another concern was the satisfaction of the people occupying two types of buildings; the main attribute of an intelligent office building is to provide a healthy environment for adults while a residential building should meet comfort requirements of all ages.

Hereunder are given the indicators of the systems that were omitted in any of the case studies regarding the considerations cited above.

- In HVAC system: provide management staff with database and analytical tools for operation and service evaluation and Self-diagnostic of operation deviations were considered as unnecessary for residential building due to the scale of the project.
- In BAS: reports generation and output of statistical and trend profiling of controls and operations, ability to provide operational and analytic functions for totalized building performance review, analyze operation function parameters to select the best and effective operation logic to run the building services systems over time, automatically adapt to daily occupied space changes to control building services systems and provide adaptive control algorithms based on seasonal changes to control building services systems were omitted for the residential building due to the scale of the project, building type and priority of indicators.
- In fire alarm system: automatic or remote controlling was omitted for the office tower due to the type of the building.
- In security system: interface with phone system and multiple detection or verification mechanism were omitted for office tower and residential building, respectively due to the type and scale of the buildings.
- In vertical transportation system: accommodate changes of passenger traffic pattern, pre-scheduled of special events and normal routines and on-line investigation and analysis of lift activity were considered as unnecessary for the residential building since, it is not a large scale project and also does not concern multiple lift strategies required for high rise office buildings that hold maximum and zero traffic hours.
- In lighting system: provide management staff with database and analytical tools for operation and service evaluation was omitted for the residential building since, it holds more dynamic and variable lighting values rather than an office with pre-defined lighting strategies.

These check lists were used to assess the two case studies that are claimed to be intelligent. In the first stage intelligence characteristics and attributes of both case studies were explained by aforementioned companies, then further information concerning deficient or ambiguous material were questioned by the author, finally case studies were evaluated based upon the existence of systems and specific indicators regarding building type in constructed models but, since both of the case studies have not yet been occupied, it was not possible to ask the occupants about the efficiency of the systems.

Personal interviews were made with project directors for both of the case studies. The author visited the residential project and incorporated systems in the building were explained clearly by Mete Eryilmaz, from Teknoboyut Company. Interview with Tuncay Kaya in Atasarim was made to obtain the information regarding systems and intelligence attributes of telecommunication headquarters building.

CHAPTER 4

RESULTS AND DISCUSSION

The checklists prepared by bringing together the attributes cited commonly in the various reference sources from literature, includes 6 main intelligent building systems, as: HVAC, BAS, fire alarm, security, vertical transportation and lighting systems. Each system is then divided further into its relevant attributes which are the most common intelligent characteristics of each system regarding building type.

Information on the presence or absence of systems and services necessary in an IB was entered into the check lists for both the case studies, according to the answers given by the representatives of the companies related to the two projects (see Table 4.1 and Table 4.2).

Each case study was evaluated on the basis of the duly filled check lists to find out the extent of intelligence; i.e. in terms of the percentage of required attributes. In evaluating the case studies the following information was taken into considerations:

- When the answer related to the existence of a system in the case study building was "maybe", it was taken as an indication of absence.
- In residential case study an integrated HVAC system is not considered so, the specifications cited in the table comprise only heating system.
- In residential case study there exists a control unit which has a similar operation to building automation system except that, it controls the system operations within one unit and does not integrate the systems in the whole

building. Therefore evaluation statements express controllability and integration of systems in any particular unit.

In evaluation Tables 4.1 and 4.2 below the symbol ✓ means the attribute was present; × means the attribute was absent and TBD is short for to be decided, i.e. a decision had not yet been made.

Table 4.1 Evaluation checklist for residential case study

Systems	Attributes	Status
HVAC system	Automated fault detection	×
	adaptive to occupancy working or living pattern	✓
	Utilize natural ventilation control to reduce air conditioning power consumption	×
	sensing the external temperature and auto adjustment of the system	×
	sensing the internal temperature and auto adjustment of the system	✓
	operation control mechanism to achieve efficient power consumption	×
	Pre-programmed responses and zoning control	✓
	Interface with BAS	×
	Interact with lighting and sun blind's system	×
	Acoustic comfort	✓
	service life	✓
	Operating and maintenance costs	✓
	Self-diagnostic of operation deviations	×
	Sub total	*6 / 13*
BAS	Year-round time schedule operation	✓
	Ability to link multiple standalone building control systems from a variety of manufacturers	×
	Remote control via Internet	✓
	Ability to connect multiple locations	✓
	Control and monitor HVAC equipment on sequence control, time scheduling, thermal comfort, ventilation, fault recovery operations	×
	Control and monitor security system interlock operation with other services	×
	Control and monitor fire detection interlock operation with other services	×
	Control and monitor vertical transportation operation	×
	Control and monitor lighting time schedule/zoning operation	×
	Web base interface to any location and wireless terminal for functional access (pocket PC, mobile phones)	✓
	Single operation system/ platform for multiple location supervision	×
	Run continually with minimal human supervision	×
	Operation and maintenance costs	×
	Sub total	*4 / 13*
Fire alarm system	Alarm deployment algorithm within the building and notification to Fire Department	×
	Integration and control of sensors, detectors, fire-fighting equipment	×
	Run continually with minimal human supervision	✓
	Self-diagnostic analysis for false alarm reduction	×
	Self test of sensors, detectors and control points	×
	Interface with BAS	×
	Interact with security system	×

Table 4.1 Continued

	Interact with HVAC system	×
	Interact with lift systems	×
	Interact with emergency generator systems	×
	Provide management staff with database and analytical tools for operation and service evaluation	×
	Pre-scheduled of special events and incidents	×
	Ability to further upgrade	✓
	Automatic or remote control/ monitoring	✓
	Operation and maintenance costs	✓
	Fire resistance code compliance	✓
	Sub total	*5 /16*
Security system	Interface with communication network, phone system, etc	✓
	Interface with BAS	×
	Provide management staff with database and analytical tools for operation and service evaluation	×
	Pre-scheduled of special events and normal routines	×
	Minimum time for informing building management	✓
	Minimum time for public announcement	×
	Ability to further upgrade	✓
	Operation and maintenance costs	✓
	Sub total	*4 / 8*
Vertical transportation system	Auto-controlled navigation at emergency	×
	Automatic or remote control	×
	Remote monitoring	×
	Interface with BAS	×
	Human engineering design to facilitate convenience of passengers (i.e. voice announcement, fit for disables, lighting)	✓
	Provide management staff with database and analytical tools for operation and service evaluation	×
	Safety regulations compliance	✓
	Waiting time	×
	Journey time	×
	Operation and maintenance costs	✓
	Acoustic comfort	✓
	Air change	✓
	Sub total	*5 / 12*
Lighting system	Adaptive to occupancy work or live schedule	✓
	Presence detection	✓
	Provide multiple level and control mode for occupants to program custom-made settings	✓
	Sensing the light intensity and angle of projection and solar radiation to maximize natural light and reduce lighting power	×
	Interface with BAS	×
	Pre-programmed response and control	✓
	User interface via internet or remote control	✓
	Automatic lighting and shading controls	×
	Ability to further upgrade	✓
	Service life	✓
	Sub total	*7 / 10*
	Grand Total	***31 / 72***

Table 4.2 Evaluation check list for office case study

Systems	Attributes	Status
HVAC system	Automated fault detection	TBD
	adaptive to occupancy working or living pattern	✓
	Utilize natural ventilation control to reduce air conditioning power consumption	×
	sensing the external temperature and auto adjustment of the system	×
	sensing the internal temperature and auto adjustment of the system	✓
	operation control mechanism to achieve efficient power consumption	TBD
	Pre-programmed responses and zoning control	✓
	Interface with BAS	✓
	Provide management staff with database and analytical tools for operation and service evaluation	TBD
	Interact with lighting and sun blind's system	✓
	Acoustic comfort	✓
	service life	✓
	Operating and maintenance costs	✓
	Self-diagnostic of operation deviations	TBD
	Sub total	*9 / 14*
BAS	Year-round time schedule operation	✓
	Ability to link multiple standalone building control systems from a variety of manufacturers	✓
	Remote control via Internet	TBD
	Ability to connect multiple locations	✓
	Control and monitor HVAC equipment on sequence control, time scheduling, thermal comfort, ventilation, fault recovery operations	✓
	Control and monitor security system interlock operation with other services	✓
	Control and monitor fire detection interlock operation with other services	✓
	Control and monitor vertical transportation operation	✓
	Control and monitor lighting time schedule/zoning operation	✓
	Web base interface to any location and wireless terminal for functional access (pocket PC, mobile phones)	TBD
	Reports generation and output of statistical and trend profiling of controls and operations	TBD
	Ability to provide operational and analytic functions for totalized building performance review	✓
	Single operation system/ platform for multiple location supervision	✓
	Run continually with minimal human supervision	✓
	Analyze operation function parameters to select the best and effective operation logic to run the building services systems over time	×
	Automatically adapt to daily occupied space changes to control building services systems	×
	Provide adaptive control algorithms based on seasonal changes to control building services systems	×
	Operation and maintenance costs	TBD
	Sub total	*11 / 18*
Fire alarm system	Alarm deployment algorithm within the building and notification to Fire Department	TBD
	Integration and control of sensors, detectors, fire-fighting equipment	✓
	Run continually with minimal human supervision	✓
	Self-diagnostic analysis for false alarm reduction	×
	Self-test of sensors, detectors and control points	TBD
	Interface with BAS	✓
	Interact with security system	✓
	Interact with HVAC system	✓

Table 4.2 Continued

	Interact with lift systems	✓
	Interact with emergency generator systems	✓
	Provide management staff with database and analytical tools for operation and service evaluation	TBD
	Pre-scheduled of special events and incidents	×
	Ability to further upgrade	✓
	Operation and maintenance costs	✓
	Fire resistance code compliance	✓
	Sub total	*10 / 15*
Security system	Interface with BAS	✓
	Multiple detection or verification mechanism	TBD
	Provide management staff with database and analytical tools for operation and service evaluation	TBD
	Pre-scheduled of special events and normal routines	×
	Minimum time for informing building management	✓
	Minimum time for public announcement	TBD
	Ability to further upgrade	✓
	Operation and maintenance costs	✓
	Sub total	*4 / 8*
Vertical transportation system	Auto-controlled navigation at emergency	✓
	Automatic or remote control/ monitoring	✓
	Accommodate changes of passenger traffic pattern (up peak/down peak)	×
	Remote monitoring	TBD
	On-line investigation and analysis of lift activity	×
	Interface with BAS	✓
	Human engineering design to facilitate convenience of passengers (i.e. voice announcement, fit for disables, lighting)	✓
	Provide management staff with database and analytical tools for operation and service evaluation	TBD
	Pre-scheduled of special events and normal routines	×
	Safety regulations compliance	✓
	Waiting time	✓
	Journey time	✓
	Operation and maintenance costs	✓
	Acoustic comfort	✓
	Air change	✓
	Sub total	*10 / 15*
Lighting system	Adaptive to occupancy work or live schedule	✓
	Presence detection	✓
	Provide management staff with database and analytical tools for operation and service evaluation	TBD
	Provide multiple level and control mode for occupants to program custom-made settings	×
	Sensing the light intensity and angle of projection and solar radiation to maximize natural light and reduce lighting power	×
	Interface with BAS	✓
	Pre-programmed response and control	✓
	User interface via internet or remote control	×
	Automatic lighting and shading controls	✓
	Ability to further upgrade	✓
	Service life	✓
	Sub total	*7 of 11*
	Grand Total	***51 / 81***

The results of the evaluation are tabulated for the two buildings, under separate IBS headings, in Table 4.3 below. Presence of indicators in each system regarding related check list is presented as a percentage of all indicators.

Table 4.3 Evaluation of results of the two case studies

IBS / Case Study	HVAC	BAS	Fire alarm	Security systems	Vertical transport	Lighting	Overall	
Residential	46%	30%	31%	50%	41%	70%	43%	31/72
Office	64%	61%	67%	50%	67%	67%	62%	51/81

The telecommunication tower holds more intelligence attributes than residential building; this is due to the scope of the projects and difference in function of the buildings. The differences are discussed in the following:

- HVAC system in office building holds just 1 more indicator because thermal comfort has a direct link to both working efficiency and human comfort.
- Office tower includes 5 more indicators of BAS than residential building since it is a high rise and large scale building that needs some requirements that are not necessary for the residential building.
- Fire alarm system in residential building holds 1 more indicators due to the type of the building.
- Security system includes the same number of indicators for both of the buildings; however they occupy some different indicators regarding building type.
- Vertical transportation and lighting systems in office tower holds 3 and 1 more indicators respectively, due to the scale and function of the building.

It can be understood from the table above that:

- In residential building vertical transportation and HVAC systems hold the same percentage of indicators while, in office tower vertical transportation and lighting systems incorporate the same percentage of indicators.
- BAS in both of the case studies, specially the residential building, needs more dynamic integrations to meet the user's needs regarding the common goal of the both project, to provide comfortable, secure and healthy place.
- Both types of buildings had incorporated the same amount of security system indicators and almost the same intelligent lighting attributes.
- In the office tower the most intelligence attributes are considered in fire alarm system; whereas, in residential building lighting system has been paid the most attention.
- The least intelligence attributes are the ones of security system in office tower, this could be either due to lack of given information to the author or, a disadvantage of such a great project.
- The least intelligence attributes in residential building are the ones of BAS even in the scope of an apartment unit, in that control unit lacks the integration between systems.
- BAS, fire protection, vertical transportation, HVAC, lighting and security system include the most and the least number of indicators, respectively.
- In residential building lighting, security, HVAC and vertical transportation, fire alarm and BAS systems include the highest and lowest percentage of present attributes, respectively.
- In office building fire alarm, vertical transportation and lighting, HVAC, BAS and security systems include the highest and lowest percentage of present attributes, respectively.

CHAPTER 5

CONCLUSION

The integration of advanced technologies into buildings in order to provide comfortable, healthy and secure spaces for occupants to live or to work in, has made intelligent building systems very popular in recent years. Within the framework of this study, existence of specific attributes to meet the aforementioned concerns, have been examined through case studies. This chapter presents the conclusions derived from the study.

Both telecommunication office tower and residential building claimed to be intelligent and provide their occupants with efficient facilities that produce comfortable, safe, secure and healthy environment. The overall concept of telecommunication tower was focused on providing a healthy and comfortable place for working via a double skin glass façade with automatic blinds; similarly comfortableness and safety were the main goals for selected residential building.

In telecommunication office tower, building automation system is designed to integrate and control lighting, HVAC, security, fire alarm and vertical transportation systems. This will result in an increase in occupants' comfort level, safety and security, and also a decrease in heating, cooling and electric loads. However, results show that the building lacks such dynamism and responsiveness that a truly intelligent building should hold. In fact, it only provides 62% of required intelligence attributes. The main intelligence provision is temperature and natural light control; thus, it is possible to state that telecommunication tower is intelligent in terms of temperature and daylight control.

Residential case study provides 43% of required intelligence attributes and since building automation systems do not exist, the project can hardly called intelligent because building automation system is referred as the heart of every intelligent building. But when a single apartment unit is taken into consideration it can be concluded that ability to monitor and control remotely is the most important advantage of the project.

Adding the term “intelligence” to the name of any building gains commercial values and a rise in prestige and also its market value. There exist huge claims regarding buildings called intelligent but in fact most of these buildings do not meet the intelligence requirements. Intelligence cannot be achieved by incorporating sensors or other systems alone. Existed deficiencies are risen from that the concept of intelligent building has not been developed by owners and architects; therefore it is essential to understand the concept in first stage and then develop it in practical model.

In this study it was tried to give a general idea concerning intelligence of intelligent buildings and develop considerations which architects should have in mind when designing an intelligent building. Therefore, check lists have been formulated as a guide line for aspiring architects so that, they may have source guidance as what needs to be integrated into their design to make their project an intelligent one. If this aim is achieved then intelligence will no longer be a slogan but will actually add value to a building.

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APPENDIX A

SUMMARY OF INITIAL ATTRIBUTES REGARDING INTELLIGENT BUILDING SYSTEMS AND COMPONENTS

Table A1. Summary of initial attributes regarding intelligent building systems and components (source, Wong & Li 2006)

Building Automation System	Work efficiency	Grade and level of BAS
		Ability of integration
		Complied with standard
		Use of internet protocol
		Reliability
		Efficiency (speed)
		Allow for further upgrade
		Maintenance factors
		Remote control and monitoring
		Life span
	Cost effectiveness	First cost
		Life cycle cost
Information and Communication Network System	Work efficiency	Transmission rate/speed
		Reliability
		Electromagnetic compatibility
		Mobile phone coverage
		Office automation (level)
		Public address system
		Clean earth
		Number of telephone line
		Satellite conferencing or high speed video conference
		Intranet management system
		Broadband internet connection
		GOS & exchange lines

Table A.1 Continued

		IP address per staff
		Allow for further upgrade
		Life span (year)
	Technological related	Advanced IT system
		Existence of artificial intelligent (AI)
	Cost effectiveness	First cost
		Life cycle cost
Fire Protection System	Work efficiency	Compliance with fire protection & fighting code
		Compliance with fire resistance code
		Automatic sensoring and detection system for flame, smoke and gas
		Remote control
		Signal transmission rate
		Maintainality of installation
		Comprehensive scheme of preventive maintenance
		Life span (year)
		Allow for further upgrade
		Compatibility with other building systems
		Integrated with BAS
	Technological related	Existence of AI based supervisory control
		Modernization of system
	Cost effectiveness	First cost
		Life cycle cost
HVAC System	Environmental related	Pollution related to fuel consumption
		Energy recycling
		Total energy consumption (kWh/year/m2)
		Method of cooling
		Condition of pipe insulation
		Contamination
	User comfort	Thermal comfort: Predict mean vote (PMV)
		Thermal comfort: Indoor air quality
		Thermal comfort: OTTV (W/m2)
		Amount of fresh air changes per second (litres/s/occupant)
		Coefficient of performance of the whole building
		Cool air distribution
		Noise level (NC)
		Special ventilation for kitchen and toilet measured in are changes per hour (AC/h)
		Odour & freshness of indoor air
		Appearance
		Cleanliness

Table A.1 Continued

	Work efficiency	Heat pump & heat wheel
		Frequency of breakdown
		Refrigerant leakage detection
		Access for erection & maintenance
		Condensate drain water leakage
		Life span (year)
		Allow for further upgrade
		Compatibility with other building systems
		Integrated with BAS
	Technological related	Existence of artificial intelligent (AI) based supervisory control
		Modernization of system
	Cost effectiveness	First cost
		Life cycle cost
Electrical Installation System	Environmental related	Electricity demand provision (VA/m2)
		Electric power quality
	Work efficiency	Electric power outlet
		Electric power supply (A/m2)
		Frequency of major breakdown
		Life span (year)
		Allow for further upgrade
		Compatibility with other building systems
		Integrated with BAS
	Technological related	Extensive use of artificial intelligence for monitoring
	Safety related	Compliance with regulations (i.e. electrical wiring regulation)
		Comprehensive scheme of preventive maintenance
	Cost effectiveness	First cost
		Life cycle cost
Lighting System	Environmental related	Permanent artificial lighting average glare index
		Permanent artificial lighting average lux level (lux)
		Average efficacy of all lamps (lm/W)
	User comfort	Adequate daylighting measured in average daylight factors (%)
		Ventilation for excessive heat from lighting
		Noise from luminaries
		Ease of control
		Cleanliness
		Average colour temperature (nm)
		Colour rendering
		Glare (glare index)

Table A.1 Continued

		Suitability for the task
		Colour matching of the finishes
		Appearance of finishes of lighting
	Work efficiency	Permanent artificial lighting average power density (W/m2)
		Uniformity of lux level
		Automatic control/adjustment of lux level
		Maintenance factors (total lumen output in aging/ total lumen output in new)
		Life span (year)
		Allow for further upgrade
		Compatibility with other building systems
		Integrated with BAS
	Technological related	Architectural design (image)
		Extensive use of artificial intelligence for control and monitoring
	Cost effectiveness	First cost
		Life cycle cost
Hydraulic and Drainage System	User comfort	Cleanliness
		Automatic flushing water control system (refilling speed, flow rate)
		Automatic fresh water control system (flow rate)
	Work efficiency	Automatic flushing water control system
		Automatic fresh water control system
		Life span (year)
		Allow for further upgrade
		Compatibility with other building systems
		Integrated with BAS
	Technological related	Existence of artificial intelligent (AI) based supervisory control
		Architectural design (modernization of system)
	Cost effectiveness	First cost
		Life cycle cost
Safety and Security System	Work efficiency	Time needed for public announcement of disasters (second/minute)
		Time needed to report a disastrous event to the building management (second/minute)
		Time for total egress (minute)
		Connectivity of CCTV system to security control system
		Number (or %) of monitored exits and entrances
		Earthquake monitoring devices

Table A.1 Continued

		Wind load monitoring devices
		Structural monitoring devices
		Maintainality of installation
		Comprehensive scheme of preventive maintenance
		Life span (year)
		Allow for further upgrade
		Compatibility with other building systems
		Integrated with BAS
	Technological related	Existence of artificial intelligent (AI) based supervisory control Modernization of system
		Area monitored by CCTV
	Cost effectiveness	First cost
		Life cycle cost
Vertical Transportation System	Environmental related	Energy consumption (kJ/passenger/minute)
		In-car and lobby noise (dBA)
		Machine room noise (dBA)
		Maximum allowable electrical power (kW)
		Total harmonics distortion (THD) of motor drive systems
		Regeneration into supply system (energy conservation)
	User comfort	Acceleration and deceleration (m/s2)
		Average illumination (lux)
		Air change (AC/hr)
		Noise (dBA)
		Vibration (m/s2)
	Work efficiency	Maximum interval time (second)
		Handling capacity in % of total population (%)
		Journey time (second)
		Waiting time (second)
		Servicing and repair (times per month)
		Efficiency of drive and control system
		Automatic and remote monitoring
		Life span (year)
		Allow for further upgrade
		Compatibility with other building systems
		Integrated with BAS
	Technological related	Existence of artificial intelligent (AI) based supervisory control
		Provision of indoor information display system
		Architectural design
		Modernization of system

Table A.1 Continued

	Safety related	Time to identify trapped passengers without a mobile phone (minute)
		Installation of sensoring and detecting system
		Reliability (mean time between failure
		Comprehensive scheme of preventive maintenance
	Cost effectiveness	First cost
		Life cycle cost
Building Façade System	Environmental related	Sunlight pollution to others
		Allow for natural ventilation
		Use of pollution-free product
		Prevention of noise pollution from outside
	User comfort	Automatic response to change in temperature
		Automatic response to sunlight
	Work efficiency	Ability to filter excess and harmful sunlight
		Automatic control and monitoring
		Remote control and monitoring
		Life span (year)
		Allow for further upgrade
		Compatibility with other building systems
		Integrated with BAS
	Technological related	Existence of artificial intelligent (AI) based supervisory control
		Architectural design (image of modernization)
	Cost effectiveness	First cost
		Life cycle cost
Building Interior Layout	Environmental related	Pollution-free product
		Acoustics: Indoor ambient noise level (dBA)
		Acoustics: Reverberation time
	Spacial management	Flexibility for installing new false ceilings and floor utilities for a totally different use
		Flexibility for re-partitioning
		Flexibility of internal re-arrangement of personnel
	Work efficiency	Life span (year)
		Allow for further upgrade
		Compatibility with other building systems
		Integrated with BAS
		Colour matching of finishes
	Technological related	Architectural design (image of modernization)
	Cost effectiveness	First cost
		Life cycle cost

APPENDIX B

INTELLIGENT BUILDING INDEX PROPOSED BY AIIB

1. GREEN INDEX

1.1 Existence of green features

1.2 Lift and escalators: Energy consumption

1.3 Lift and escalators: Handling capacity in percentage of total population

1.4 Lift and escalators: Maximum interval time

1.5 Lift and escalators: Journey time

1.6 Lift and escalators: Waiting time

1.7 Lift and escalators: Drive and controls systems

1.8 Lift and escalators: In-car noise

1.9 Lift and escalators: Lobby noise

1.10 Lift and escalators: Machine room noise

1.11 Lift and escalators: Vibration

1.12 Lift and escalators: Modernization

1.13 Lift and escalators: Maximum allowable electrical power of traction lifts

1.14 Lift and escalators: Total harmonics distortion of motor drive systems for lifts and escalators

1.15 Lift and escalators: Total power factor of motor drive systems for lifts and escalators

1.16 Lift and escalators: Maximum allowable electrical power of escalators & passenger conveyors

1.17 Lift and escalators: Regeneration into the supply system

1.18 Lavatory and provision of appliances: Flushing system

1.19 Lavatory and provision of appliances: Fresh water supplies

1.20 Lavatory and provision of appliances: Provision of consumables

1.21 Lavatory and provision of appliances: Functionality of water systems

1.22 Thermal comfort: Predicted mean vote (PMV)

1.23 Thermal comfort: Indoor air quality

1.24 Thermal comfort: OTTV

1.25 Electricity demand provision

1.26 Electric power quality

1.27 Heating services: Energy recycling

1.28 Heating services: Pollution related to fuel consumption

1.29 HVAC services: Condition of pipe insulation

1.30 HVAC services: Provision of heat pump and heat wheel

1.31 Ventilation and air conditioning: Amount of fresh air changes per second

1.32 Ventilation and air conditioning: Refrigerant

1.33 Ventilation and air conditioning: Coefficient of performance of the whole building

1.34 Ventilation and air conditioning: Method of cooling

1.35 Ventilation and air conditioning: Cool air distribution

1.36 Ventilation and air conditioning: Non-smoking building

1.37 Ventilation and air conditioning: Noise Level

1.38 Ventilation and air conditioning: Special ventilation for some areas, e.g. kitchen, restaurant and toilet measured in air changes per hour

1.39 Ventilation and air conditioning: Contamination of chilled and condensing water, virus, bacteria or other contaminants

1.40 Ventilation and air conditioning: Total energy consumption

1.41 Ventilation and air conditioning: Access for erection and maintenance

1.42 Ventilation and air conditioning: Appearance

1.43 Ventilation and air conditioning: Water leakage

1.44 Ventilation and air conditioning: Cleanliness

1.45 Lighting: Adequate day lighting measured in average daylight factors

1.46 Lighting: Permanent artificial lighting average power density

1.47 Lighting: Permanent artificial lighting average glare index

1.48 Lighting: Permanent artificial lighting average lux level

1.49 Lighting: Average efficacy of all lamps

1.50 Lighting: Average color temperature

1.51 Lighting: Maintenance factor

1.52 Lighting: Ease of control

1.53 Environmental friendliness: Pollution produced

1.54 Environmental friendliness: Sunlight pollution by curtain wall

1.55 Environmental friendliness: Outdoor noise pollution

1.56 Environmental friendliness: Indoor noise pollution in terms of average noise level

1.57 Environmental friendliness: Recycle of wastes produced by the building

1.58 Environmental friendliness: Substantial use of non-exhaustible material for construction

1.59 Environmental friendliness: Plans to lower the life cycle usage of energy

1.60 Environmental friendliness: Use of natural ventilation

1.61 Environmental friendliness: Substantial use of renewable energy

1.62 Environmental friendliness: Plantation and landscape gardening

1.63 Environmental friendliness: Image of environmental friendliness

1.64 Waste disposal

1.65 Drainage

1.66 Electromagnetic compatibility (EMC)

1.67 Special feature(s) recommended by the auditor

2. SPACE INDEX

2.1 Area per person

2.2 Average width of corridor

2.3 Accommodation: Average usable area in percentage of total GFA

2.4 Circulation for the disabled

2.5 Aid provided by the building management to the disabled

2.6 Car park and transportation: Number of car park space

2.7 Car park and transportation: Location of car park

2.8 Car park and transportation: Ventilation of car park

2.9 Car park and transportation: Lighting of car park

2.10 Car park and transportation: Security of car park

2.11 Car park and transportation: Space of car park

2.12 Car park and transportation: Ease of access to main public transport terminals

2.13 Car park and transportation: Number of loading and unloading areas for taxis, cargo vehicles and private cars

2.14 Car park and transportation: Provision of refuse collection area

2.15 Flexibility for installing new false ceilings and floor utilities for a totally different use

2.16 Flexibility for re-partitioning

2.17 Flexibility of internal re-arrangement of personnel

2.18 Building provision for high-tech equipment

2.19 Special feature(s) recommended by the auditor

3. COMFORT INDEX

3.1 Area per person

3.2 Average width of corridor

3.3 Average usable area in percentage of total GFA

3.4 Lift: Vibration

3.5 Lift: Acceleration and deceleration

3.6 Lift: Average illumination

3.7 Lift: Air change

3.8 Lift: Noise

3.9 Lavatory and provision of appliances: Number

3.10 Lavatory and provision of appliances: Location

3.11 Lavatory and provision of appliances: Cleanliness

3.12 Lavatory and provision of appliances: Flushing system

3.13 Lavatory and provision of appliances: Fresh water supplies

3.14 Lavatory and provision of appliances: Provision of consumables

3.15 Lavatory and provision of appliances: Repair of water system

3.16 Thermal comfort: Predicted mean vote (PMV)

3.17 Thermal comfort: Indoor air quality

3.18 Thermal comfort: OTTV

3.19 Ventilation and air conditioning: Amount of fresh air changes per second

3.20 Ventilation and air conditioning: Noise level

3.21 Ventilation and air conditioning: Frequency of breakdown

3.22 Ventilation and air conditioning: Special ventilation for some areas, e.g. kitchen, restaurant and toilet measured in air changes per hour

3.23 Ventilation and air conditioning: Odour and freshness of indoor air

3.24 Ventilation and air conditioning: Contamination of chilled and condensing water by virus, bacteria or other contaminants

3.25 Ventilation and air conditioning: Access for erection and maintenance

3.26 Ventilation and air conditioning: Appearance

3.27 Ventilation and air conditioning: Condensate drain water leakage

3.28 Ventilation and air conditioning: Cleanliness

3.29 Lighting: Adequate day lighting measured in average daylight factors

3.30 Lighting: Permanent artificial lighting average power density

3.31 Lighting: Appearance of finishes of lighting

3.32 Lighting: Average color temperature

3.33 Lighting: Color rendering

3.34 Lighting: Ventilation for excessive heat from lighting > Mean radiant temperature

3.35 Lighting: Cleanliness

3.36 Lighting: Noise from luminaries

3.37 Lighting: Maintenance factor

3.38 Lighting: Ease of control

3.39 Lighting: Glare

3.40 Lighting: Suitability for the task

3.41 Lighting: Window shape and position

3.42 Lighting: Color matching of the finishes

3.43 Access: Entrance width

3.44 Access: Operating time of the building

3.45 Acoustics: Reverberation time

3.46 Acoustics: Indoor ambient noise level

3.47 Color

3.48 Entertainment facilities

3.49 Provision of a lobby lounge on every floor

3.50 Special feature(s) recommended by the auditor

4. WORKING EFFICIENCY INDEX

4.1 Area per person

4.2 Average width of corridor

4.3 Average usable area

4.4 Lift and escalators: Existence of AI based supervisory control

4.5 Lift and escalators: Provision of in-car information display system

4.6 Lift and escalators: Handling capacity in percentage of total population

4.7 Lift and escalators: Journey time

4.8 Lift and escalators: Waiting time

4.9 Lift and escalators: Location

4.10 Lift and escalators: Servicing and repair

4.11 Lift and escalators: Modernization

4.12 Lavatory and provision of appliances: Number

4.13 Lavatory and provision of appliances: Cleanliness

4.14 Lavatory and provision of appliances: Operational

4.15 Lavatory and provision of appliances: Location

4.16 Thermal comfort: Predicted mean vote

4.17 Thermal comfort: Indoor air quality

4.18 Lighting: Adequate day lighting measured in average daylight factors

4.19 Lighting: Permanent artificial lighting average power density

4.20 Lighting: Appearance of finishes of lighting

4.21 Lighting: Uniformity of lux level

4.22 Lighting: Ventilation for excessive heat from lighting > Mean radiant temperature

4.23 Lighting: Cleanliness

4.24 Lighting: Maintenance factor

4.25 Lighting: Ease of control

4.26 Lighting: Attractive design

4.27 Lighting: Suitability for the task

4.28 Lighting: Glare

4.29 Lighting: Color matching of the finishes

4.30 High tech: Electric power points

4.31 High tech: Electric power supply

4.32 High tech: Broad band internet > Ethernet

4.33 High tech: Broad band internet > Existence of fire wall

4.34 High tech: Broad band internet > Workstation

4.35 High tech: Broad band internet > Transmission rate inside building

4.36 High tech: Broad band internet > Transmission rate outside building

4.37 High tech: Broad band internet > IP address per staff

4.38 High tech: Availability of multi-media facilities such as video on demand and image communications etc.

4.39 High tech: Public address system

4.40 High tech: Voice mail and music for telephone system

4.41 High tech: Intranet management system

4.42 High tech: Satellite conferencing or high speed video conference by a superhighway

4.43 High tech: Office automation

4.44 High tech: Security control automation at main entrances

4.45 High tech: Area monitored by CCTV

4.46 High tech: Usage of electronic payment

4.47 High tech: Usage of electronic directory

4.48 High tech: Provision of updated information at public area

4.49 High tech: Remote monitoring of lifts and escalators

4.50 High tech: Provision of webpage for the building

4.51 High tech: Provision of hotline

4.52 High tech: Number of telephone lines

4.53 High tech: GOS and number of exchange lines

4.54 High tech: Provision of FDDI

4.55 High tech: Building services automation system

4.56 High tech: Grade of BAS

4.57 High tech: Large size wall LCD or plasma display panel

4.58 High tech: Architectural design of the building (image)

4.59 High tech: Advanced car park facilities

4.60 High tech: Area of mobile phone coverage

4.61 Sign and directory: Maps

4.62 Sign and directory: Interactive directory

4.63 Car park and transportation: Number of car park space

4.64 Car park and transportation: Location of car park

4.65 Car park and transportation: Ventilation of car park

4.66 Car park and transportation: Lighting of car park

4.67 Car park and transportation: Security of car park

4.68 Car park and transportation: Ease of access to the main public transport terminals

4.69 Car park and transportation: Number of loading and unloading areas for taxis, cargo vehicles and private cars

4.70 Property management

4.71 Access: Entrance width

4.72 Access: Operating time of the building

4.73 Access: Helicopter apron

4.74 Electromagnetic compatibility

4.75 Provision of clean earth

4.76 Frequency of major breakdown

4.77 Existence of public conference and meeting facilities

4.78 Entertainment facilities within buildings

4.79 Building provision for high-tech equipment

4.80 Maintainability of installation

4.81 Special feature(s) recommended by the auditor

5. CULTURE INDEX

5.1 Entertainment facilities within building

5.2 Food and beverage supply

5.3 Choice of color and indoor decoration

5.4 Office layout

5.5 Privacy

5.6 Feng Shui

5.7 External landscape

5.8 Indoor plants (including artificial ones)

5.9 External view (sea view, mountain view, garden view, sunrise view, sunset view etc.)

5.10 Religious facilitation

5.11 Culturally based interior design

5.12 Special feature(s) recommended by the auditor

6. HIGH-TEC IMAGE INDEX

6.1 Electrical services : Electric power points

6.2 Electrical services : Electric power supply

6.3 Broad band internet : Ethernet

6.4 Broad band internet : Workstation

6.5 Broad band internet : Transmission rate inside building

6.6 Broad band internet : Transmission rate outside building

6.7 Broad band internet : IP address per staff 151

6.8 Intranet management system

6.9 Satellite conferencing

6.10 Office automation

6.11 Security control automation at main entrances

6.12 Area monitored by CCTV

6.13 Usage of electronic payment

6.14 Usage of electronic directory

6.15 Provision of updated information at public area

6.16 Internet connection

6.17 AI based supervisory control for elevators

6.18 Choice of finishes

6.19 Remote monitoring of lifts and escalators

6.20 Provision of webpage for the building

6.21 Provision of hotline

6.22 Number of telephones

6.23 GOS and number of exchange lines

6.24 Provision of FDDI

6.25 Building services automation system

6.26 Grade of BAS

6.27 Large size wall LCD or plasma display panel

6.28 Architectural design of the building

6.29 Advanced carpark facilities

6.30 Area of mobile phone coverage

6.31 Extensive use of artificial intelligence

6.32 Extensive employment of energy sources without pollution

6.33 Extensive use of robots

6.34 Horizontal and vertical people movers

6.35 Construction materials

6.36 Building provision for high-tech equipment

6.37 Electrical services :Uninterruptible power points

6.38 Special feature(s) recommended by the auditor

7. SAFETY AND SECURITY INDEX

7.1 Earthquake monitoring devices

7.2 Wind load monitoring devices

7.3 Structural monitoring devices

7.4 Structural control

7.5 Tile debonding

7.6 Terrorist attack consideration

7.7 Indefensible space

7.8 Average width of corridor

7.9 Accommodation : Average usable area in percentage of total GFA

7.10 Means of escape

7.11 Circulation for the disabled

7.12 Fire detection and fire fighting

7.13 Fire resistance

7.14 Means of access

7.15 Electrical wiring regulation

7.16 Reliability of elevator systems

7.17 Time to identify trapped passengers without a mobile phone

7.18 Closed circuit television (CCTV)

7.19 Response to special event

7.20 Security control system

7.21 Number of unmonitored exits and entrances

7.22 Advanced AI based security system

7.23 Time needed to report a disastrous event to the building management

7.24 Time needed for public announcement of disasters

7.25 Time for total egress

7.26 Quality of systematic escape route plan

7.27 Essential electric power

7.28 Comprehensive scheme of preventive maintenance

7.29 Maintainality of installation

7.30 Thermal comfort and indoor air quality

7.31 Special feature(s) recommended by the auditor

8. CONSTRUCTION PROCESS AND STRUCTURE INDEX

8.1 Green design

8.2 Modular design and construction

8.3 Computer aided design and communication

8.4 Modern project management approach

8.5 Construction safety management system

8.6 Mechanized construction process

8.7 Construction waste and pollution

8.8 Safety in general

8.9 Serous injury (safety)

8.10 Site personnel

8.11 Water leakage during raining seasons

8.12 Cracks on finishes or spalling

8.13 Tile debonding

8.14 Settlement

8.15 Differential settlement

8.16 Building top vibration under strong wind

8.17 Building top vibration under strong wind

8.18 Green building materials

8.19 Special feature(s) recommended by the auditor

9. COST EFFECTIVENESS INDEX

9.1 Cost to rent ratio

APPENDIX C

DEVICES AND SENSORS USED IN RESIDENTIAL CASE STUDY

Door entry alarm used in residential building

Figure C.1 Door entry alarm, source: www.bticino.com.tr

An example of scenario key

Figure C.2 Scenario key in residential building, source: www.bticino.com.tr

An example of the lighting switch used in the residential building

Figure C.3 Lighting switch, source: www.bticino.com.tr

An example of temperature sensors used in case study

Figure C.4 Temperature sensors, source: www.bticino.com.tr

A key composed of temperature sensor and audio control keys

Figure C.5 Audio control & temperature sensors, source: www.bticino.com.tr

The burglar alarm used in residential case study

Figure C.6 Burglar alarm, source: www.bticino.com.tr

An example of gas detector used in the case study

Figure C.7 Gas detector, source: www.bticino.com.tr

APPENDIX D

MAIN ASSESSMENT CHECK LIST

Table D.1 Main assessment check list

Systems	Attributes
HVAC system	Automated fault detection
	adaptive to occupancy working or living pattern
	Utilize natural ventilation control to reduce air conditioning power consumption
	sensing the external temperature and auto adjustment of the system
	sensing the internal temperature and auto adjustment of the system
	operation control mechanism to achieve efficient power consumption
	Pre-programmed responses and zoning control
	Interface with BAS
	Provide management staff with database and analytical tools for operation and service evaluation
	Interact with lighting and sun blind's system
	Acoustic comfort
	service life
	Operating and maintenance costs
	Self-diagnostic of operation deviations
BAS	Year-round time schedule operation
	Ability to link multiple standalone building control systems from a variety of manufacturers
	Remote control via Internet
	Ability to connect multiple locations
	Control and monitor HVAC equipment on sequence control, time scheduling, thermal comfort, ventilation, fault recovery operations
	Control and monitor security system interlock operation with other services
	Control and monitor fire detection interlock operation with other services

Table D.1 Continued

	Control and monitor vertical transportation operation
	Control and monitor lighting time schedule/zoning operation
	Web base interface to any location and wireless terminal for functional access (pocket PC, mobile phones)
	Reports generation and output of statistical and trend profiling of controls and operations
	Ability to provide operational and analytic functions for totalized
	building performance review
	Single operation system/ platform for multiple location supervision
	Run continually with minimal human supervision
	Analyze operation function parameters to select the best and effective operation logic to run the building services systems over time
	Automatically adapt to daily occupied space changes to control building services systems
	Provide adaptive control algorithms based on seasonal changes to control building services systems
	Operation and maintenance costs
Fire alarm system	Alarm deployment algorithm within the building and notification to Fire Department
	Integration and control of sensors, detectors, fire-fighting equipment
	Run continually with minimal human supervision
	Self-diagnostic analysis for false alarm reduction
	Self-test of sensors, detectors and control points
	Interface with BAS
	Interact with security system
	Interact with HVAC system
	Interact with lift systems
	Interact with emergency generator systems
	Provide management staff with database and analytical tools for operation and service evaluation
	Pre-scheduled of special events and incidents
	Ability to further upgrade
	Automatic or remote control/ monitoring
	Operation and maintenance costs
	Fire resistance code compliance
Security system	Interface with communication network, phone system, etc
	Interface with BAS
	Multiple detection or verification mechanism

Table D.1 Continued

	Provide management staff with database and analytical tools for operation and service evaluation
	Pre-scheduled of special events and normal routines
	Minimum time for informing building management
	Minimum time for public announcement
	Ability to further upgrade
	Operation and maintenance costs
Vertical transportation system	Auto-controlled navigation at emergency
	Automatic or remote control/ monitoring
	Accommodate changes of passenger traffic pattern
	Remote monitoring
	On-line investigation and analysis of lift activity
	Interface with BAS
	Human engineering design to facilitate convenience of passengers
	Provide management staff with database and analytical tools for
	operation and service evaluation
	Pre-scheduled of special events and normal routines
	Safety regulations compliance
	Waiting time
	Journey time
	Operation and maintenance costs
	Acoustic comfort
	Air change
Lighting system	Adaptive to occupancy work or live schedule
	Presence detection
	Provide management staff with database and analytical tools for operation and service evaluation
	Provide multiple level and control mode for occupants to program custom-made settings
	Sensing the light intensity and angle of projection and solar radiation to maximize natural light and reduce lighting power
	Interface with BAS
	Pre-programmed response and control
	User interface via internet or remote control
	Automatic lighting and shading controls
	Ability to further upgrade
	Service life