ASSESSING THE SERVICE QUALITY OF INTELLIGENT BUILDING CONTROL SYSTEMS: AN IMPORTANCE-PERFORMANCE ANALYSIS

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ABSTRACT

ASSESSING THE SERVICE QUALITY OF INTELLIGENT BUILDING CONTROL SYSTEMS: AN IMPORTANCE-PERFORMANCE ANALYSIS

Recently, control systems are being integrated to an increasing number of buildings, which are then labeled as “intelligent”. Even though the intelligence label creates a considerable market share, intelligence-indicator building control systems are under-researched in terms of the expectations of customers.

This thesis analyzes customer satisfaction for intelligent building control systems by assessing expected and perceived service levels that reveals service quality. In order to achieve this, two web-based surveys inquiring both the importance and the performance levels of control systems were conducted. The collected data were then analyzed by a customer gap analysis depending on an importance-performance analysis.

Among the seven control systems investigated, building automation system is found to be the most important intelligent control system integrated to a building. Yet, it is also found to be one of the underperforming control systems investigated. Thus, the largest customer gap indicating the lowest service quality is defined for building automation system towards which managerial effort and concentration should be directed urgently for proper improvement purposes. Heating, ventilating and air conditioning system shows the second largest customer gap that constitutes the second highest priority. Although, vertical transportation system is found to be one of the most under-performing control systems, since it is also found to be the least important intelligent control system, it has the lowest customer gap, which indicates low-priority.

The findings of the thesis could be of help to develop effective strategies for the management policies of construction and building automation companies.

ÖZET

AKILLI BİNA KONTROL SİSTEMLERİNİN HİZMET KALİTESİNİN DEĞERLENDİRİLMESİ: BİR ÖNEM-BAŞARIM ANALİZİ

Son zamanlarda, kontrol sistemleri giderek artan sayıda binada kullanılmaya başlanmıştır; öyle ki bu sebeple bu tip binalar daha sonra “akıllı” olarak etiketlenmiştir. Binalardaki akıllı etiketi önemli bir pazar payı yaratsa da, akıl göstergesi olarak kabul edilen bina kontrol sistemleri müşteri beklentisi açısından yeterince araştırılmamıştır.

Bu tez akıllı bina kontrol sistemleri açısından müşteri memnuniyetini hizmet kalitesini belirleyen beklenen ve algılanan hizmet düzeyi üzerinden analiz etmektedir. Bu sebeple, kontrol sistemlerinin hem önem hem de başarım seviyelerini araştıran iki internet tabanlı anket yapılmıştır. Elde edilen veri bir önem-başarım analizi olan müşteri odaklı fark analizi ile incelenmiştir.

Araştırılan yedi kontrol sistemi arasında, bina otomasyon sistemi bir akıllı binada bulunan en önemli kontrol sistemi olarak belirlenmiştir. Ancak, ayrıca en düşük başarım düzeyine sahip sistem de bina otomasyon sistemidir. Bu sebeple en düşük servis kalitesine işaret eden en büyük müşteri odaklı fark bu kontrol sistemine aittir ve geliştirilmesi amacıyla yönetimsel çabanın ve odağın acilen buraya kaydırılması gerekmektedir. Isıtma, soğutma ve havalandırma sistemi en büyük ikinci müşteri odaklı farkı dolayısıyla en yüksek ikinci önceliği teşkil etmektedir. Asansör sistemi en düşük başarım gösteren sistemlerden biri olmasına rağmen aynı zamanda en düşük öneme sahip akıllı bina kontrol sistemi olarak da belirlendiği için en düşük müşteri odaklı farka yani en düşük önceliğe sahiptir.

Bu tezin bulguları yapım ve otomasyon şirketlerinin yönetim politikaları açısından etkin stratejiler geliştirebilmesine yardımcı olabilir.

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LIST OF ABBREVIATIONS

AFA	: Addressable Fire Detection and Alarm
AHP	: Analytical Hierarchical Process
AHU	: Air Handling Unit
AIIB	: Asian Institute of Intelligent Buildings
ANP	: Analytical Network Process
BAS	: Building Automation System
BRE	: Building Research Establishment
CABA	: Continental Automated Buildings Association
CCTV	: Closed Circuit TV
CIBSE	: Chartered Institution of Building Services Engineers
DALI	: Digital Addressable Lighting
ETI	: Energy Time Consumption Index
GAPA	: Gap Analysis
HRV	: Heat Recovery Ventilator
HVAC	: Heating, Ventilating and Air Conditioning
IB	: Intelligent Building
IBI	: Intelligent Building Index
IBMS	: Intelligent Building Management System
IPA	: Importance-Performance Analysis
KPI	: Key Performance Indicator
MAUT	: Multiple Attribute Utility
MCDM	: Multi Criteria Decision Making
MSIR	: Magnitude of Systems’ Integration Index
POE	: Post Occupancy Evaluation
SEC	: Security
SERVQUAL	: Service Quality Gap Model
SIS	: System Intelligence Score
TD	: Telecom and Data
VT	: Vertical Transportation

CHAPTER 1

INTRODUCTION

The developments in information technology and the growing awareness of the environmental problems have increased the demand for 'intelligent building'. The growing computer technology, the invention and rapid spread of the internet usage are the most important developments in information technology that trigger the developments in computerized and automatized systems.

For the past three decades, in order to meet such demand the designers started to add 'intelligence' to their new designs. Adding intelligence technically increases the buildings' effectiveness and efficiency in a practical perspective. Therefore, it is important. This 'intelligence' increases the marketability of the new buildings. As a result, a satisfactory design of the intelligent buildings has become one of the most important issues.

This thesis assesses the service quality of seven main intelligent building control systems (e.g., building automation system, telecom and data system, addressable fire detection and alarm system, heating ventilating and air conditioning control system, digital addressable lighting control system, security system, and vertical transportation system). Accordingly, it uses importance-performance analysis for a detailed inquiry of priorities in satisfaction of the clients.

In this chapter, the problem statement, the objectives and the research questions, the design and limitations of the study of the study are presented. This chapter concludes with the outline presenting the organization of the thesis.

1.1. Problem Statement

Since 1980's, numerous intelligent buildings have been built. Developments in computer and information technologies, the increasing environmental problems and the need for a healthy living environment urged an increase in the demand for intelligent buildings. Therefore, a wide variety of intelligent building control systems have been developed. As a result of these developments, numerous studies are done to identify the intelligence indicators and determine whether a building is truly intelligent or not. In other words, the previous studies tried to define the criteria for intelligent building and assess the intelligence quantity of buildings.

After all, the advanced technologies and automated components in the buildings have been attracting clients. The question that comes to mind is whether these automated systems satisfy the expectations of the clients or not. The expectations and satisfaction of the users/occupants in these buildings are crucial for strategic development of the intelligent building construction industry. Each newly constructed intelligent building includes automated systems but currently there is no feedback to assess service quality of these systems. The priorities of the intelligent building users, potential buyers, current occupants is an under-researched crucial area for the intelligent building designers, the sellers of those buildings and the developers of the automation systems. Both expected service quality and perceived service quality of intelligent building control systems regarding technical aspects should be investigated for the beneficial guidance of the capital management and allocation of the resources. First and foremost, the priorities for improvement purposes in intelligent building systems in practical aspects should be identified.

1.2. Objectives of the Study

This study aims to identify and evaluate the indicators which affect the occupant's satisfaction of intelligent building control systems. This is vital for the future service strategy of the intelligent building designers, the developers and providers of the automation systems. The objective of this thesis is to develop a model to measure the occupants' service quality perception and derived satisfaction regarding the intelligent building control systems. The thesis aims to accord the priority treatment for improvement purposes in an intelligent building environment. The results and the statistical analysis regarding the perceived service quality can be used to help both designers and developers to determine managerial implications in the intelligent building construction sector. Consequently, the goal of this research is to provide a feedback to identify the priorities in providing intelligent control systems to improve the perceived service quality.

The overall purpose of the thesis can be summarized as follows; 1) to define the dimensions and attributes which are mentioned as intelligence indicators in the previous researches on intelligent buildings to describe service quality of intelligent building control systems and satisfaction of occupants 2) to show how the occupants assess dimensions with regards to the intelligent building service quality and client satisfaction and 3) to identify the priorities for improvement in intelligent building sector to optimize perceived service quality and client satisfaction.

The aim of the thesis is to answer the following questions:

1) How do the users and occupants assess the service quality attributes of intelligent building control systems with regard to the expected and perceived service quality?

2) How do the customer gaps between the expected and perceived service differ among the various service quality dimensions (i.e., intelligent building control systems)? How do the gaps differ for small and large scale building types?

3) Which service quality dimensions do display priority for the future development of intelligent building control systems?

1.3. Design of the Study

The methodology used to fulfill the objectives of the study is structured in eight steps and summarized in Figure 1.1.

Firstly, a review of existing intelligent building literature for identifying the research deficiencies and for verifying the service quality dimensions and attributes is conducted. Then, a model for measuring the intelligent building control systems service quality and client's satisfaction is developed. The developed model based on two variables. These variables are the customers' perception of intelligent building control systems service quality and derived satisfaction of the customers with these systems. Two web-based questionnaires are constructed to measure service quality and customer satisfaction for the most common seven intelligent building control systems and 59 attributes of these systems in the related literature. First questionnaire is the expected service (importance) questionnaire and the second questionnaire is the experienced service (performance) questionnaire. Two pilot studies are conducted to refine both questionnaires. The objective of piloting is to identify any misunderstood survey questions. The main intent of constructed questionnaires is to identify the priorities for improvements of the intelligent building control systems to create a satisfactory intelligent building experience. The respondents of the questionnaires are both visitors and the occupants of the intelligent buildings. This means that the survey is conducted to both the long-term-users and the short-term-users.

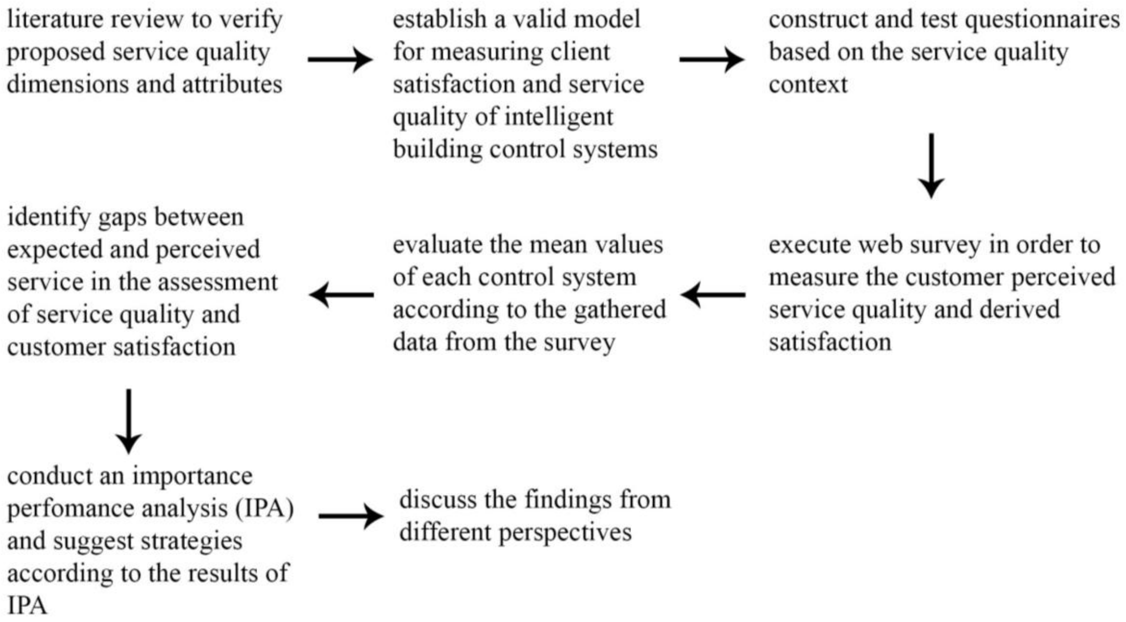


Figure 1.1. Research design of the study.

The intelligent building control systems of both small and large scale buildings are evaluated according to their service quality. Mean values of each proposed indicator of each seven intelligent building control systems are calculated with regard to both expected service (importance) and experienced service (performance). The mean scores show the impact of each attribute in perceived service quality and determine the priorities for a possible improvement.

Then, gap analysis is conducted to identify the customer gaps between the expected and the perceived service in the assessment of service quality and client satisfaction. The findings of both customer gap analysis and Importance-Performance Analysis are evaluated to indicate deficiencies and improvement potentials both from an architectural design and management perspective.

1.4. Chapter Organization

The thesis is presented in six chapters. The content of each chapter is summarized in this section.

Chapter 1 is the introduction of the study. It presents problem area and the research methodology of the thesis. It also includes the significance and objectives of the study, and the chapter organization of the study.

Chapter 2 contains the definition of intelligent building. The most common seven intelligent building control systems are explained. The technological aspects and developments of the systems are summarized in this chapter.

Chapter 3 presents an overview for performance evaluation models of intelligent buildings. It contains the evolution process and a detailed review.

Chapter 4 presents the research methodology of the thesis. The know-how of measuring service quality, gap analysis and Importance-Performance Analysis are defined.

Chapter 5 presents the customer gap analysis and Importance-Performance Analysis results. The findings are discussed comparatively.

Chapter 6 is the conclusion chapter. It involves a brief summary of the study, practical implications, suggestions for further research.

CHAPTER 2

INTELLIGENT BUILDINGS AND CONTROL SYSTEMS

The term ‘intelligent building’ was first used at the beginning of the 1980s. Until this date, the concept has not been used, so the question can be asked why the concept of intelligent building has been pervaded in recent years. Geisler (1989) states that when the word intelligence come into use for a building, it is for commercial slogan to sell or rent more floor area in buildings, thus, the concept of ‘intelligent building’ means fast return of the invested money. The recent increasing demand for the concept of intelligent building can be explained by three reasons: the need for healthy living environment, environmental problems, and the developments in information technology.

In the first stance, a building plays a vital role on health and comfort of its occupants. A building must provide comfortable and healthy conditions for its occupiers and users, if it does not provide these, sick building syndrome occurs (D. Clements-Croome, 2004; Wigginton & Harris, 2002). As reported by Smith (2002) , a research in recent years has shown the effect of a healthy and comfortable internal environment on good well-being of people. Wigginton and Harris (2002) state that the concept of intelligent building is pervaded by the increasing demand for comfort living environment. Therefore, designers of intelligent buildings are trying to find a solution for healthy and comfortable living of their users. These attempts on finding a solution increase the demand for intelligent buildings.

Environmental problems are the most important problems. Because of these problems, our world is getting more uninhabitable. Wigginton and Harris (2002) suggest that the greenhouse effect and the impact of climate change are the most effective ones of these environmental problems that change our environment. Buildings have a huge impact on these environmental problems with their energy consumption, carbon dioxide emissions, and electricity consumption. Wigginton and Harris (2002) report that in the U.K. buildings are responsible for 46 percent of the total energy consumption. In addition, EMSD (2006) reports the results of a research in Hong Kong and states that residential and commercial buildings are responsible for 85 percent of the total domestic electricity consumption. So, energy conservation is one of the most important issues in the design of a building. As a result of environmental concerns, people try to design environmentally friendly buildings.

Besides the environmental concerns, the development of information technology has a vital role in the spread of the concept of ‘intelligent building’. Wong, Li, and Wang (2005) support this idea and state that the demand for intelligent building is raising day by day because of the rapid development of information technology and growing awareness of building constraints about the intelligent technology developments. In the same line, Wong (2007) suggests that the invention of Internet and its widespread use are the important developments in history of intelligent buildings. In addition, the reason of the rising interest in intelligent buildings in recent years is not technological advancements, the reason is the benefits of these. Wong (2007) classifies the benefits of intelligent buildings in four main groups: 1) improved user comfort and productivity, 2) enhanced operational and energy efficiency, 3) enhanced cost effectiveness, 4) increased system robustness and reliability.

The reasons for spreading the concept of intelligent building in recent years are discussed above as an introduction. Moreover, a literature review of definitions of the intelligent building and intelligent building control systems are covered in this chapter. To this end, this chapter is composed of two main sections. The first section includes the definitions of intelligent building. The second section presents intelligent building control systems in detail.

2.1. The Concept of Intelligent Buildings

In the related literature, there are many technical and academic resources that investigate the definition of intelligent building. However, still there is not a universally accepted definition for intelligent building. The common point most designers agree, is that “intelligent buildings are not intelligent, they make their occupants more intelligent” (So & Chan, 1999). On the other hand, there are so many variations of the definition in the literature. The variations are arising from time periods, common key factors in the definitions, and geography. Therefore, this chapter comprises the short history of the concept of intelligent building and discusses the definitions of the intelligent building.

The word ‘intelligent’ describes buildings occurred initially in early 1980s in the United States (Wong et al., 2005). The concept of ‘intelligent building’ has pervaded and become a sophisticated demand in recent years. Therefore, there are so many variations in the early and recent definitions. Intelligent building definition has a short history. Intelligent buildings were defined as buildings which were automatically controlled to function and minimize the human interaction with the building till 1985. From 1986 to 1991, intelligent buildings were defined as buildings which were capable of responding to the changing needs. Then, from 1992 to present, intelligent buildings referred buildings with features effectively satisfying the changing needs (Ghiaus, 2006). Supporting this short history, Wigginton and Harris (2002) pointed out that earlier definitions were entirely concentrated on major technological systems and they stated that such as building automation, building communications and office automation are examples of these technological systems. Additionally, Cardin (1983: cited in Wigginton & Harris, 2002) defined the intelligent building as the “one which fully automated building service control systems”. Extending this simple definition of Cardin (1983), The Intelligent Building Institution in Washington (1988) gives a more detailed definition. The Intelligent Building Institution in Washington (1988: cited in Kroner, 1997 and Clements-Croome, 1997) defined the intelligent building as “one which integrates various systems to effectively manage resources in a coordinated mode to maximize technical performance, investment and operating cost savings, and flexibility”.

Besides early definitions which focused on being fully automated, in definitions after 1991, user needs and comfort requirements became more important. Most existing definitions of IBs, defined after 1991, try to make certain that IB is a building which provides its occupants safe, comfortable, efficient and effective working and living environment (So & Chan, 1999). In other words, optimal building intelligence is the matching of solutions to occupant needs (So & Chan, 1999). A true intelligent building must be able to consider the requirements of users (Loveday, Virk, Cheung, & Azzi, 1997; Preiser & Schramm, 2002; Robathan, 1994; Wigginton & Harris, 2002). A growing awareness for the relationship between the well-being of humans and the service systems and work process management of a building emerged. In recent years, debates over the definition have extended and as a result of this extension ‘learning ability’ and ‘performance adjustment from its occupancy and the environment’ have been added to the most recent definitions. Wong et al. (2005) proposed that an intelligent building is not only able to react and change accordingly to individual, organizational and environmental requirements, but also should be capable of learning the requirements and adjusting its performance according to its occupants and the environment.

Bradshaw and Miller (1993) emphasize the interaction between the advanced technologies and user needs for comfortable environment, and state that intelligent buildings are different from typical buildings as they are equipped with advanced and intelligent control technologies. With these technologies, intelligent buildings aim to create a productive and efficient environment. Intelligent Building Dictionary (2012) supports the integration between technology and the occupants' needs, and defines intelligent building as "a building that integrates technology and process to create a facility that is safer, more comfortable and productive for its occupants, and more operationally efficient for its owners. Advanced technology combined with improved processes for design, construction and operations provide a superior indoor environment that improves occupant comfort and productivity while reducing energy consumption and operations' staffing". Additionally, Clements-Croome (2001) suggests that an intelligent building "will provide for innovative and adaptable assemblies of technologies in appropriate physical, environmental and organizational settings, to enhance worker productivity, communication and overall human satisfaction." Similarly, Arkin and Paciuk (1997) define intelligent building as 'a dynamic tool which can be used to create the personal, environmental, and technological conditions necessary for building occupants to maximize their individual capabilities, productivity and satisfaction'. Arkin and Paciuk (1997) state these goals can be achieved by the integration of the buildings' service systems. In literature, there are a few definitions which support Arkin and Paciuk (1997) and emphasize the integration of systems in intelligent building (Carlini, 1988; Geisler, 1989; Gann, 1990; DEGW *et al.*, 1992; Harrison *et al.*, 1998; Sharples *et al.*, 1999; So and Chan, 1999; Fu and Shih, 2000; Arkin and Paciuk, 1997).

Clements-Croome (1997) states that each culture and civilization uses different technologies. The level of being developed in technology causes the difference in definitions. Different countries or geographic regions defined building intelligence from different aspects. The inter-connection of service systems for the benefit of occupants was defined as the most important feature of an intelligent building in the US (Arkin & Paciuk, 1997). The Europeans emphasizes the interaction between the systems and the responsive structural elements (Kroner, 1997). In addition to these variations, different intelligent building research institutes in different regions have different interpretations of intelligent building. According to The Intelligent Building Institute of the USA, intelligent building is one that provides a productive and cost-effective environment through optimization of its four basic components - structure, systems, services and management and their interrelationship. In addition, in a report by the Intelligent Building Institute of USA, it is stated that "there is no fixed set of characteristics that defines IB. The only characteristic that all Intelligent Buildings must have in common is a structure designed to accommodate change in a convenient, cost effective manner". The definition accepted by the UK-based European Intelligent Building Group (EIBG) is "an Intelligent Building creates an environment that allows organizations to achieve their business objectives and maximizes the effectiveness of its occupants while at the same time allowing efficient management of resources with minimum life-time cost." Both definitions of the US-based and UK-based Intelligent Building Institutions emphasize the same purpose, which provides an efficient and productive environment for occupants, at minimum overall cost. It is clearly understood from these definitions that inclusion of high-tech, sophistically controlled service systems in a building are not enough to define the building as an intelligent building. On the other hand, there is a difference between the definitions of US and UK based Intelligent Building Institutions. While the definition of Intelligent Building Group in Europe is more focused on the users' requirements; the definition of Intelligent Building Institution in the US is more concentrated on technologies.

Additionally, IB has different meanings in Asia, Singapore, China and Japan. The Public Works Department of Singapore government states that an intelligent building is;

> "One that must fulfill three conditions such as; the building should have advanced automatic control systems to monitor various facilities, including air conditioning, temperature, lighting, security, fire etc. to provide a comfortable working environment for the tenants; the building should have good networking infrastructure to enable data flow between floors; the building should provide adequate telecommunication facilities."

In Shangai, there are two label types such as “3A” and “5A”. “3A” means the building has three automatic functions; communication automation, office automation, and building management automation. If fire automation system and comprehensive maintenance automation system are added on to 3As and it becomes “5A”. Japanese IBs must be designed to suit Japan’s cultural climate. Regarding cultural considerations, IBs must maintain an effective working environment, run automatically, and be flexible enough to adopt to future changes in the needs of the working environment (So & Chan, 1999). It can be revealed from the above discussions that in both definitions used in Singapore and China, it is given importance to control and communications using advanced technologies; while the emphasis of Japanese definition has been placed on the occupants themselves. According to So and Chan (1999), Japanese definition is more suitable than other Asian definitions to formulate a universal definition, which could be extendible to the whole world.

So and Chan (1999) state there is not a certain definition which helps designers in detailed design. For this reason, a definition of IB was formulated as “intelligent building is the one which is designed and constructed based on an appropriate selection of quality environment modules to meet the user’s requirements by mapping with appropriate building facilities to achieve long term building values” (Wong, So & Leung, 2005). The definition has been accepted by The Asian Institute of Intelligent Building (AIIB). The environmental modules of IB are defined as environmental friendly, space utilization and flexibility, human comfort, working efficiency, culture, image of high technology, safety and security, construction process and structure, and cost effectiveness. In addition, key elements were defined as functional spaces, functional requirements and technologies.

As discussed above, there are so many definitions for intelligent buildings. The content of the definition of IB changes according to years, common key factors and regions. All definitions reviewed above have importance in literature and history of intelligent building definition.

This thesis aims to develop an evaluation model which is based on service quality context. The proposed model aims to suggest strategies for designers, engineers, automation companies and construction companies according to both technical aspects and user needs. The integration of technical aspects and human needs provide a long-termed and more detailed evaluation model and assessment. Therefore, this thesis adopts the given definition of Wong, So & Leung (2005) which has been accepted by AIIB and addresses the integration of technical aspects and human needs.

2.2. Control Systems for Intelligent Buildings

Intelligent building control systems primarily support and operate functions of the building. Intelligent buildings are equipped with these control systems to provide a productive and efficient environment for their occupants with some qualities, such as security and safety, thermal comfort, acoustical comfort, air quality and visual comfort, system integration and functionality (Bradshaw & Miller, 1993). The building automation system (BAS) usually refers to the top level of building control (Arkin & Paciuk, 1997) and it manages a number of control systems. The commonly referred control systems are as listed below (So & Chan, 1999; Wong & Li, 2006; Wong, Li, & Lai, 2008a, 2008b; Wong et al., 2005; Wong & Li, 2008):

1. Building automation system (BAS)
2. Telecom and data system
3. Addressable fire detection and alarm system
4. Heating, ventilation and air-conditioning (HVAC) control system
5. Addressable lighting and control system
6. Security system
7. Vertical transportation system

The primary functions of the control systems are summarized in Table 2.1. This section provides an overview of the state-of-art of the intelligent building control systems. Descriptions and latest developments for each control system are explained in details in the following subsections.

Table 2.1. Common building control systems and their functions.

INTELLIGENT BUILDING CONTROL SYSTEM	FUNCTION OF THE SYSTEM
Building automation system (BAS)	Manages overall building
Heating, ventilation and air conditioning (HVAC)	Controls indoor air quality and provides thermal comfort
Addressable fire detection and alarm (AFA) system	Prevents fire and handles incidents
Telecom and data (TD) system	Handles all digital communications
Security (SEC) system	Access control and surveillance
Digital addressable lighting (DALI) control system	Control of lighting in overall building
Vertical transportation (VT) system	Manages all the lifts and escalators

2.2.1. Building Automation System (BAS)

BAS was created in the 1980's and then it was upgraded to the intelligent building management system (IBMS) (Wong, 2007). The BAS can be defined as "the core of intelligent building" (Gann, 1990). The automatic control of the building system functions are: heating, ventilating, air conditioning, security, fire protection, lifts and other systems, and managing the daily operations of the building. The relation between BAS and the other building systems is displayed in Figure 2.1.

Eng Loo (2006) states that BAS automatically integrates separate functions of building systems under one operation system. It includes an electronic equipment which analyzes the electricity, gas and water consumption, the building performance and reports the power quality. Accordingly, Wong (2007) categorized BAS as "automatic functional control of building services to maintain the building's normal daily operation with the emphasis on standalone". To emphasize the objectives of BAS, Carlson and Di Giandomenico (1991) defines BAS as "a tool in the hands of building operations personnel to provide more effective and efficient control over all building systems". Figure 2.2. schematically shows the equipment of BAS which coordinates, organizes and optimizes all other building systems.

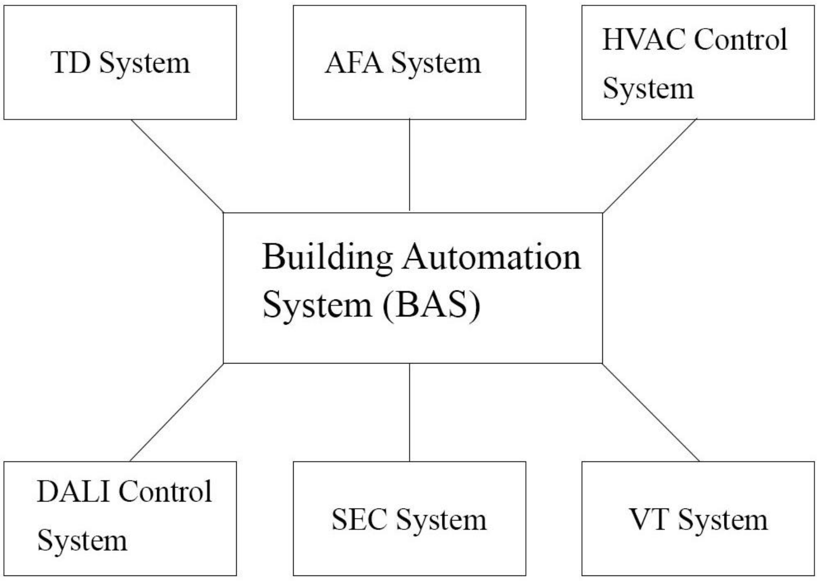


Figure 2.1. BAS integrates and controls all other building systems.

Figure 2.2. BAS controls and monitors all other building systems by electronic equipment. (Source: www.digiplatform.com)

The common functions of BAS are equipment scheduling, optimal start or stop, operator adjustment, monitoring and alarm reporting. The list of the applications of BAS is given in Table 2.2.

Table 2.2. The applications of BAS.
(Source: www.jhsimpsoncompany.com)

Equipment scheduling	Turning equipment off and on as required
Optimal start or stop	Turning heating and cooling equipment on in advance to the required temperature during occupancy
Operator adjustment	Accessing operator set-points that tune system to changing conditions
Monitoring	Logging of temperature, energy use, equipment start times
Alarm reporting	Notifying the operator of failed equipment, out of limit temperature/pressure conditions or need for maintenance

There are many benefits of BAS. First of all, BAS improves user comfort and reduces heating, ventilation and cooling costs. In addition, it allows remote control and reduces time needed for monitoring and managing the operations. On the other hand, there are challenges about BAS. Besides its advantages, it has also some disadvantages. The first is that it is difficult to integrate IBMS the Internet and enterprise applications. The second is that integration opportunities are prevented by the incompatibilities products of different vendors (Wong, 2007).

2.2.2. Telecom and Data System

Telecom and data system is important for an effective operation of a building and its occupants. The data system also plays a big role in continuity of the integration of all other automated building systems. Wong et al. (2008) indicate that the objective of telecom and data system is "to provide effective and efficient information transmission or exchange inside and outside of the building". So and Chan (1999) explain the function of the system as generating, processing, storing and transmitting information.

The telecom and data system include voice services (e.g., telephones, voicemail and intercoms), building systems (e.g., paging, elevator music and kiosks), video and audio conferencing, local and wide area networks, electronic mail, internet access, database access, remote access to building services and television systems (CABA, 2002). The latest developments in the telecom and data system are wireless network and intelligent control system, Bluetooth, LonWorks, Internet technology, and Java soft-computing. The use of Web-enabled devices allow remote monitoring by the interaction of the IBMS or BAS and these devices provide a mechanism to report the building performance remotely, so the security and maintenance costs are reduced (Finch, 2001).

2.2.3. Addressable Fire Detection and Alarm System

The reaction time and the reliability of fire detection and alarm systems are vital for the safety of the occupants. Sinopoli (2010) identifies fire alarm system as “the basis of life safety system” in the buildings. The main objectives of the system are successful rescue operations and least damage (Tränkler & Kanoun, 2001). The design and the installation of the system are driven by the standards, regulations and codes to limit the possibility of damage and loss of life.

Slow response rate and false alarming are generally the most common problems indicated in the related literature. In recent years, many different systems such as microprocessor-based distributed process system technology have been developed to increase the system reliability and flexibility and decrease the number of false alarming (So & Chan, 1999). The reliability and the response time of the fire detectors are very important. In the system, there are three types of sensors: 1) gas sensors, 2) temperature sensors, and 3) smoke sensors. These three types of sensors are combined into one sensor, an example of such a sensor is given in Figure 2.3. To emphasize the importance of each sensor, So and Chan (1999) state that “each sensor can report its individual point address and an analog value to the fire alarm control unit which can communicate with higher central host computer”.

Figure 2.3. Addressable fire sensor.
(Source: www.yanginalarmsistemleri.net)

Intelligent fire protection system should be able to identify the location of the occupants to rescue them. In addition, the fire protection system must allow a smooth integration with other systems. According to CABA (2002), an efficient and intelligent fire detection and alarm system must have reliable integration with the HVAC system. This is important to extract smoke, pressurize stairwell and recall elevators. Another integration should be with lighting system to turn on the lights through the rescue pathways. In addition, the integration with data system is vital to send emergency messages to occupants and integration with the security system to lock doors per code constraints.

2.2.4. Heating, Ventilating and Air-conditioning (HVAC) Control System

The main aim of HVAC control system is to provide thermal comfort, humidity and the overall air quality and adequate ventilation in indoor spaces (Wong et al., 2008). So and Chan (1999) state that HVAC control system provides a comfortable indoor environment to live and work for occupants and defines HVAC control system as "a critical service in modern buildings".

While managing internal environment, HVAC control system consumes a lot of energy and significant impact on both building's energy consumption and the total electricity consumed. Orme (1998) states that HVAC control system generally consumes 25 to 30 percent of the total building energy. So and Chan (1999) support Orme's (1998) argument and suggest that up to 50 percent of the total electricity consumption of a building is through HVAC systems. As a result, these findings reveal that the most important issue regarding the design process of an HVAC system is energy efficiency (Wong, 2007).

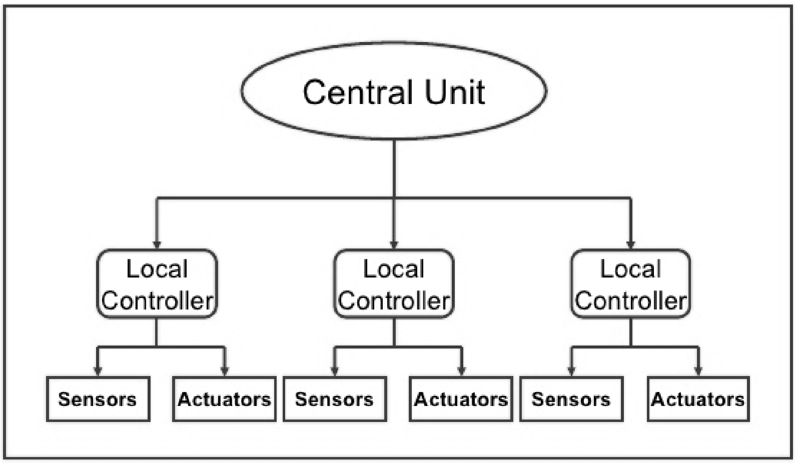


Figure 2.4. Sensors and actuators preceive indoor air quality conditions and transmits message to local controller and then central unit.

HVAC system controls the indoor air quality according to the measured temperature, humidity and CO_2 by its sensors to meet the thermal comfort of the occupants. The HVAC system adjusts its mechanism according to the requirements of the indoor air quality. In order to achieve such an increase, the requirements are identified by the sensors and then actuators give messages to local controller and then the message is delivered to the central unit. The relation of the local and central units is shown in Figure 2.4. The system uses an air handling unit (AHU) which seperates the heat production and cool production. According to requirements of indoor air quality, the heat or cool air is generated in the AHU and then transferred by ductwork to the spaces where it is needed. In the mechanism of AHU, there is also a filter to remove particles and a humidifier to add humidity to the air in case it may be required for thermal comfort. In an HVAC system, there is also a heat recovery ventilator (HRV) to reduce the energy consumption. The HRV transfers the heat of the exhaust streams to the supplied air. The controller in the system operates HRV and AHU to deliver fresh air which is required in the system for indoor thermal comfort.

The HVAC system process in a small residential building is shown in Figure 2.5. The system transfers air from outside into the system, then mixes it with the air in the system and filters the air. Then, according to the requirements, it cools or heats and finally distributes the air where it is needed.

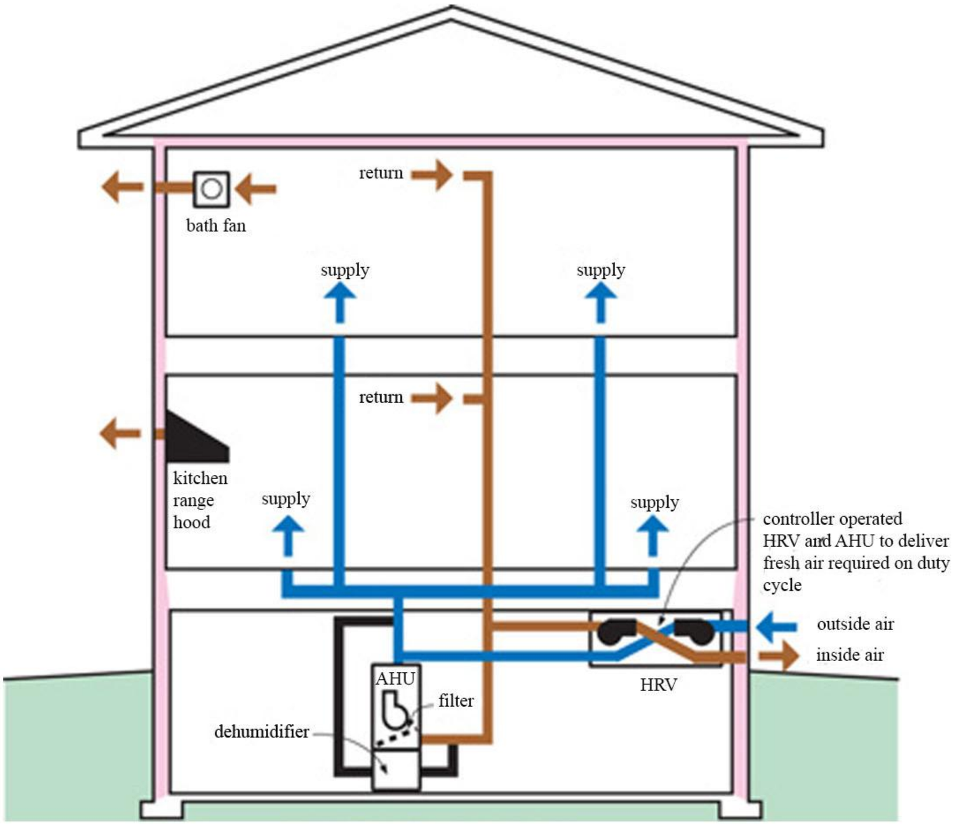


Figure 2.5. HVAC system in a small and residential building.
(Source: www.buildingscience.com)

The sensors are vital to monitor and manage air quality. Figure 2.6. shows the examples of HVAC monitoring and managing panels which include sensors on it. According to CABA (2002), there are three types of sensors as listed below;

1) temperature sensors for fresh air, return air and supply air;
2) humidity sensors for return air and fresh air;
3) the static pressure sensors for supply air.

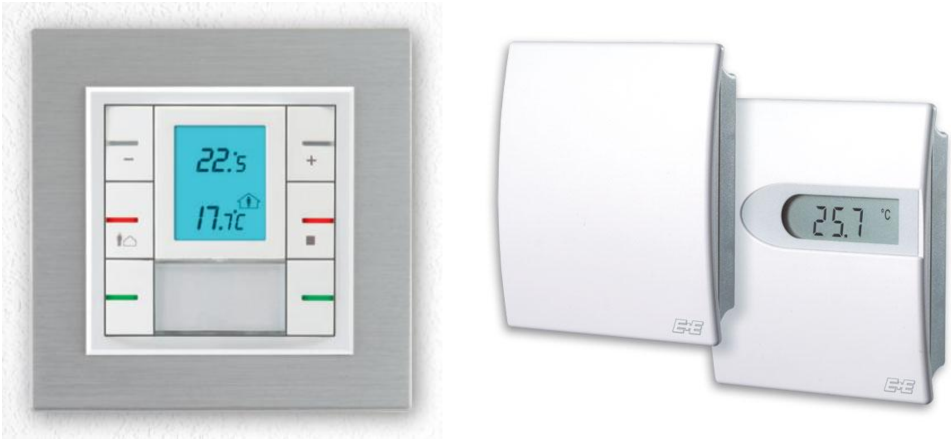


Figure 2.6. Examples of HVAC monitoring and managing panels.
(Source: www.makelsmarthome.com.tr)

So and Chan (1999) emphasize the significance of the sensors by stating that the quality of HVAC relies on measuring devices/sensors, if the sensors do not work efficiently, air quality cannot be monitored; and supplementation of the required air quality becomes impossible. Inefficient work of sensors is critical for wellbeing of occupants. Inadequate ventilation in buildings can cause serious health problems, such as sick building syndrome and building related illnesses (Bischof et al., 1993).

According to CABA (2002), efficient HVAC control systems should:

1) allow occupants to change indoor temperature,

2) control and monitor temperatures and adapt it according to the given scenario,

3) adapt indoor air quality according to the real time room occupancy control and building standards,

4) regulate temperature, humidity and air flow speeds.

There are new developments in HVAC control systems. One of the developments in HVAC is the real time zone control which can count the number of occupants in the space by a computer vision system and controls the system's work (So & Tse, 2001). The other development is HVAC control system's being integrated to the internet based IBMS/BAS that allows occupants to have direct contact by a mobile phone or computer and adjust the system wherever the occupant is. In Figure 2.7., the integration of motion sensors and HVAC system is shown. This integration provides energy conservation. The motion sensors perceive whether the room is occupied or not. If it is occupied, HVAC system starts to work to provide thermal comfort, and when the occupant leaves the room, HVAC systems stops.

Figure 2.7. The integration of motion sensors and HVAC system.
(Source: www.makelsmarthome.com.tr)

2.2.5. Digital Addressable Lighting Control System

The primary objective of digital addressable lighting control system is to adjust the level of illumination and provide energy conservation by efficient lighting usage. So and Chan (1999) define the quality of lighting as a vital aspect in the building because the illumination and contrast levels play a vital role on the wellbeing, motivation and productivity of the occupants. Lighting system in buildings consumes the second highest amount of electrical energy (So & Chan, 1999). According to their statement, it can be understood that great savings in building total energy consumption can be achieved by a reduction in energy used for lighting system. Light sensors, occupancy sensors, motion detectors, photocells, touch switches and dimmable ballasts are developed and used to control the lighting level and reduce energy consumption. The sensor examples are shown in Figure 2.8.

(a) (b) (c)

Figure 2.8. (a) day light sensor (b) motion sensor (c) occupancy sensors
(Source: www.makelsmarthome.com.tr)

With the use of day light sensors, it is possible to manage the lighting level of your space. For instance, in sunny days, your lighting devices will not work, but if it is rainy or cloudy, your devices will adjust the lighting level to a pre-scheduled level automatically. By motion sensors, even if you forget to swith off, during non occupancy the lighting system stops to work and do not consume any energy. By the help of these sensors, huge energy conservations could be achieved. An example of integration occupancy sensor and the lighting system is illustrated in Figure 2.9.

Figure 2.9. The integration of occupancy sensor and the lighting system.
(Source: www.makelsmarthome.com.tr)

There are many lighting types and functions. Each building needs different lighting system. The goal during the design process of DALI must be to furnish the room with the required and appropriate lighting level to help to complete the visual tasks of occupants in an efficient way. In intelligent building technology, there are two different methods to control the lighting level. These are multilevel lighting and modulated lighting (Harrison & Read, 1998). The type of the lighting differs according to the design of the control ballasts.

By the integration of the system with the Internet, the user of the building can schedule the on/off time of the system for a building or zone and control the luminaires in a room by a telephone or PC. In addition, the integration of the lighting system with other building systems is important. Sinopoli (2010) gives an example for such an integration; when fire alarm starts to work, lighting system may turn on emergency lighting symbols to show the way and rescue the occupants. As a result, the lighting system must be integrated with security system, fire alarm system for providing a life safety function by lighting the pathways in any emergency.

In CABA (2002) it is stated that an effective lighting system should:

1) automatically be turned on/off by a schedule or photocell or computer,
2) allow occupant interface with computer or telephone to control lighting level,
3) allow centralized control by linking the lighting controller and user,
4) provide energy consumption by adjusting the lighting level according to different situations.

2.2.6. Security System

Security is "the anticipation, recognition and appraisal of a crime risk and the initiation of some actions to remove or reduce that risk" (So and Chan, 1999). Wong et al. (2008) explain the objective of the security system as improving the security and safety inside the building by surveillance and controlling the entries to the building.

According to CABA (2002), security systems generally have three sub-components: 1) access control, 2) intrusion, and 3) surveillance which are required for the effectiveness of the security system. CABA (2002) also pays attention to the integration of security system with the vertical transportation system and suggests that in case of emergency, the vertical transportation system should lock the lifting operation of the lifts.

In an effective security system, there must be automatic functions such as access monitoring, card access control, guard tour monitoring, motion detectors, networked digital closed circuit TV (CCTV) and person identification systems. The CCTV devices are shown in Figure 2.10 and different types of occupancy and motion detectors are shown in Figure 2.11. According to CABA (2002), a typical security system must also involve door interface, elevator interface, sensor detection for moisture, temperature, glass breakage, intrusion detection, and parking control.

Figure 2.10. CCTV devices for security.
(Source: www.sg-cctv.com)

Figure 2.11. Motion and occupancy sensors.
(Source: www.makelsmarthome.com.tr)

Sensors in the security system should give information about the condition of the windows, doors, exits, and entrances of a building. In addition, with motion and occupancy sensors, the security system should monitor and give information about occupancy. For example, as shown in Figure 2.12., when somebody enters a room, the motion sensors should receive this occupancy and transmit an automatic signal to the security system. So, the security system should give information about the entries and exits to the spaces in the entire building.

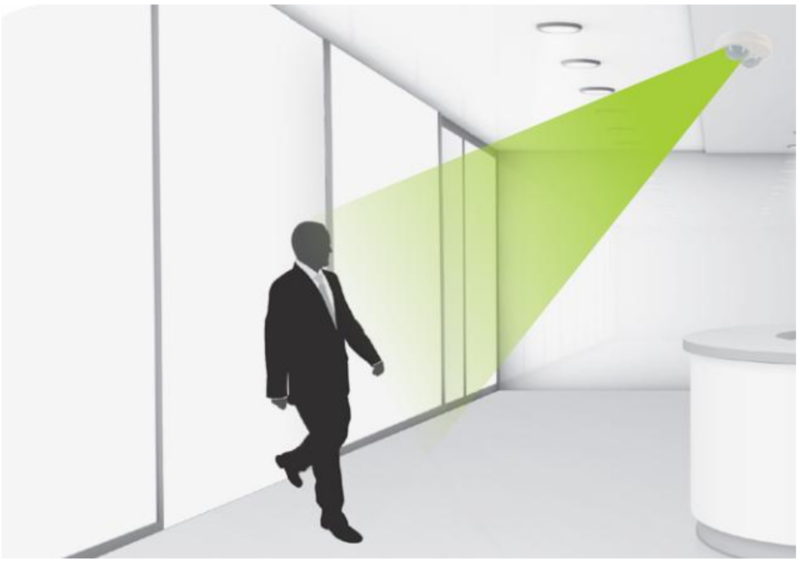


Figure 2.12. Detection of the occupancy sensor and security system relation.
(Source: www.makelsmarthome.com.tr)

2.2.7. Vertical Transportation System

The primary aim of the vertical transportation system is to transport passengers to desired floor quickly, safely and comfortably (Bien, Bang. D.Y, & Han, 2002). Vertical transportation system includes escalators, lifts, passenger conveyors and hydraulic hoists. Vertical transportation system can be regarded as one of the most vital and critical building service systems in high rise buildings, but not in low ones. In high rise buildings, an improved elevator service has a crucial role in satisfying the occupants' needs. Accordingly, in recent years for this satisfaction, the elevators with higher handling capacity, improved riding comfort and a better man-machine interface have been designed (So & Chan, 1999). CABA (2002) mentions that crowded and complex buildings, multiple elevator groups and changing traffic patterns make the system more complex to control and maintain. An intelligent lift control system should be able to accommodate changes of passenger traffic patterns (CIBSE, 2000). The latest lift control systems are able to monitor the number of passengers at each lobby and traveling in each lift car (Wong, 2007).

AIIB (2001) mentions automatic control and monitoring of lift during emergency events as one of the most important feature of elevator systems. In intelligent buildings, there must be 24 hour assistance in the situation of emergence and the system may allow the passengers for voice announcement. In addition, So and Chan (1999) state that a remote monitoring system in a lift must have features such as trapped passenger alarms, inoperable lift alarms, performance alarms, two-way voice communication and lift performance data.

Lift system in an intelligent building must decrease the energy consumption. For energy conservation, CABA (2002) suggests the elevators should be shut down according to a pre-defined schedule and the escalators should slow down and stop when there is no traffic. Some elevators allow using access control cards and permit dynamic changes to user privileges, for instance they could deny the access to certain floors even with an access control card if the floors are even unoccupied, thus the mechanical components of the system are protected and energy conservation is achieved (CABA, 2002).

CHAPTER 3

PERFORMANCE EVALUATION MODELS FOR INTELLIGENT BUILDINGS

There are considerable amount of studies devoted to evaluate intelligence of buildings. Related literature about intelligent building studies have focused on three topics; 1) advanced and innovative technologies, 2) investment evaluation, and 3) performance evaluation. Since, the thesis aims to investigate the performance of the intelligent building control systems, performance evaluation models are reviewed.

Performance evaluation models aim to aid occupants and owners of buildings, potential buyers, designers to assess according to their expectations and needs. In addition, they can be used to produce a database for comparison of the level of building intelligence. The evaluation models allow to reflect changing expectations and requirements for intelligent buildings. The evaluation process can be considered as a feedback mechanism aimed to facilitate learning (Serafeidimis, 2001). According to Remenyi, White, and Sherwood-Smith (1997), the process of evaluation is "a series of activities incorporating understanding, measurement and assessment. It is either a conscious or tacit process which aims to establish the values of or the contribution made by a particular situation and can relate to the determination of the worth of an object". Performance can be defined as the quality of a function or an operation. The results of building performance evaluation can be considered as a reference and feedback function on the performance of building materials and components for the future improvement. Performance evaluation studies provide performance criteria for intelligent buildings.

In the present study, intelligent building performance evaluation models are reviewed in two parts. In the first part, an overview of the evolution of the evaluation models is given. In second part, the review of the evaluation models of intelligent building is given in more detailed way with the answers of the questions: 'how the researchers select the attributes of the models?', 'how the researchers develop a model?' and 'which research techniques the researchers prefer to use?'.

3.1. Evolution of Performance Evaluation Models

Different evaluation models to assess the performance of intelligent buildings have been developed. Early performance evaluation models were developed by Manning in 1965 and Markus et al. in 1972 (Preiser & Schramm, 2002). After those, in 1997, Preiser and Schramm improved an evaluation model. This model within the integrative building performance evaluation framework suggested to evaluate intelligent buildings regarding the whole lifecycle of building.

Measuring the level of intelligence of a building and setting up criteria for selection of the best intelligent building has been the subject of many studies. 'Post-occupancy evaluation process model (POE)' was improved by Preiser to identify the level of intelligence of intelligent buildings (Preiser & Schramm, 2002). The POE model allows to assess the effectiveness and performance of the new high-tech systems and their effects on building occupants. Preiser and Schramm (2002) state that this model enhances the performance of intelligent buildings especially in a long term and continuing basis.

Wong et al. (2005) stated that classifying the level of intelligence is very difficult without a rating system. For this reason, many studies have tried to improve rating systems for intelligent buildings. 'Building rating method' developed by DEGW (1992) is based on 'building IQ rating method', and the 'building quality assessment' was developed by Intelligent Buildings Europe Work (Wong et al., 2005). Moreover, in order to analyze the level of systems' integration in intelligent buildings, 'Magnitude of Systems' Integration Index (MSIR)' was developed by Arkin and Paciuk (1997). Then, the MSIR model was adapted by Yang and Peng (2001).

To assess the level of intelligence of the buildings, in 2001, Asian Institute of Intelligent Buildings (AIIB) developed a quantitative assessment method, 'Intelligent Building Index (IBI)'. The method assesses the intelligent buildings according to nine 'Quality Environment Modules' (M1-M9). Each index has a score within the range of 1-100. According to this method, first the building is evaluated regarding the modules and gets a score, then building is ranked on a scale of A to E to indicate overall intelligence performance (So & Wong, 2002).

To assess the performance of intelligent buildings, the Building Research Establishment Ltd. (BRE) improved a matrix tool called MATOOL (Z. Chen, Clements-Croome, Hong, Li, & Xu, 2006; Kahraman & Kaya, 2012). Chen et al. (2006) improved a MCDM model using an analytical network process (ANP), named IBAssessor for assessment of lifespan energy efficiency of intelligent buildings. Kahraman and Kaya (2012) aimed to assess intelligent buildings and suggested a fuzzy multiple attribute utility (MAUT) model.

Another important point in evaluation of intelligent buildings is selecting indicators and systems which affect the performance of intelligent buildings. In this sense, Alwaer and Clements-Croome (2010) developed a conceptual model for the appropriate selection of key performance indicators (KPIs). They used a consensus-based analytical hierarchical process (AHP) method, which is a type of multi criteria decision making (MCDM), to identify key issues related to sustainable intelligent buildings (Kahraman & Kaya, 2012). Wong and Li (2008) used a MCDM model using the analytical hierarchy process (AHP) model for selection and evaluation of intelligent building systems.

This review of literature shows that, there are several rating and assessment model systems designed for intelligent buildings and there are different new systems under development and still being tested for their effectiveness. In addition to the model mentioned above, there are some assessment models, which provide certificates for intelligent buildings. There are several councils, institutes, associations and certifying organizations which provide performance evaluation criteria. The well-known current building assessment systems for Intelligent Buildings are listed below:

1) Assessment Standards for Certifying Intelligent Buildings (ASCIB, by Intelligent Building Society of Korea (IBSK), Seoul, Korea)

2) Building IQ Rating Criteria (BIQRC, by Task Force 1- Intelligent Building Ranking System, Continental Automated Building Association (CABA), Ottawa, Canada)

3) IB Index (by Asian Institute of Intelligent Buildings (AIIB), Hong Kong)

4) IB Rating (by Shanghai Construction Council (SCC), Shanghai, China)

5) A matrix tool called MATOOL to evaluate the performance of intelligent buildings (by Building Research Establishment Ltd. (BRE), UK)

Z. Chen et al. (2006) compare the assessment models have been stated so far and states that the AIIB method is the most comprehensive method for intelligent building assessment; the SCC method focuses on one assessment cluster (i.e. engineering); the

CABA is still under construction and aims to assess more general way; and the BRE method has less coverage of assessment than IB Index.

3.2. Analysis of Performance Evaluation Models

Since building performance evaluation provides a feedback about the performance of building materials and components, it plays an important role in future improvement in intelligent building field (Preiser, 2001). In addition, performance evaluation models set priorities of the users about intelligent buildings, which help to identify priorities for development. In this sense, different researchers have aimed to create evaluation models for evaluating the performance of intelligent building. Such studies in the literature are increasing in number. There have been substantial amount of studies about performance evaluation of intelligent buildings. Just a few of them are summarized in detail in this part of the thesis. The detailed performance evaluation models of intelligent buildings are below.

An overview of literature related to intelligent building performance evaluation shows that previous researches can be viewed in two different groups such as 1st generation and 2nd generation evaluation models. First generation researches aims to answer the question 'How can we evaluate the performance of an intelligent building?'. In other words, they aim to develop models for evaluating the performance of intelligent buildings. In addition, early studies on intelligent building design focus on which criteria that should be used to assess intelligent building. These models are called 'identification models' as they aim to identify the performance evaluation criteria for intelligent buildings. First generation intelligent building performance models primarily focus on the identification of performance criteria, while the second generation models primarily focus on assessing the performance of intelligent buildings by already developed models. The second generation models are more concentrated on the application of the developed models in a practical way.

Another way of classification for these intelligent building performance evaluation models could be done whether the models include technical aspects, or other aspects rather than technical. In the models which have other aspects rather than technical, generally these aspects are social, psychological, economical. The models focusing on technical aspects concentrate on the services and building systems and the attributes of them. In other words, the first group of the evaluation models involves the attributes of the intelligent buildings under the headings according to common aspects of them while the second group is grouping the attributes under the headings of intelligent building systems and services.

In this part of the thesis, the models focusing on different aspects rather than technical and the models focusing on building systems in technical way are reviewed. The first group models do not focus on building control systems. The model of Z. Chen et al. (2006), Alwaer and Clements-Croome (2010), Huang (2014), Kahraman and Kaya (2014) are included in the first group. The studies of Arkin and Paciuk (1997), Wong and Li (2006), Wong (2007), Wong and Li (2008), Wong et al. (2008a), Wong et al. (2008b), Moghammad (2012) create second group which concentrates on services of intelligent building system and groups the attributes under the intelligent building systems. In this part of the thesis, the studies are reviewed in more detailed than previous part. The way of selecting the attributes and the systems for the evaluation, data collection and assessment techniques and all details of each study is given below.

Starting from the first group, Z. Chen et al. (2006) improved their evaluation model with 43 indicators which were extracted from 378 elements of 10 modules of AIIB intelligent building index. In the selection of the indicators, a quantitative method named ETI (energy time consumption index) was used in the study. Modules used in the research were: 1) Green Index, 2) Space Index, 3) Comfort Index, 4) Working Efficiency Index, 5) Culture Index, 6) High Tech Image Index, 7) Safety and Structure Index, 8) Management Practice and Security Index, 9) Cost Effectiveness Index, and 10) Health sanitation Index. Z. Chen et al. (2006) proposed an estimation for the scope of ETI (i.e. ETI, max = 1000 and the ETI, min = 20) to select the key performance indicators (KPIs) for the ANP model named IBAssessor. Two KPI groups were created. The first group, KPI Group1, contains 18 indicators with ETI scores above 100 and below 260. The second group, KPI Group2, consists of 25 indicators with ETI scores 100 and below 100. Two types of pairwise comparisons were completed for the evaluation by the importance weight which was valued from 1 to 9. One type of pairwise comparison completed in this research was between a KPI and a building alternative, and the other was between two KPIs.

In another study, Alwaer and Clements-Croome (2010) identified 115 individual indicators at the beginning of the research. The indicators were prepared from

BREEAM, LEED, AIIB. A questionnaire survey was conducted with four architects, four engineers, and three sustainability assessors. By the results of the survey, 16 main categories and 57 indicators and sub indicators were identified. Alwaer and Clements-Croome (2010) listed the key performance indicators (KPIs) under four main groups: 1) environmental, 2) socio-cultural, 3) economic, and 4) technological factors. Respondents of the survey were asked to classify the indicators according to their importance. By the participants' responses, four groups were created according to the importance of the indicators such as micro scale indicators, meso scale indicators, macro scale indicators, global scale indicators (Alwaer & Clements-Croome, 2010). After the general survey, AHP (pairwise comparison) was conducted with a 10-point scale to find the relative importance of the indicators. Alwaer and Clements-Croome (2010) formed a five-level decision hierarchy model for the intelligent buildings. Model levels beginning with goals followed by dimensions, categories, indicators and interrelationships between indicators were selected.

Huang (2014) constructed his research with 58 intelligent indicators under three main groups: 1) technology, 2) function and 3) economy. Indicators were derived from the intelligent building literature and trade publications. The number of indicators was increased by the advice of industry experts and practitioners (Huang, 2014). ANP method with 1-9 priority scale was conducted.

Kahraman and Kaya (2014) determined 27 sub attributes and 5 main attributes. The five main attributes were: 1) engineering, 2) environmental, 3) economical, 4) socio cultural, and 5) technological. Fuzzy AHP with Saaty's scale (1-9 point scale) was conducted. Three professors and a top manager in the construction sector evaluated three intelligent building alternatives for a business center project. Kahraman and Kaya (2014) created the hierarchical structure for intelligent building assessment with four levels. The top level was defined as the goal which is intelligent building assessment. The second and third comprise main attributes and sub attributes.

Such effort in above studies should be appreciated but they seem to be hybrid models. They have criteria set that are commonly used in general performance evaluation models. In intelligent building performance evaluation model, more technical aspects and building control system should be included. More technical effort is seen in the below studies.

Arkin and Paciuk (1997) comprise the evaluation according to intelligent building systems regarding systems' integration. Their method offers evaluating the magnitude of systems' integration by an objective index. According to Carlini (1988) and Arkin and Paciuk (1997), there are three levels of system integration in many intelligent buildings top level, middle level and bottom level. Arkin and Paciuk (1997) describe levels as the top level contains intelligent building management system; the middle level contains energy management system, building automation system, communication management system and office automation, which coordinate and control the intelligent building subsystems which constitute the bottom level. The subsystems in the bottom level are lighting system, heating, ventilation and air conditioning (HVAC) system, telecommunication, data processing, fire / smoke sprinkles, vertical transportation. In the study of Arkin and Paciuk (1997), a ten point scale according to the degree of integration is preferred to quantify the systems' integration. 17 existing multi-storey office buildings in Europe, which were selected from the published literature, were evaluated by the magnitude of systems' integration (MSIR). In the evaluation process, the technical information about their service system was taken from the published literature. The evaluation was performed with ten service systems. These were: 1) HVAC, 2) lighting, 3) fire safety, 4) security and access, 5) occupancy, 6) telecommunication, 7) sanitary and plumbing, 8) data processing, 9) transportation, and 10) power.

Wong and Li (2006) developed a specialist model for the assessment of intelligent building. They examined building intelligence among 11 building systems by a questionnaire survey. They indicated 4 main criteria and 76 sub criteria for 11 building systems. According to Wong and Li (2006), the main criteria of an intelligent building are work efficiency, cost effectiveness, environmental and user comfort. Wong and Li (2006) listed intelligent building systems are as in the following;

1. Integrated building management system (IBMS)
2. Energy management system
3. HVAC system
4. Addressable fire detection and alarm system
5. Telecom and data system
6. Security monitoring and access system
7. Smart/energy efficient vertical transportation system

8. Digital addressable lighting control system

9. Hydraulic and drainage system

10. Building facade systems

11. Building layout systems.

Having knowledge and experience in intelligent buildings is the common feature of all participants. Participants were asked to rate the attributes according to their importance. They were also asked whether it is necessary to add new ones. Likert 5-point scale was used for rating and then t-test analysis was used to define the important and most important attributes. The findings revealed that five building systems such as building automation, information and communication network system, fire protection system, HVAC system, safety and security system were more important building systems than electrical installation system, lighting system, hydraulic and drainage system, vertical transportation system, building façade system, building interior layout system were defined. Wong and Li (2006) formed hierarchy system with five levels:

Level 1: Goal – Selection of intelligent buildings

Level 2: Key categories – Primary and secondary building systems

Level 3: Building systems – 11 intelligent building systems were listed

Level 4: Main criteria – Work efficiency, cost effectiveness, environmental and user comfort.

Level 5: Sub criteria – 76 sub criteria were defined.

Out of 11 building systems (Wong & Li, 2006), Wong (2007) used the seven most important building systems in his new research. He aimed to investigate the building intelligence by the questionnaires' results of same respondents in the previous research. As in the previous research, a five-point Likert scale was used. 59 critical selection criteria for seven building systems were extracted from 120 criteria. Then, AHP survey (pairwise comparison) was conducted. The selected 7 building systems were;

1. Integrated building management system (IBMS),
2. Heating, ventilation and air conditioning (HVAC),
3. Addressable fire detection and alarm system,
4. Telecom and data system,
5. Security monitoring and access system,
6. Smart/energy efficient lift system,

7. Digital addressable lighting control system.

In the second part of his thesis (Wong, 2007), generated 102 intelligence indicators for seven intelligent building systems were used. By using a five-point Likert scale, 64 intelligence indicators were extracted from generated indicators. After the general survey, AHP and ANP survey was conducted. As a result of the research, Wong (2007) formed a hierarchy system with three levels. According to Wong (2007), the first level is goal, the second level is intelligent attributes and the third level is intelligence indicators.

Wong and Li (2008) applied the analytical hierarchy process for the selection of intelligent building systems. This study was a follow-up study of Wong and Li (2006) and the data of this research was used. 11 intelligent building systems, four main criteria and 76 sub criteria were listed. In addition to the research in 2006, AHP survey with 9-point scale was conducted. As a result of the research, four level hierarchy system were established. In this research, the authors eliminated one level of hierarchy system in Wong and Li (2006).

Wong et al. (2008b) focused on developing a model for selecting key intelligent indicators among eight intelligent building systems. Wong et al. (2008a) added computerized maintenance management system to the systems mentioned in Wong (2007). 69 key intelligent indicators were identified by using five-point Likert scale. In Part 2, Wong et al. (2008a) conducted ANP survey with nine experts. The pair wise comparisons were completed with nine point priority scale. Wong et al. (2008a) proposed 'system intelligence score (SIS)' for assessment of intelligent buildings. At the end of the research, Wong et al. (2008b) created a hierarchic model with the same levels of the previous research (Wong, 2007).

Moghammad (2012) examined building intelligence among 6 intelligent systems and 85 indicators. Moghammad (2012) created assessment check list to conduct for residential and company buildings. The indicators of the check list were derived from the assessment models of ((AIIB), 2001; Wong & Li, 2006; Wong et al., 2008a, 2008b; Wong & Li, 2008). The study focused on six main intelligent building systems: 1) HVAC system, 2) BAS, 3) Fire alarm system, 4) Security system, 5) Vertical transportation system, and 6) Lighting system.

There are various studies conducted to develop assessment models for intelligent buildings. In most of intelligent building performance evaluation studies, indicators in the research are identified and listed as a result of an extensive review of intelligent building literature and later are expanded with the advice of industry experts and practitioners. A review of literature reveals that in such researches questionnaire survey is the most preferred data collection technique (Alwaer & Clements-Croome, 2010; Wong, 2007; Wong & Li, 2006; Wong et al., 2008a, 2008b; Wong & Li, 2008). Generally, the respondents are asked to rate the indicators through five to ten point scale. In addition to general survey, an AHP / ANP survey with pairwise comparison are performed to prioritize the intelligent indicators. The summary of the developed models are displayed in Table 3.1.

In conclusion, literature review shows that there are studies to identify criteria for intelligent building evaluation or to assess buildings by the comparison of alternative intelligent buildings. Intelligent building designers, architects, sellers of those buildings, managers of construction companies and automation system companies, engineers and developers of building control systems should have more information about the priorities of intelligent buildings according to the expectations of the users, potential buyers, occupants of these buildings. Therefore, there is a need to investigate these priorities. In other words, research in the literature conducted service quality of the intelligent buildings is lacking. In order to fill this gap, both expected service and perceived service of intelligent buildings regarding the technical aspects of the intelligent building systems should be investigated. Hence, the objective of this thesis is to develop a model to measure customers' service quality perception and derived satisfaction about intelligent building systems. With the data and statistical analyses of the thesis, the priorities for the improvement in intelligent building systems according to practical perspective should be evaluated. The findings of the present thesis regarding the perceived service quality are significant in that they could help both designer and managerial implications of intelligent building sector. The results of proposed model in this thesis will provide a feedback to identify the priorities of intelligent buildings to improve the perceived service quality.

Table 3.1.Summary of the previous models.

year	author	selecting attributes/evaluating	evaluation aspects	number of dimensions	number of attributes	scoring method	number of buildings
1997	H.Arkin & M.Paciuk	evaluating	technical	10 building systems	-	10 point	17 buildings
2006	Zhen Chen & Derek Clements-Croome & Ju Hong & Heng Li & Qian X	evaluating	not technical	10 headings	46	9 point	2 buildings
2006	Johnny Wong & Heng Li	selecting attributes	technical	11 building systems	76	5 point	-
2007	Johnny K.W. Wong	selecting attributes	technical	7 building systems	59	5 point	-
2008	Johnny K.W. Wong & Heng Li	selecting attributes	technical	11 building systems	76	9 point	-
2008	Johnny Wong & Heng Li & Jenkin Lai (part 1)	selecting attributes	technical	8 building systems	69	5 point	-
2008	Johnny Wong & Heng Li & Jenkin Lai (part2)	evaluating	technical	8 building systems	69	9 point	2 buildings
2010	H. Alwaer & D.J. Clements-Croome	selecting attributes	not technical	4 headings	57	10 point	-
2012	Maryam Farzin Moghammad	evaluating	technical	6 building systems	85	check list	2 buildings
2014	Zhi-Ye Huang	evaluating	not technical	3 headings	58	9 point	11 buildings
2014	Cengiz Kahraman & İhsan Kaya	evaluating	not technical	5 headings	27	9 point	3 buildings

CHAPTER 4

METHODOLOGY

This thesis aims to measure clients'/occupants' service quality perception and their derived satisfaction from intelligent building control systems. Thus, there are two variables; clients' expectations about intelligent building control systems service quality and the derived satisfaction of clients from these systems. In order to investigate the expectations of clients and the derived satisfaction from intelligent building control systems, two questionnaires are constructed. The first questionnaire aims to explore the importance level of each intelligent building control systems according to the expectations of the occupants and users; and the second questionnaire aims to investigate the performance level of each intelligent building control systems regarding the perceptions of the respondents about these systems.

This chapter explains the methods used to gather and analyze the collected data. It contains five sections. In the first and the second section, measuring service quality is explained and the participants' profiles are given. Then, in the third section of the chapter, data collection tool is defined. In the fourth section, the data collection procedure is explained. Finally, in the fifth section, data analysis methods used in the thesis (i.e., importance-performance analysis and customer gap analysis) are explained.

4.1. Measuring Service Quality

There has been considerable research about service quality for nearly 35 years. This phrase was first developed in 1980's in two major schools: the Scandinavian School and the North American School (Grönroos, 1984; Zeithaml, Parasuraman, & Berry, 1990). The North American School defines service quality as a marketing issue which focuses on people, place, position and promotion, while Swedish researchers define service quality as a building relationship issue with a focus on customers (Williams & Buswell, 2003).

In recent years, it has been commonly agreed that customers of a service evaluate the service quality and it is all about customer's expectations and satisfaction.

Thus, a company or a manager cannot deliver service without paying attention to the customer's expectations because an evaluation of the customers affects his/her future improvements about the service and this evaluation is the result of the relation between the expectations and the received service.

Service quality is the interaction between the company or service provider and customer. Quality is the responsibility of a company and satisfaction is an experience of the customer. The satisfaction is about whether the right quality has been delivered or not. Cronin Jr and Taylor (1992) state that customer satisfaction is formed according to the perceived service quality.

Grönroos (1988) states that "the perceived quality of a service will be the outcome of an evaluation process where consumers compare expectations with the service they perceive they have got". Zeithaml et al. (1990) define service quality as a form of attitude and adds that service quality is about the satisfaction and comparison between expectations and perceptions of service performance. The relationship between expectations and received service is shown in Figure 4.1.

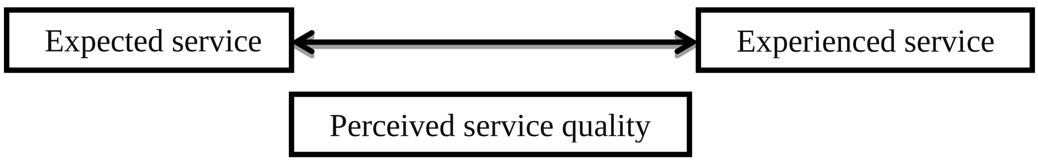


Figure 4.1. Perceived service quality is formed from expected and experienced service quality.

Zeithaml et al. (1990) introduce SERVQUAL (service quality gap model) to measure perceived service quality. SERVQUAL is a gap method in service quality measurement. SERVQUAL measures quality with the difference between the expectation and evaluation of the performance. The result of this comparison gives the level of satisfaction. According to Zeithaml et al. (1990), the model aims to identify the gap between customer expectation and provided services. After identifying the gaps, the objective of the model is to close the gaps by improving the customer service. The dimensions of service quality have two measures: expected service and perceived service. These measures create perceived service quality (Figure 4.2.).

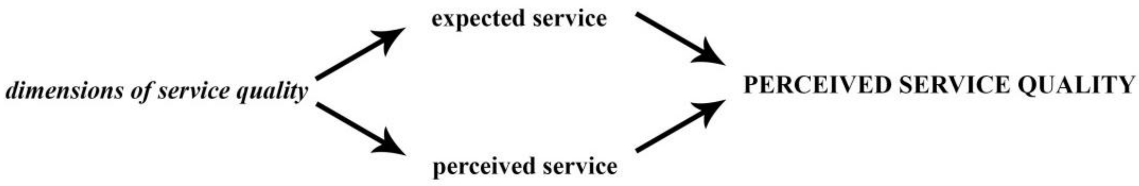


Figure 4.2. Perceived service quality is formed from expected and experienced service quality.

In this thesis, seven intelligent building control systems and 59 attributes are defined as the dimensions of service quality of intelligent buildings. In Figure 4.3., the research model is displayed according to the model of Zeithaml et al. (1990). The attributes of each intelligent building system are shown in Figure 4.4. It can be understood from the model, that all attributes have effect on both the expected and the perceived service.

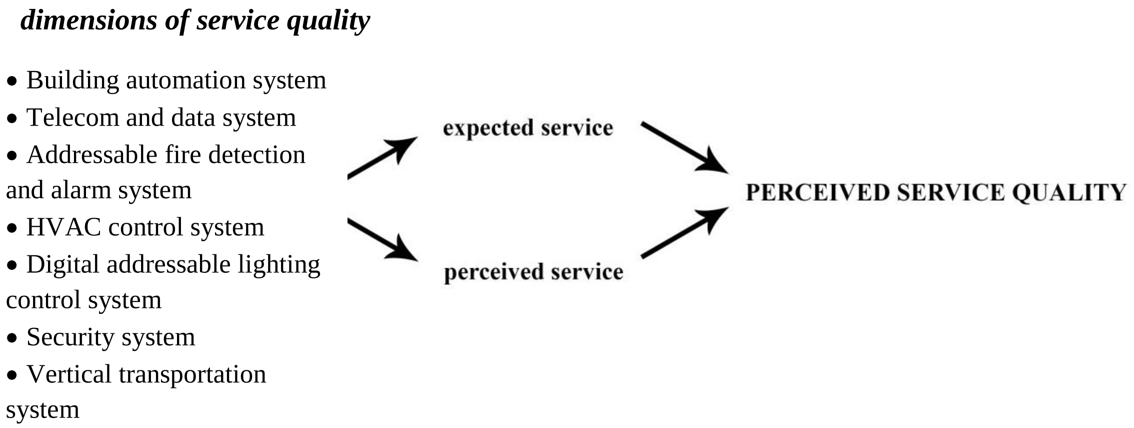


Figure 4.3. Research model for service quality.

F. Y. Chen and Chang (2005) state that in recent years, in some research fields, “expectation” is defined as “importance” because customers have difficulty to define their expectations. On the other hand, importance is easier to define and evaluate. According to Chen and Chang’s statement, in this thesis, the level of importance is measured to assess expected service.

In the following sections, according to the service quality model, the customer gap analysis is conducted to compare the difference between the expected and perceived service and with this basis an importance-performance analysis is conducted, respectively.

System	Dimensions of service quality
Building automation system	• ability of integration • reliability • efficiency (speed) • life cycle cost
Telecom and data system	• transmission rate/speed • reliability • allow for further upgrade • life span (year) • life cycle cost
Addressable fire detection and alarm system	• compliance with fire protection and fighting code • compliance with fire resistance code • automatic sensoring and detection system • signal transmission • life span (year) • allow for further upgrade • life cycle cost
HVAC control system	• total energy consumption • thermal comfort: predict mean value • thermal comfort: indoor air quality • amount of fresh air changes per second • noise level • frequency of breakdown • life span (year) • compatibility with other building systems • integrated with BAS • first cost • life cycle cost
Digital addressable lighting control system	• average efficacy of all lamps • ease of control • permanent artificial lighting average power density • automatic control/adjustment of lux level • life span (year) • allow for further upgrade • compatibility with other building systems • integrated with BAS • life cycle cost
Security system	• time needed for public anouncement of disasters • time needed to report a disastrous event to the building management • time for total agress • life span (year) • allow for further upgrade • compatibility with other building systems • integrated with BAS • first cost • life cycle cost
Vertical transportation system	• energy consumption • acceleration and deceleration • air change • noise level • vibration level • maximum interval time • journey time • waiting time • automatic and remote monitoring • life span (year) • compatibility with other building systems • integrated with BAS • reliability (mean time between failure) • life cycle cost

Figure 4.4. The dimensions of service quality of intelligent building control systems.

4.2. Survey Participants

The thesis aims to measure the service quality of intelligent building control systems among the clients' expectation and satisfaction. Thus, the clients of intelligent building control systems are defined as the participants of the thesis. In this thesis, people who are visitors, users, occupants, architects, engineers and automation system providers of intelligent buildings having experience with intelligent building control systems are referred as the client.

Requests for online survey participation were sent to 75 people who were asked to respond to the questionnaires. Responses sent from 65 of them, which constitutes 87% completion rate. For preparing the data for the analysis, the gathered data was processed. The data processing is the control of missing, irregular and extreme values for preparing the data for the analysis (Jensen & Knudsen, 2006).

In data processing, eight missing values from the questionnaires were detected. Six of them were dropped out within three questions which means the respondents answered a few of the initial questions and then did not answer the others. Thus, those were excluded from the dataset. After eliminating the six surveys, the remaining two surveys were re-evaluated. For such situation, Bryman and Cramer (2005) state that mean substitution can be applied to handle the missing values. Mean substitution is a technique for missing values, which replaces them with the mean answer. The mean substitution does not affect the final results of the analysis (Bryman & Cramer, 2005). Additionally, there were four answers which have the same values for all attributes in the dataset. Such answers are not reliable for the analysis, so these answers were also excluded from the dataset.

Table 4.1. The number of complete questionnaires.

	Entire Data		Data for Small Scale Buildings		Data for Large Scale Buildings	
	Importance Questionnaire	Performance Questionnaire	Importance Questionnaire	Performance Questionnaire	Importance Questionnaire	Performance Questionnaire
Data Type 1	53	30	30	13	23	17
Data Type 2	26	26	13	13	13	13

4.2.1. Participants for Data Type 1

At the end of the data processing, 53 valid responses for importance questionnaire and 30 valid responses for performance questionnaire were determined. These valid answers constitute Data Type 1 (Table 4.1.).

For Data Type 1, the distribution of the number of respondents in importance questionnaire is shown in Figure 4.5 and the distribution of the number of respondents in performance questionnaire is shown in Figure 4.6. The occupants represent 39,62% of the respondents in importance questionnaire; whereas the occupants represent 40,00% of all respondents in performance questionnaire. The architects represent 35,84% of the respondents in importance questionnaire and they represent 30,00% of the respondents in performance questionnaire. 11,32% of the respondents of importance questionnaire and 16,66% of the respondents of performance questionnaire are engineers. The rest of the respondents of the importance questionnaire consists of automation experts (9,43%), users (11,32%) and others (15,09%). In the performance questionnaire, the rest of the respondents consists of automation experts (10,00%), users (13,33%) and others (20,00%). This reveals that the distribution proportions of the respondents in both questionnaires are approximately the same. The total of the percentages is above 100% because the identification question has not restricted response scale, where the respondents are free to select more than one answer, if they have more than one identification for example they are allowed to select both the architect and the occupant of the building.

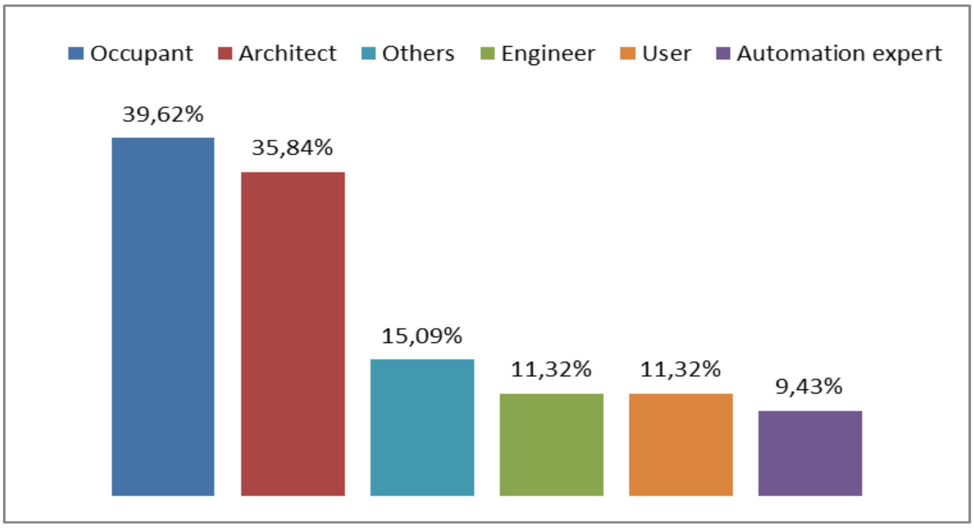


Figure 4.5. The distribution of the respondents in importance questionnaire in Data Type 1.

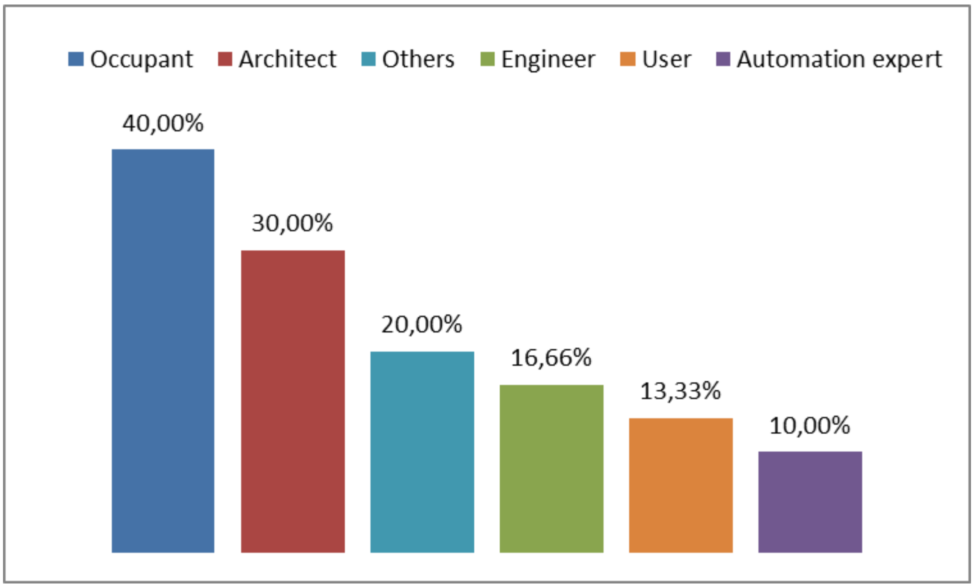


Figure 4.6. The distribution of the respondents in performance questionnaire in Data Type 1.

With regard to the building scales, the Data set 1 is divided into two groups. The building types are grouped according to the building scales: small scale buildings and large scale buildings. According to this grouping, villas, apartments and residences are included in the small scale buildings. Large scale buildings cover business centers, shopping malls, airports, hospitals and factories. The number of respondents is distributed between small scale buildings and large scale buildings (Table 4.1.). The responses for small scale buildings represent 56,60% of the all importance questionnaires while 43,40% of the responses are importance assessment for large scale buildings. The responses for small scale buildings represent 43.33% of the all performance questionnaires while 56.67% of the responses show performance assessment for large scale buildings.

4.2.2. Participants for Data Type 2

The statistical analysis such as the gap assessment and Importance-Performance analysis, which are conducted to the data in the thesis, involve the comparison of the means. Analyzing the difference between the means is defined as t-tests in the literature (Blumberg, Cooper, & Schindler, 2005; Jensen & Knudsen, 2006). Hence, the gap assessment and Importance-Performance Analysis are examples of the paired-sample t-test. Bryman and Cramer (2005) indicate that mean values from the questionnaires could be compared if they contain the data which come from the same population. As a result, the answers are matched up and paired valid responses from both importance and performance questionnaires constitute the Data Type 2. After matching up the completed and valid questionnaires from both importance and performance questionnaires, 26 paired questionnaires constitute Data Type 2 (Table 4.2.).

In Data Type 2, there are 26 valid completed questionnaires. 34,62% and 26,92% of the questionnaires are answered by the occupants and the users, respectively. 19,23% of the responses represent architects and 15,38% of the responses represents engineers. The rest of the responses belongs to the automation experts (11,54%) and others (7,69%). The distribution of the respondents in Data Type 2 is illustrated in Figure 4.7.

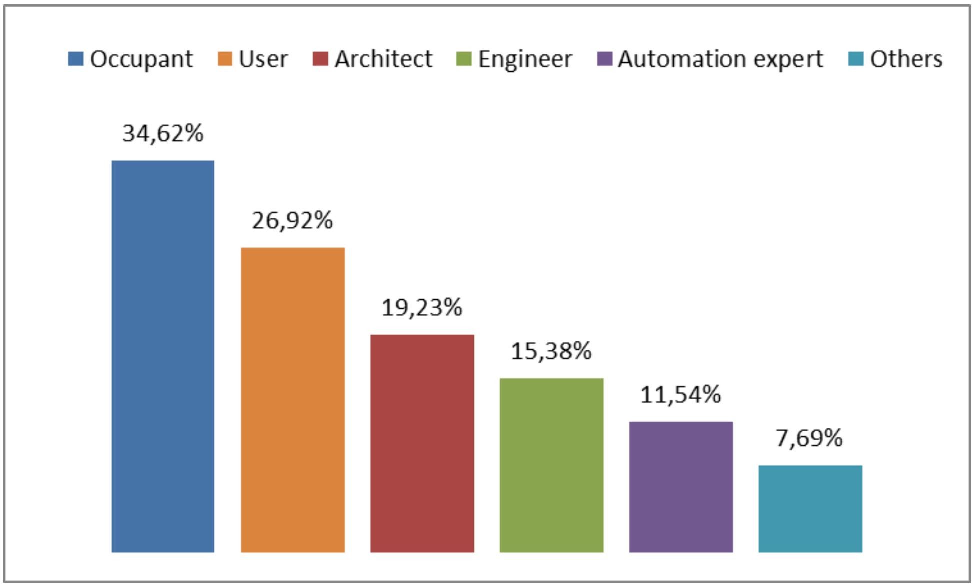


Figure 4.7. The distribution of the respondents in Data Type 2.

4.3. Data Collection Tool

Questionnaire is used to gather data as the data collection tool. There are two questionnaires: importance (expected service) questionnaire and performance (experienced service) questionnaire. The primary objective of the questionnaires is to measure the expectations and perceptions of the participants about intelligent building automation systems. The purpose of the questionnaires is to identify the priorities for improvement of the intelligent building systems and which creates a satisfactory intelligent building experience.

Importance questionnaire aims to evaluate the expectations of the participants and to measure importance level of each control system according to the expected service quality of intelligent building control systems. The questionnaire has two parts. The first part consists of two questions. It aims to get demographic information about the participants and the buildings. In the second part of the questionnaire, there are seven questions which aim to gather information about each attribute of the each intelligent building control system investigated. Each question refers to one intelligent control system. In other words, each system has one corresponding question. This part covers totally 59 attributes about seven intelligent building control systems. In this part, the respondents are asked to define the degree of importance of each attributes of these seven intelligent building control systems.

The first question in regard to demographic information is asked to identify each respondent according to the relation of his/her with the intelligent building. The second question is asked to identify the building scale. The objective of the two questions of demographic information is to segregate the different respondents and their evaluations. This segmentation helps to assess the intelligent building control systems according to the building scales. The questions aim to find out the differences in service qualities of different building scales.

The performance questionnaire aims to evaluate perceptions of the participants and to measure performance level of the control systems among the perceived service quality of control systems. The performance questionnaire is similar to the importance questionnaire. As in the importance questionnaire, the first part consists of questions to get demographic information. The second part aims to measure the perceptions of the participants with regard to their previous experiences. In this part, the respondents are asked to answer the questions according to their perceptions. The attributes and the number of the questions are the same with the importance questionnaire.

The attributes of the intelligent building systems have been defined by Wong (2007) and are used in this study. Each system has different number of attributes to evaluate. The number of the attributes of each system is shown in Table 4.2.

Table 4.2. Number of attributes in each control system.

Name of the System	Number of Attributes
Building Automation System (BAS)	4
Telecom and Data System	5
Addressable Fire Detection and Alarm System	7
HVAC Control System	11
Digital Addressable Lighting Control System	9
Security System	9
Vertical Transportation System	14

With the purpose of examining whether the attributes are comprehensible or not to customers who are not expert of intelligent building control systems, piloting is conducted with seven persons who live in an intelligent building or some ordinary people who have an idea about intelligent building control systems. Pilot test is conducted to identify possible misunderstandings, misinterpretations and functional errors of the questionnaire. Pilot test is important to find the weaknesses in the design of the questionnaire and the scaling method. In addition, during piloting, the visual layout is tested. In other words, whether the questions are comprehensible or not is evaluated. The piloting is vital to create the final version of the questionnaire which measures both intelligent building system service quality and customer satisfaction.

After the pilot tests, the layout, order of the questions and the scaling technique are found appropriate. However, some misspellings, punctuation corrections, interpretation errors are detected. Some of the attributes are rephrased according to the comments from the pilot tests. The final questionnaires are presented in Appendix A.

4.4. Data Collection Procedure

In this study, two web surveys are used. By the aim of reaching more participants, online fill-out forms are utilized. The questionnaires are conducted in Turkish.

The questionnaires are e-mailed to the participants. In the e-mails, the respondents are informed about the aim of the questionnaire and general information about the questionnaires is given. In the given information, the participants are asked to answer the questionnaire about the expected service quality (importance degree) and then, if they have a prior experience about the intelligent building control systems, they are asked to answer the second questionnaire about the perceived service quality (performance degree). For the evaluation of the performance degree, prior experience is required. There is no constraint for the respondents of the importance questionnaire. Every participant can complete the importance questionnaire according to his/her expectations from intelligent building control systems. This requirement leads to a difference in the number of completed importance questionnaire and performance questionnaire in Data Type 1.

The participants are asked to evaluate all the attributes on a Likert-scale ranging from 1 to 7. In importance questionnaire, 1 represents that the attribute is extremely unimportant, 2 represents moderately dissatisfied, 3 represents slightly important, 4 represents neither important nor unimportant, 5 represents slightly important, 6 represents moderately important and 7 represents extremely important. In performance questionnaire, 1 refers to extremely dissatisfied, 2 refers to moderately dissatisfied, 3 refers to slightly dissatisfied, 4 refers to neither satisfied nor satisfied, 5 refers to slightly satisfied, 6 refers to moderately satisfied and 7 refers to extremely satisfied. In addition to this scale, “do not know” and “the system is not included in this building” answers are added to ignore wrong assessments. The Likert-scale is chosen for all questions that concern service quality dimensions except the demographic information questions. For demographic information questions, Multiple-Choice-Response has been applied.

4.5. Data Analysis Procedure

The data from the both importance and performance questionnaire are used to answer the research questions. Data Analysis procedure in this thesis constitutes three phases. In order to answer research question 1, the importance mean values and performance mean values of each system are calculated. To answer research question 2, customer gap analysis is conducted. Finally, Importance-Performance Analysis was conducted to answer the research question 3.

4.5.1. Evaluation of the Means

The importance mean values and performance mean values of each system are calculated to determine the assessments of the participants in regard to the expected and perceived service quality in both Data Type 1 and Data Type 2.

Intelligent building control systems are ranked according to the importance mean values. The mean values come from the expected service (importance) questionnaire indicates the effect of each control system on perceived service quality of intelligent buildings. By this rank, the effect of each control system on perceived service quality is illustrated. The mean values come from the experienced service (performance) questionnaire helps to rank the control systems and to identify the most and the least satisfying control systems.

The calculated mean values create the basis of the following analysis. The mean values are used in customer gap analysis and Importance-Performance Analysis.

4.5.2. Customer Gap Analysis (GAPA)

The customer gap defines the gap between customer expectation and customer perceptions (Zeithaml et al., 1990). The expectation is subjective and influenced by various factors such as cultural background, family lifestyle, demographics and personality. The perception is formed by the quality of delivered service. The customer gap is vital for the companies that have customer oriented strategy and closing the gap must be the first and the most important goal of a company. Closing the gap could be achieved by improving the customer service. For this objective, the customer needs and expectations must be known by the company. In order to identify the customer gaps in intelligent building control system, the customer gap analysis is conducted.

According to the participants' responses, the gaps between the expected and the perceived service quality are measured. The customer gap analysis is conducted to the both Data Type 1 and Data Type 2. In order to find out how the gaps differ in different scales of the intelligent buildings, customer gap analysis is conducted for small scale and large scale buildings.

The evaluated gaps show us the balance of expected service quality and satisfaction of the customers. The findings of customer gap analysis help managers, architects, automation system suppliers, real estate agents and owners of the intelligent buildings to understand the expected attributes and the satisfaction of people in relation to these attributes. The Importance-Performance analysis can be seen as an extension of the gap analysis. In Importance-Performance analysis, the service quality attributes are allocated in a prioritization map. The Importance-Performance analysis is conducted to define the priorities from the management perspective.

4.5.3. Importance-Performance Analysis (IPA)

In order to answer research question 3, Importance-Performance Analysis is conducted. Importance-Performance Analysis is performed to find out the priorities for future improvement in intelligent building control systems according to practical perspective. The findings of importance performance analysis help the companies in managerial implications. In this section, related literature, the concept of IPA, application areas and the components of IPA are explained in detail.

4.5.3.1. IPA concept

The IPA technique is a basic diagnostic tool which has gained widespread acceptance in many fields of research. The tool is used to understand the customer satisfaction and set priorities about the service quality improvements by importance and performance measurement. The results from IPA, facilitate to enhance strategic planning (Matzler, Bailom, Hinterhuber, Renzl, & Pichler, 2004). In addition, Magal, Kosalge, and Levenburg (2009) state that IPA makes it easier to decide how to use the scarce resources. Oh (2001) states that IPA is used for understanding the role of the key attributes for deciding marketing and management strategy.

IPA emphasizes both importance and performance of the various product or service attributes. Silva and Fernandes (2010) state that IPA analyzes not only the performance of an item, but also the importance of that item according to the satisfaction of the respondents. In other words, IPA answers two questions; 'How important is a certain product or service attribute to customers?' and 'How satisfied are the customers with the performance of attributes?'. Azzopardi and Nash (2013) define importance as "the perceived worth/value of attributes of purchasing experience" and performance as "the perceived state of the attributes of the consumptive experience". Both importance and performance are combined measures and they identify better marketing and management insights (Guadagnolo, 1985; Martilla & James, 1977). Guadagnolo (1985) suggests that IPA is a tool which assesses the customer's satisfaction, while Martilla and James (1977) state that the difference between importance and performance values is an indicator of the customer's dissatisfaction.

Importance and performance analysis was first formulated and introduced by Martilla and James (1977). The authors tried the technique via a simple study about an automobile service. The purpose of the study was to improve service department profits and to increase sales of the new vehicles. In other words, Martilla and James (1977) introduced the technique to measure customer satisfaction. The attributes, affecting service department patronage, were defined from the literature and the conversations with the service and sales employees. By a questionnaire survey using a scale rating, they assessed the importance and performance value of each attributes. Due to extend Martilla and James's original framework, several researchers have tried to add more information to the original method (Dolinsky, 1991; Vaske, Beaman, Stanley, & Grenier, 1996).

IPA is an easy and useful research technique to identify strengths and weaknesses of the services and to develop strategies to become more successful. With its being easy to use, it is possible to apply in different fields, IPA is used in various fields of research such as transportation, (Feng and Jeng, 2005; Huang et al., 2006), banking (Joseph et al., 2005), education (Pike, 2004 ; Alberty and Mihalik, 1989; Siniscalchi et al., 2008), healthcare (Hawes and Rao, 1985 ; Dolinsky, 1991 and Miranda et al., 2010), public management (Riviezzo et al., 2009; Lai and To, 2010), tourism (Zhang and Chow, 2004; Fuchs and Weiermair, 2003; Smith and Carol, 2009; Ziegler et al., 2012), industry (Sampson and Showalter, 1999), telecommunication (Pezeshki et al., 2009), airport and airline services (Mikulić and Prebežac, 2008 and Mikulić and Prebežac, 2011b), supermarket retailing (Vázquez, Rodríguez-Del Bosque, Díaz, & Ruiz, 2001), e-government (Wong et al., 2011) and leisure (Tarrant and Smith, 2002; Rial et al., 2008).

The results of importance and performance analysis are shown on an easily interpreted and two dimensional grid. The x-axis is the horizontal axis of the plot and represents performance. The y-axis is the vertical axis and represents importance. The graph consists of four zones. Each area is the combination of the importance and the performance defined by the respondents (Table 4.3.). The presentation of the results on the grid system provides opportunity to interpret the data in an easy way and to make strategic decisions about the services and company (Martilla & James, 1977). In addition, managers can easily decide which attribute has the most and the least priority for the improvement by the help of the graph (Charaf & Bescos, 2013). Each zone gives a different message and suggests a strategy for managers (Figure 4.8.).

Table 4.3.The traditional Importance-Performance Matrix.
(Adapted from Azzopardi & Nash, 2012, p. 224)

Importance/Performance level of attribute	Low performance	High performance
High importance	Quadrant A Concentrate here (Increase resources)	Quadrant B Keep up the good work (Sustain resources)
Low importance	Quadrant C Low priority (No change in resources)	Quadrant D Potential overkill (Curtail resources)

The four zones in Importance-Performance grid are (1) concentrate here, (2) keep up the good work, (3) low priority and (4) possible overkill (Martilla & James, 1977). Similarly in the present thesis, Martilla and James's categorization is applied. Martilla and James (1977) explain the messages of each grid as below;

Quadrant A "Concentrate here": The attributes in that zone have low performance and high importance; thus, an increase in resources is required.

Quadrant B "Keep up the good work": The attributes in that zone have high performance and high importance; the managers of the company could sustain the resources as it is.

Quadrant C "Low priority": The attributes in that zone have low performance and low importance; no change in resources is needed.

Quadrant D "Possible overkill": The attributes in that zone have high performance and low importance; the managers of the company should curtail the resources.

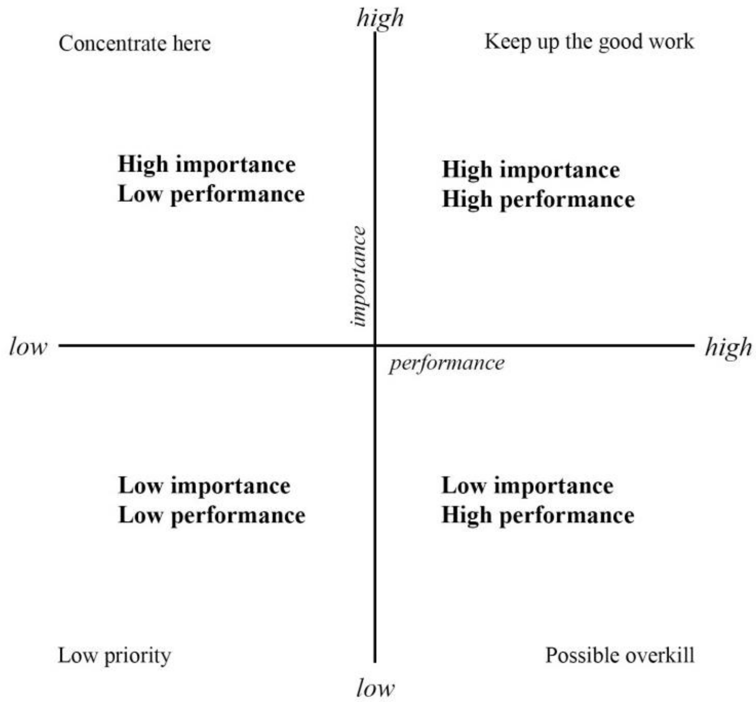


Figure 4.8. Importance-Performance Matrix.
(Adapted from Martilla & James, 1977, p. 78)

4.5.3.2. Importance-Performance Analysis Methods

In the literature, there are several approaches to define the priorities and to measure the importance. The important point is to determine the best alternative technique which represents customer preferences and choices. The variations are discussed in this section.

The data-centered, scale-centered, and diagonal methods are the most commonly used approaches in the IPA literature. Quadrant analysis is the most common method for service improvement in literature. The details of each approach are discussed here.

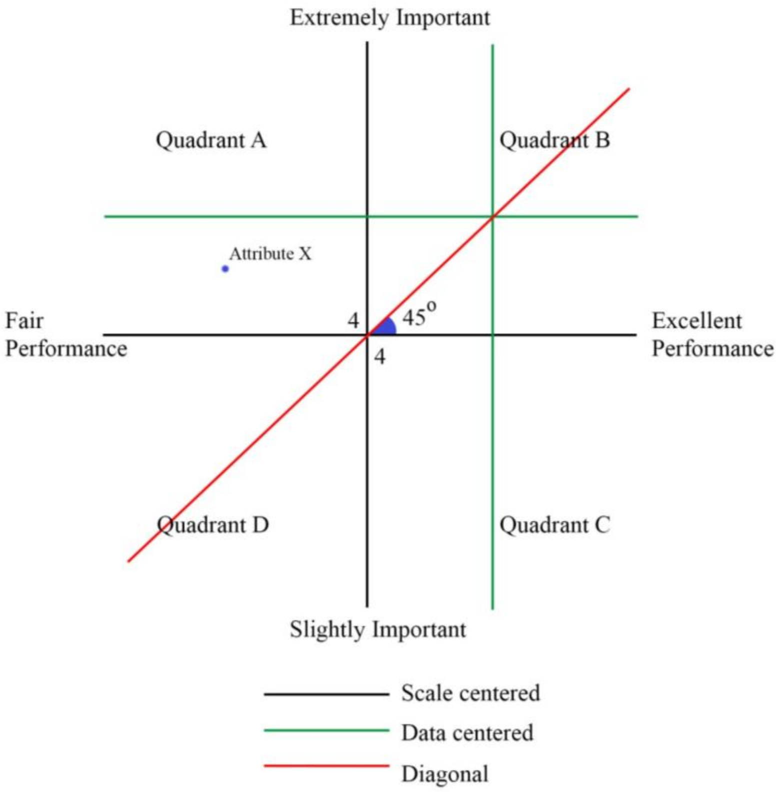


Figure 4.9. Quadrant partitions of Importance-Performance Analysis.

The partitions and categories in the grid are established by the x axis and y axis. So, the positioning of them differs the categories that each attributes fall in. The junction of x and y axis is defined as crosshair points. Actual or scale means can be used as crosshair points of importance-performance grid. Oh (2001) states that alternative scaling of the axes means different categorization of attributes and as a result, it leads to different interpretation of results. In other words, alternative determinations of crosshair points allocate the attributes in different quadrants. The cross-hair point is determined by the researcher. Martilla and James (1977) define this subjectivity of the selecting the place of the axes as “a matter of judgement”.

The alternative approaches are illustrated in Figure 4.9. Black lines refer to the axes of scale centered approach. In scale centered approach, the cross-hair point is defined by the mean values of the established scale such as 4 in a 7 point Likert scale. The crosshair point is where the importance and performance are both equal to 4.

Green lines in the figure refer to the axes of data centered approach. In data-centered approach, the cross-hair point is defined by the mean values of observed importance-performance ratings.

For example, if the scale centered is used to position the axes, Attribute X falls in quadrant A, but if data centered approach is used, it falls in quadrant D. The places of the attributes change according to the selected approach. The approach should be selected according to the gathered data and the aim of the research.

The quadrant approach divides the importance-performance grid into four categories and groups the attributes into the categories. Tarrant and Smith (2002) state that the quadrant approach cannot distinguish the attributes placed in the same region. They support their statement with an example, and state that some points can be too close to the intersection of all the quadrants or overlap either of the two axes (Tarrant & Smith, 2002). For example, if the axis is set at 4 and the attribute has a value of 4.1, the attribute could not be interpreted with confidence. Tarrant and Smith (2002) state that the problem becomes worse with smaller sample size less than 400. Bacon (2003) and Eskildsen and Kristensen (2006) support that statement and suggest that small change in the place of an attributes causes big and significant changes in the results of the research about the priority. In order to predict consumptive behavior, the Importance-Performance Analysis should be supported by the gap analysis (Ford, Joseph, & Joseph, 1999; Sethna, 1982). According to Sethna (1982), the difference between importance and performance is referred as ‘importance-performance error’.

The diagonal line approach offers a more continuous transition in the inferred priorities (Bacon, 2003; Eskildsen & Kristensen, 2006). In a diagonal approach, the grid is divided by sloping 45^0 line. The points above an upward of the diagonal line show high priorities for improvement and opportunity because the attributes in that place mean their importance exceed their performance (I>P) and points below the diagonal line represent the opposite situation (I<P). The diagonal line can be called as ‘iso-priority line’ because all point on the diagonal line has the same priority for improvement (I=P).

CHAPTER 5

RESULTS AND DISCUSSION

This chapter presents the application of a service quality model, which measures the degree of service quality of intelligent building automation systems with respect to the expectations and satisfactions of their occupants, users and designers.

The chapter consists of four sections. In the first section, the related measures of the service quality attributes and expectations of the respondents are listed. In the second and third sections respectively, the gap analysis and Importance-Performance Analysis results are presented. The gap analysis is conducted to evaluate the gap between the expected and the perceived service measurements. The gap analysis and Importance-Performance Analysis are conducted for the entire intelligent building automation systems market and for different building types to outline the differences and similarities depending on the satisfaction and expectations of the occupants for various types of buildings. Finally, the discussion of the results is presented in the fourth section.

5.1. Evaluation of the Means

This thesis concerns the evaluation of the intelligent building control systems service quality. For this concern, the expected and the perceived service level of the attributes of intelligent building automation systems are evaluated. The analysis of the dataset starts with the calculation of the mean values of the answers. The mean values show the attributes which have greater importance than the other attributes. By the mean values, the satisfaction of the respondents is identified. After the calculation of the mean values, standard deviation (s.d.) is calculated. According to Blumberg et al (2005) the standard deviation represents the average distance between the respective values and the consolidated mean and it is calculated by the following equation:

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2} \qquad (5.1)$$

In this equation, $\{x_1, x_2, ..., x_N\}$ are the observed values of the sample and $\overline{x}$ is the mean value of these observations. N represents the size of the sample. Standard deviation helps the researcher to realize significant variations. In other words, standard deviation shows whether the values are realistic or not.

5.1.1. Evaluation of the Means of Data Type 1

The respective mean values and standard deviation values of each system according to the responses of the questionnaires for Data Type 1 are illustrated in Table 5.1. In Table 5.2., the rank of the intelligent building control systems according to the importance mean values is represented. The rank of the intelligent building control systems according to the performance mean values is represented in Table 5.3.

Table 5.1. Respective mean values and standard deviation values of Data Type 1.

INTELLIGENT BUILDING CONTROL SYSTEM	importance (expected service)			performance (perceived service)		
	rank	mean	s.d.	rank	mean	s.d.
Building Automation System	1	6,17	0,62	7	5,22	1,42
Telecom and Data System	4	5,95	0,76	2	5,53	0,87
Addressable Fire Detection and Alarm System	3	6,00	0,87	1	5,57	1,29
HVAC Control System	5	5,95	0,70	5	5,34	1,11
Digital Addressable Lighting Control System	6	5,81	0,69	4	5,36	1,05
Security System	2	6,04	0,75	3	5,44	1,11
Vertical Transportation System	7	5,57	0,84	6	5,24	1,13
AVERAGE MEAN VALUE		5,93	0,75		5,39	1,14

The respondents rated all the attributes above the median of the response scale (4) which is a 7-point Likert scale. Importance mean values differ from 5,57 to 6,17. The average of the mean values is 5,93.

Table 5.2. Ranking of the intelligent building control systems according to the importance mean values of Data Type 1.

INTELLIGENT BUILDING CONTROL SYSTEM	RANK	MEAN
Building Automation System	1	6,17
Security System	2	6,04
Addressable Fire Detection and Alarm System	3	6,00
Telecom and Data System	4, 5	5,95
HVAC Control System	4, 5	5,95
Digital Addressable Lighting Control System	6	5,81
Vertical Transportation System	7	5,57

Table 5.3. Ranking of the intelligent building control systems according to the performance mean values of Data Type 1.

INTELLIGENT BUILDING CONTROL SYSTEM	RANK	MEAN
Addressable Fire Detection and Alarm System	1	5,57
Telecom and Data System	2	5,53
Security System	3	5,44
Digital Addressable Lighting Control System	4	5,36
HVAC Control System	5	5,34
Vertical Transportation System	6	5,24
Building Automation System	7	5,22

The attributes 'building automation system', 'security system', 'addressable fire detection and alarm system' are considered as the three most important service quality systems, respectively (Table 5.2.). The other control systems are considered as less important drivers of a satisfactory intelligent building experience. ‘Telecom and data system’ and ‘HVAC control system’ are considered to be relatively less important for the respondents. According to the mean values, the two least important attributes are the ‘digital addressable lighting control system’ and the ‘vertical transportation system’. The standard deviations of the importance attributes range from 0,62 to 0,87, and the calculated average is 0,75. The highest standard deviation belongs to the importance value of ‘addressable fire detection and alarm system’ with the value of 0,87. The value is considered as reasonable and representative. The standard deviation of ‘building automation system’ is the highest among the standard deviations of the performance responses with the value of 1,42. The findings emphasize that the values are reliable.

The respondents show their satisfaction with the perceived service mean value of 5,39 (Table 5.1.). The average mean value of the perceived service (5,39) is lower than the average mean value of the expected service (5,93). It can be said that the respondents expect more than they perceive. ‘Addressable fire detection and alarm system’ and ‘telecom and data system’ are perceived as the two most satisfactory attributes in intelligent buildings, respectively. ‘Security system’ is considered to be relatively less satisfactory attribute for the respondents. ‘HVAC control system’ and ‘digital addressable lighting control system’ are perceived as minor satisfactory attributes. Lastly, ‘vertical transportation system’ and ‘building automation system’ are considered as the least satisfactory attributes of intelligent buildings.

Both ‘addressable fire detection and alarm system’ and ‘security system’ are considered to be two of the three most important attributes and at the same time, they are perceived to be two of the three most satisfactory attributes (Table 5.4.). ‘Vertical transportation system’ is considered to be the least important control system in intelligent building and it has been perceived as one of the least satisfactory control systems. ‘Building automation system’ is considered as the most important factor in intelligent buildings. However, it is perceived as the least satisfied attribute of intelligent buildings according to the respondents. According to this finding, the managers, architects and automation experts should work to increase the satisfaction level of this system and the future improvements in the system should be prioritized.

Table 5.4. Ranking of the intelligent building control systems according to the mean values of Data Type 1.

RANK	according to importance mean values	according to performance mean values
1	Building Automation System	Addressable Fire Detection and Alarm System
2	Security System	Telecom and Data System
3	Addressable Fire Detection and Alarm System	Security System
4	Telecom and Data System	Digital Addressable Lighting Control System
5	HVAC Control System	HVAC Control System
6	Digital Addressable Lighting Control System	Vertical Transportation System
7	Vertical Transportation System	Building Automation System

As in the overall evaluation of the attributes in Data Type 1, the mean values and standard deviations of both expected and perceived service in small and large scale buildings are calculated. The mean and standard deviation of small scale buildings in Data Type 1 are illustrated in Table 5.5 and the mean and standard deviation of large scale buildings in Data Type 1 are illustrated in Table 5.9.

The importance mean values in small scale buildings of Data Type 1 differ from 5,44 to 6,12. The average of the mean values is 5,87. The standard deviations of the importance attributes range from 0,64 to 0,94, and calculated average is 0,78. The standard deviations of the performance attributes range from 0,64 to 1,20 with the average value of 0,96.

According to the Data Type 1, in small scale intelligent buildings, the attributes of ‘building automation system’, ‘security system’, ‘HVAC control system’ are considered as the three most important service quality systems, respectively (Table 5.6). ‘Telecom and data system’ and ‘addressable fire detection and alarm system’ are considered to have relatively minor importance for the respondents. According to the mean values, ‘digital addressable lighting control system’ and ‘vertical transportation system’ are perceived to be the two least important control systems in small scale intelligent buildings.

Table 5.5. The mean and standard deviation values of small scale buildings in Data Type 1.

INTELLIGENT BUILDING CONTROL SYSTEM	importance (expected service)			performance (perceived service)		
	rank	mean	s.d.	rank	mean	s.d.
Building Automation System	1	6,12	0,64	6	4,87	1,20
Telecom and Data System	5	5,89	0,79	2	5,32	0,64
Addressable Fire Detection and Alarm System	4	5,92	0,94	1	5,40	0,80
HVAC Control System	3	5,97	0,74	7	4,76	1,15
Digital Addressable Lighting Control System	6	5,72	0,79	3	5,14	0,89
Security System	2	6,02	0,72	5	5,07	0,97
Vertical Transportation System	7	5,44	0,83	4	5,12	1,10
AVERAGE MEAN VALUE		5,87	0,78		5,10	0,96

Table 5.6. Ranking of the intelligent building control systems according to the importance mean values of small scale buildings in Data Type 1.

INTELLIGENT BUILDING CONTROL SYSTEM	RANK	MEAN
Building Automation System	1	6,12
Security System	2	6,02
HVAC Control System	3	5,97
Addressable Fire Detection and Alarm System	4	5,92
Telecom and Data System	5	5,89
Digital Addressable Lighting Control System	6	5,72
Vertical Transportation System	7	5,44

Table 5.7. Ranking of the intelligent building control systems according to the performance mean values of small scale buildings in Data Type 1.

INTELLIGENT BUILDING CONTROL SYSTEM	RANK	MEAN
Addressable Fire Detection and Alarm System	1	5,40
Telecom and Data System	2	5,32
Digital Addressable Lighting Control System	3	5,14
Vertical Transportation System	4	5,12
Security System	5	5,07
Building Automation System	6	4,87
HVAC Control System	7	4,76

Performance mean values in small scale buildings of Data Type 1 differ in the range from 4,76 to 5,40. The respondents show their satisfaction with the average perceived service mean value of 5,10 (Table 5.5.). ‘Addressable fire detection and alarm system’ and ‘telecom and data system’ are perceived as the most satisfactory attributes in intelligent buildings, respectively. ‘Digital addressable lighting control system’, ‘vertical transportation system’ and ‘security system’ are perceived as the fourth, fifth and sixth satisfactory attributes. Lastly, ‘building automation system’ and ‘HVAC control system’ are considered as the least satisfactory attributes of small scale intelligent buildings, respectively.

‘Building automation system’ and ‘HVAC control system’ are considered as the two of the three most important factors in small scale intelligent buildings. However, they are perceived as the least satisfied attributes of small scale intelligent buildings according to the respondents’ responses. ‘Digital addressable lighting control system is perceived to be one of the least important factors, on the other hand, it is perceived to be one of the most satisfactory control systems in small scale intelligent buildings. According to these findings, the managers, architects and automation experts should change their priorities and make a decision for the efficient use of resources.

Table 5.8. Ranking of the intelligent building control systems according to the mean values of small scale buildings in Data Type 1.

RANK	according to importance mean values	according to performance mean values
1	Building Automation System	Addressable Fire Detection and Alarm System
2	Security System	Telecom and Data System
3	HVAC Control System	Digital Addressable Lighting Control System
4	Addressable Fire Detection and Alarm System	Vertical Transportation System
5	Telecom and Data System	Security System
6	Digital Addressable Lighting Control System	Building Automation System
7	Vertical Transportation System	HVAC Control System

Importance mean values in large scale buildings of Data Type 1 differ from 5,74 to 6,24 (Table 5.9.). The average of the mean values is 6,00. The standard deviations of the importance attributes range from 0,55 to 0,84, and calculated average is 0,71. The standard deviations of the performance attributes range from 0,91 to 1,56 with the average value of 1,23.

According to the Data Type 1, in large scale intelligent buildings, the attributes of 'building automation system', 'addressable fire detection and alarm system' and 'security system' are considered by the respondents as the three most important service quality systems, respectively (Table 5.10.). 'Telecom and data system' and 'HVAC control system' are considered to be the fourth and fifth important control systems in large scale intelligent buildings for the respondents. According to the mean values, 'digital addressable lighting control system' and 'vertical transportation system' are perceived to be the two least important control systems in small scale intelligent buildings.

Table 5.9. The mean and standard deviation values of large scale buildings in Data Type 1.

INTELLIGENT BUILDING CONTROL SYSTEM	importance (expected service)			performance (perceived service)		
	rank	mean	s.d.	rank	mean	s.d.
Building Automation System	1	6,24	0,61	5	5,52	1,56
Telecom and Data System	4	6,02	0,73	4	5,67	0,98
Addressable Fire Detection and Alarm System	2	6,10	0,79	3	5,72	1,62
HVAC Control System	5	5,93	0,65	2	5,75	0,91
Digital Addressable Lighting Control System	6	5,91	0,55	6	5,52	1,17
Security System	3	6,06	0,80	1	5,79	1,16
Vertical Transportation System	7	5,74	0,84	7	5,31	1,18
AVERAGE MEAN VALUE		6,00	0,71		5,61	1,23

Table 5.10. Ranking of the intelligent building control systems according to the importance mean values of large scale buildings in Data Type 1.

RANK	INTELLIGENT BUILDING CONTROL SYSTEM	MEAN
1	Building Automation System	6,24
2	Addressable Fire Detection and Alarm System	6,10
3	Security System	6,06
4	Telecom and Data System	6,02
5	HVAC Control System	5,93
6	Digital Addressable Lighting Control System	5,91
7	Vertical Transportation System	5,74

Table 5.11. Ranking of the intelligent building control systems according to the performance mean values of large scale buildings in Data Type 1.

RANK	INTELLIGENT BUILDING CONTROL SYSTEM	MEAN
1	Security System	5,79
2	HVAC Control System	5,75
3	Addressable Fire Detection and Alarm System	5,72
4	Telecom and Data System	5,67
5, 6	Building Automation System	5,52
5, 6	Digital Addressable Lighting Control System	5,52
7	Vertical Transportation System	5,31

Table 5.12. Ranking of the intelligent building control systems according to the mean values of large scale buildings in Data Type 1.

RANK	according to importance mean values	according to performance mean values
1	Building Automation System	Security System
2	Addressable Fire Detection and Alarm System	HVAC Control System
3	Security System	Addressable Fire Detection and Alarm System
4	Telecom and Data System	Telecom and Data System
5	HVAC Control System	Building Automation System
6	Digital Addressable Lighting Control System	Digital Addressable Lighting Control System
7	Vertical Transportation System	Vertical Transportation System

Performance mean values in large scale buildings of Data Type 1 differ in the range from 5,31 to 5,79. The average of the performance mean values is 5,61. ‘Security system’, ‘HVAC control system’ and ‘addressable fire detection and alarm system’ are perceived as the most satisfactory attributes in intelligent buildings, respectively (Table 5.11.). ‘Building automation system’ and ‘digital addressable lighting control system’ with the mean value of 5,52 and ‘vertical transportation system’ with the mean value of 5,31 are considered as the least satisfactory attributes of large scale intelligent buildings.

‘Addressable fire detection and alarm system’ and ‘security system’ are considered as two of the three most important factors in large scale intelligent buildings and also they are perceived to be two of the three most satisfactory factors in large scale buildings. The satisfaction levels of the attributes which have high importance level are vital for the service quality of intelligent buildings. Thus, the satisfaction levels of these control systems must be kept as high as the current level. According the mean values, ‘Building automation system’ is the most important control system in large scale buildings with the mean value of 6,24. However, it is perceived as one of the least satisfied attributes of the large scale intelligent buildings according to the respondents of Data Type 1. ‘Vertical transportation system’ is the seventh intelligent building control system according to both importance and performance mean values. There is no need for additional resource and attention to the control system.

5.1.2. Evaluation of the Means of Data Type 2

The respective mean values and standard deviation values of each system according to the responses of the questionnaires for Data Type 2 are illustrated in Table 5.13.

In Data Type 2, the respondents rated all the attributes above the median of the response scale (4) which is a 7-point Likert scale. Importance mean values differ in the range from 5,50 to 6,25. The average of the mean values is 5,94.

The attributes ‘building automation system’, ‘addressable fire detection and alarm system’ and ‘telecom and data system’ are considered as the three most important service quality systems, respectively (Table 5.14). ‘HVAC control system’, ‘digital addressable lighting control system’ and ‘security system’ are considered to be relatively less important for the respondents. According to the mean values, the least important attribute is ‘vertical transportation system’. The standard deviations of the importance attributes range from 0,53 to 0,85, and calculated average is 0,70. The standard deviations of the performance attributes range from 0,76 to 1,20 with the average value of 0,99 (Table 5.13). The standard deviation values are not so high. The findings represent a realistic picture.

Table 5.23. Respective mean values and standard deviation values of Data Type 2.

INTELLIGENT BUILDING CONTROL SYSTEM	importance (expected service)			performance (perceived service)		
	rank	mean	s.d.	rank	mean	s.d.
Building Automation System	1	6,25	0,53	6	5,26	1,20
Telecom and Data System	3	6,00	0,68	2	5,48	0,76
Addressable Fire Detection and Alarm System	2	6,20	0,69	1	5,67	0,88
HVAC Control System	4	5,96	0,70	7	5,25	1,09
Digital Addressable Lighting Control System	5	5,83	0,63	3	5,33	1,00
Security System	6	5,82	0,85	4	5,32	1,06
Vertical Transportation System	7	5,50	0,83	5	5,30	0,93
AVERAGE MEAN VALUE		5,94	0,70		5,37	0,99

Table 5.14. Ranking of the intelligent building control systems according to the importance mean values of Data Type 2.

RANK	INTELLIGENT BUILDING CONTROL SYSTEM	MEAN
1	Building Automation System	6,25
2	Addressable Fire Detection and Alarm System	6,20
3	Telecom and Data System	6,00
4	HVAC Control System	5,93
5	Digital Addressable Lighting Control System	5,83
6	Security System	5,82
7	Vertical Transportation System	5,50

The respondents of Data Type 2 show their satisfaction with the perceived service mean value of 5,37 (Table 5.13.). Performance mean values differ in the range from 5,25 to 5,67. ‘Addressable fire detection and alarm system’ and ‘telecom and data system’ are perceived as the most satisfactory attributes in intelligent buildings, respectively (Table 5.15). ‘Digital addressable lighting control system’, ‘security system’ and ‘vertical transportation system’ are perceived as minor satisfactory attributes. Lastly, ‘building automation system’ and ‘HVAC control system’ are considered as the two least satisfactory attributes of intelligent buildings.

Table 5.15. Ranking of the intelligent building control systems according to the performance mean values of Data Type 2.

RANK	INTELLIGENT BUILDING CONTROL SYSTEM	MEAN
1	Addressable Fire Detection and Alarm System	5,67
2	Telecom and Data System	5,48
3	Digital Addressable Lighting Control System	5,33
4	Security System	5,32
5	Vertical Transportation System	5,30
6	Building Automation System	5,26
7	HVAC Control System	5,25

Both ‘telecom and data system’ and ‘addressable fire detection and alarm system’ are considered to be two of the three most important attributes and at the same time, they are perceived to be two of the three most satisfactory attributes. ‘Building automation system’ is considered as the most important attribute. However, it is perceived as one of the least satisfied attributes of intelligent buildings according to the respondents. The managers, architects and automation experts should realize the priority of the system for future improvements and work for increasing the satisfaction level of the system.

Table 5.16. Ranking of the intelligent building control systems according to the mean values of Data Type 2.

RANK	according to importance mean values	according to performance mean values
1	Building Automation System	Addressable Fire Detection and Alarm System
2	Addressable Fire Detection and Alarm System	Telecom and Data System
3	Telecom and Data System	Digital Addressable Lighting Control System
4	HVAC Control System	Security System
5	Digital Addressable Lighting Control System	Vertical Transportation System
6	Security System	Building Automation System
7	Vertical Transportation System	HVAC Control System

Table 5.17. The mean and standard deviation values of small scale buildings in Data Type 2.

INTELLIGENT BUILDING CONTROL SYSTEM	importance (expected service)			performance (perceived service)		
	rank	mean	s.d.	rank	mean	s.d.
Building Automation System	2	6,12	0,46	6	4,87	1,20
Telecom and Data System	4	5,78	0,65	2	5,32	0,64
Addressable Fire Detection and Alarm System	1	6,22	0,57	1	5,40	0,84
HVAC Control System	3	5,88	0,76	7	4,76	1,15
Digital Addressable Lighting Control System	5	5,75	0,69	3	5,14	0,89
Security System	6	5,74	0,73	5	5,07	0,97
Vertical Transportation System	7	5,23	0,86	4	5,12	1,10
AVERAGE MEAN VALUE		5,82	0,67		5,10	0,97

Importance mean values of small scale buildings differ from 5,23 to 6,22. The average of the mean values is 5,82 (Table 5.17.). The attributes ‘addressable fire detection and alarm system’, ‘building automation system’ and ‘HVAC control system’ are considered as the three most important service quality systems in small scale buildings, respectively (Table 5.18). 'Telecom and data system', 'digital addressable lighting control system' and 'security system' are considered to have relatively minor importance for the respondents. According to the mean values, the least important attribute is 'vertical transportation system'. The standard deviations of the importance attributes range from 0,46 to 0,86 and calculated average is 0,67. The standard deviations of the performance attributes range from 0,64 to 1,20 with the average value of 0,97. Hence, standard deviation values are not so high.

The respondents show their satisfaction with the perceived service mean value of 5,10 (Table 5.17.). Performance mean values differ in the range from 4,76 to 5,40. 'Addressable fire detection and alarm system' and 'telecom and data system' are perceived as the most satisfactory attributes in intelligent buildings, respectively (Table 5.19). 'Digital addressable lighting control system', 'vertical transportation system' and 'security system' are perceived to be relatively less satisfactory attributes. Lastly, 'building automation system' and 'HVAC control system' are considered as the two least satisfactory attributes of intelligent buildings.

Table 5.18. Ranking of the intelligent building control systems according to the importance mean values of small scale buildings in Data Type 2.

RANK	INTELLIGENT BUILDING CONTROL SYSTEM	MEAN
1	Addressable Fire Detection and Alarm System	6,22
2	Building Automation System	6,12
3	HVAC Control System	5,88
4	Telecom and Data System	5,78
5	Digital Addressable Lighting Control System	5,75
6	Security System	5,74
7	Vertical Transportation System	5,23

Table 5.19. Ranking of the intelligent building control systems according to the performance mean values of small scale buildings in Data Type 2.

RANK	INTELLIGENT BUILDING CONTROL SYSTEM	MEAN
1	Addressable Fire Detection and Alarm System	5,40
2	Telecom and Data System	5,32
3	Digital Addressable Lighting Control System	5,14
4	Vertical Transportation System	5,12
5	Security System	5,07
6	Building Automation System	4,87
7	HVAC Control System	4,76

Table 5.20. Ranking of the intelligent building control systems according to the mean values of small scale buildings in Data Type 2.

RANK	according to importance mean values	according to performance mean values
1	Addressable Fire Detection and Alarm System	Addressable Fire Detection and Alarm System
2	Building Automation System	Telecom and Data System
3	HVAC Control System	Digital Addressable Lighting Control System
4	Telecom and Data System	Vertical Transportation System
5	Digital Addressable Lighting Control System	Security System
6	Security System	Building Automation System
7	Vertical Transportation System	HVAC Control System

'Addressable fire detection and alarm system' is considered to be the most important attribute and at the same time, it is perceived to be the most satisfactory attribute (Table 5.20). The managers, automation system engineers and architects should continue to keep the current level of satisfaction. 'Building automation system' and 'HVAC control system' are considered as the two least satisfactory attributes.

However, they are perceived as the two of the three most important attributes of intelligent buildings according to the respondents. The satisfaction level of the system should be increased because of the high importance values. They should focus on resource allocation according to the priorities of the occupants and users.

Importance mean values of large scale buildings differ in from 5,75 to 6,38. The average of the mean values is 6,04 (Table 5.21.). The attributes of 'building automation system', 'telecom and data system' and 'addressable fire detection and alarm system' are considered as the three most important service quality systems in large scale buildings, respectively (Table 5.22). 'HVAC control system', 'digital addressable lighting control system' and 'security system' are considered to be relatively less important for the respondents. According to the mean values, the least important attribute is 'vertical transportation system'. The standard deviations of the importance attributes range from 0,57 to 0,98, and calculated average is 0,71. The standard deviations of the performance attributes range from 0,69 to 1,28 with the average value of 0,93. The standard deviation values are not so high.

Table 5.21. The mean and standard deviation values of large scale buildings in Data Type 2.

INTELLIGENT BUILDING CONTROL SYSTEM	importance (expected service)			performance (perceived service)		
	rank	mean	s.d.	rank	mean	s.d.
Building Automation System	1	6,38	0,58	3	5,69	1,17
Telecom and Data System	2	6,22	0,66	4	5,61	0,71
Addressable Fire Detection and Alarm System	3	6,18	0,81	1	5,96	0,81
HVAC Control System	4	5,97	0,67	2	5,71	0,69
Digital Addressable Lighting Control System	5	5,91	0,57	6	5,52	1,23
Security System	6	5,90	0,98	5	5,59	1,28
Vertical Transportation System	7	5,75	0,71	7	5,43	0,63
AVERAGE MEAN VALUE		6,04	0,71		5,64	0,93

Table 5.22. Ranking of the intelligent building control systems according to the importance mean values of large scale buildings in Data Type 2.

RANK	INTELLIGENT BUILDING CONTROL SYSTEM	MEAN
1	Building Automation System	6,38
2	Telecom and Data System	6,22
3	Addressable Fire Detection and Alarm System	6,18
4	HVAC Control System	5,97
5	Digital Addressable Lighting Control System	5,91
6	Security System	5,90
7	Vertical Transportation System	5,75

Table 5.23. Ranking of the intelligent building control systems according to the performance mean values of large scale buildings in Data Type 2.

RANK	INTELLIGENT BUILDING CONTROL SYSTEM	MEAN
1	Addressable Fire Detection and Alarm System	5,96
2	HVAC Control System	5,71
3	Building Automation System	5,69
4	Telecom and Data System	5,61
5	Security System	5,59
6	Digital Addressable Lighting Control System	5,52
7	Vertical Transportation System	5,43

The respondents show their satisfaction with the perceived service mean value of 5,64 (Table 5.21.). Performance mean values differ from 5,43 to 5,96. ‘Addressable fire detection and alarm system’, ‘building automation system’ and ‘HVAC control system’ are perceived as the three most satisfactory attributes in intelligent buildings, respectively (Table 5.23). 'Telecom and data system' and 'security system' are perceived as minor satisfactory attributes. Lastly, 'digital addressable lighting control system' and 'vertical transportation system' are considered as the least satisfactory attributes of large scale intelligent buildings.

Table 5.24. Ranking of the intelligent building control systems according to the mean values of large scale buildings in Data Type 2.

RANK	according to importance mean values	according to performance mean values
1	Building Automation System	Addressable Fire Detection and Alarm System
2	Telecom and Data System	HVAC Control System
3	Addressable Fire Detection and Alarm System	Building Automation System
4	HVAC Control System	Telecom and Data System
5	Digital Addressable Lighting Control System	Security System
6	Security System	Digital Addressable Lighting Control System
7	Vertical Transportation System	Vertical Transportation System

Both 'building automation system' and 'addressable fire detection and alarm system' are considered to be two of the three most important attributes and at the same time, they are perceived to be two of the three most satisfactory attributes (Table 5.24.). The satisfaction level of the respondents about the systems should be kept as they are.

As presented above, the evaluation of the means of both the expected and the perceived service quality of intelligent building control systems provide an overview of the attitude of respondents towards intelligent building service quality. For further analysis, in the following section, the gap analysis is conducted for two types of data.

5.2. Results of Gap Analysis

In the previous section, overall mean values for the expected and perceived service are calculated. With the aim of comparing the mean values of expected and perceived service, the gap analysis is conducted. The mean differences for the service quality attributes are discussed in this part. Mean differences indicate customer gap.

Customer gap can be defined as the difference between the expectations of the customers and the perceptions of the customer. The results of the gap analysis for the intelligent building service quality attributes convey effective messages for managerial and architectural implications. Firstly, gaps in all attributes for both the small and the large scale buildings of Data Type 1 and Data Type 2 are calculated. Then, gap differences between the small and large scale buildings are evaluated.

5.2.1. Gap Analysis for Data Type 1

The comparison of the means of expected and perceived service, in other words gaps between importance and performance is summarized in Table 5.25. The largest gaps are highlighted in dark grey. The means of expected and perceived service rating of the attributes are not significantly different from each other. All gaps in Table 5.25 display a negative value, which means the expectation for any attribute is bigger than the perception of that attribute. Thus, that results in customer dissatisfaction. When the gap has a positive value, this means the expectations are below the perceptions and so customer satisfaction appears.

Table 5.25. Results of gap analysis for Data Type 1 (Comparison of mean values).

NAME OF THE CONTROL SYSTEM	IMPORTANCE MEAN	PERFORMANCE MEAN	GAP
Building Automation System	6,17	5,22	-0,95
Telecom and Data System	5,95	5,53	-0,42
Addressable Fire Detection and Alarm System	6,00	5,57	-0,43
HVAC Control System	5,95	5,34	-0,61
Digital Addressable Lighting Control System	5,81	5,36	-0,45
Security System	6,04	5,44	-0,60
Vertical Transportation System	5,57	5,24	-0,33

In Table 5.25., the importance mean values represent the expectations of the respondents and the performance mean values represent the perceptions of the respondents.

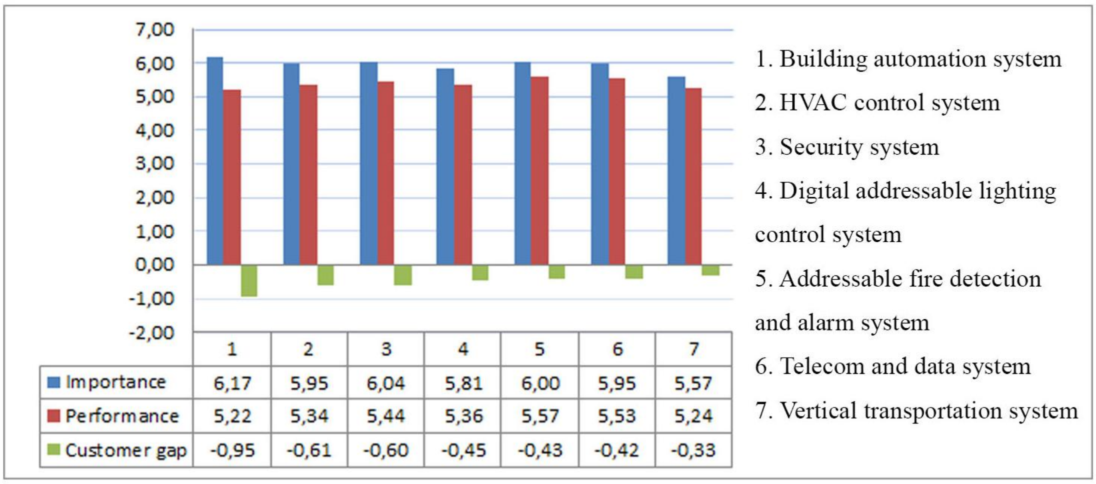
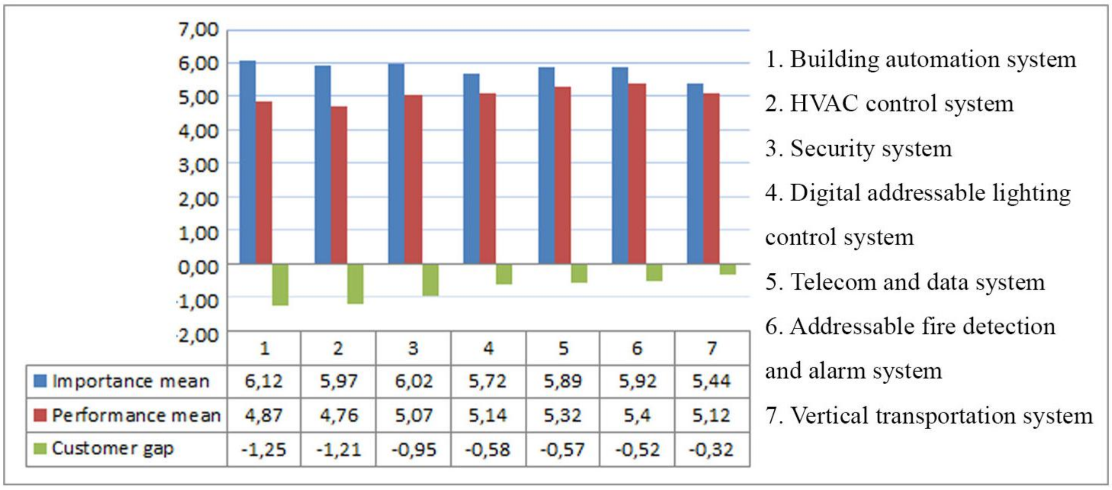


Figure 5.3. Results of gap analysis for Data Type 1.

According to Figure 5.1., the largest gaps occur in ‘building automation system’, ‘HVAC control system’ and ‘security system’. With the highest gap value, -0,95, ‘building automation system’ indicates the most important but the least satisfied service element. ‘HVAC control system’ and ‘security system’ with negative gap values -0,61 and -0.60 rank the second and the third, respectively. With the gap evaluation, a relative comparison between expectations and perceptions could be realized.

Following an overview of all customer gap values including small and large scale buildings in Data Type 1 for the seven service quality dimensions of the intelligent building control systems, gaps for each scale are evaluated. The comparison of gaps for the seven control systems for small scale buildings in Data Type 1 are shown in Figure 5.2. and for large scale buildings in Data Type 1 in Figure 5.3.

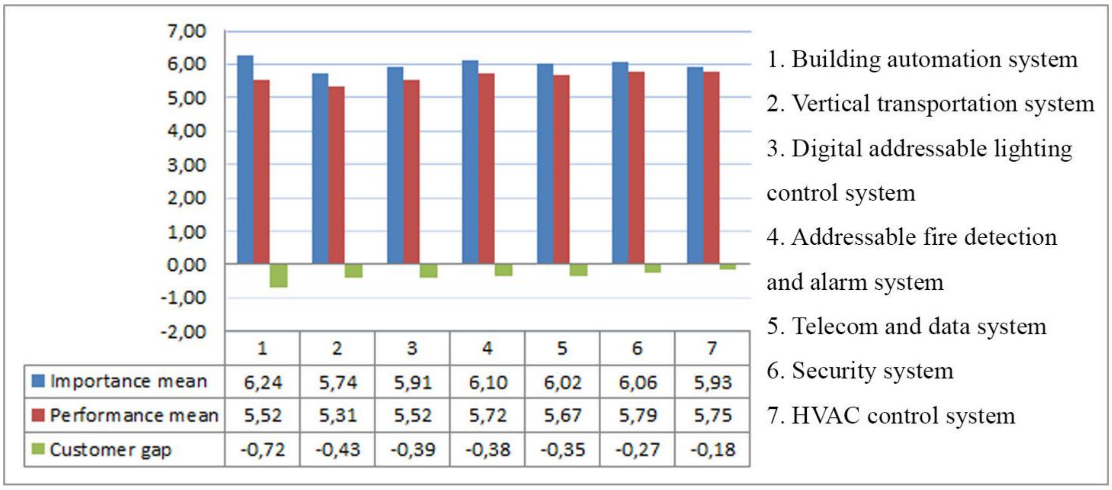
In Data Type 1, the largest gaps in small scale buildings occur in ‘building automation system’, ‘HVAC control system’ and ‘security system’. With the highest gap value, -1,25, ‘building automation system’ indicates the most important but the least satisfied service element. ‘HVAC control system’ and ‘security system’ with negative gap values -1,21 and -0.95, these systems rank as the second and the third, respectively.



	1	2	3	4	5	6	7
Importance mean	6,12	5,97	6,02	5,72	5,89	5,92	5,44
Performance mean	4,87	4,76	5,07	5,14	5,32	5,4	5,12
Customer gap	-1,25	-1,21	-0,95	-0,58	-0,57	-0,52	-0,32

Figure 5.2. Results of gap analysis for small scale buildings in Data Type 1 (Comparison of means of small scale buildings in Data Type 1).

In Data Type 1, the largest gaps in large scale buildings evaluation occurred in ‘building automation system’ and ‘vertical transportation system’. With the highest gap value, -0,72, ‘building automation system’ indicates the biggest difference between the expectations of the respondents and the perceptions of the respondents.



	1	2	3	4	5	6	7
Importance mean	6,24	5,74	5,91	6,10	6,02	6,06	5,93
Performance mean	5,52	5,31	5,52	5,72	5,67	5,79	5,75
Customer gap	-0,72	-0,43	-0,39	-0,38	-0,35	-0,27	-0,18

Figure 5.3. Results of gap analysis for large scale buildings in Data Type 1 (Comparison of means of large scale buildings in Data Type 1).

The comparison of gaps between small scale buildings and large scale buildings in Data Type 1 is presented in Table 5.26. It can be detected from the comparison of the gaps of all control systems, the gaps of the small scale buildings are greater than the large scale buildings except one attribute, which is ‘vertical transportation system’. It is indicated with a negative value in Table 5.26. The largest differences are found within the service attributes of ‘HVAC control system’, ‘security system’ and ‘building automation system’, respectively. These are also the attributes that the respondents are more dissatisfied with the service quality in small scale buildings as highlighted in Table 5.26. The ‘building automation system’ is the attribute that has a large dissatisfaction gap also at large scale buildings.

Table 5.26. Comparison of gaps between small and large scale buildings in Data Type 1.

Intelligent Building Control System	Customer gap for small scale buildings	Customer gap for large scale buildings	Comparison of gaps
Building Automation System	-1,25	-0,72	0,53
Telecom and Data System	-0,57	-0,35	0,22
Addressable Fire Detection and Alarm System	-0,52	-0,38	0,14
HVAC Control System	-1,21	-0,18	1,03
Digital Addressable Lighting Control System	-0,58	-0,39	0,19
Security System	-0,95	-0,27	0,68
Vertical Transportation System	-0,32	-0,43	-0,11

After customer gap analysis for Data Type 1, gaps for the seven intelligent building control systems in the Data Type 2 is conducted in the following section.

5.2.2. Gap Analysis for Data Type 2

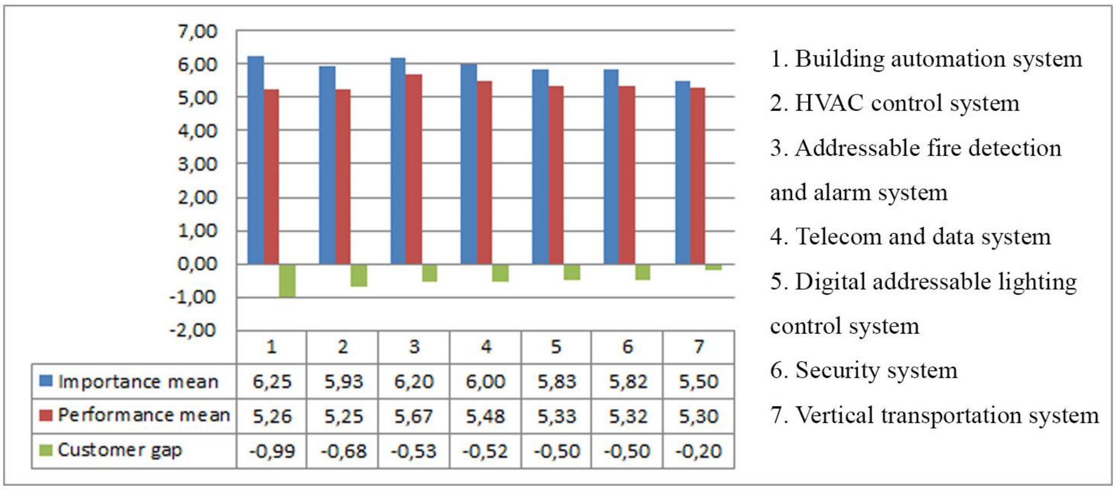
In Data Type 2, the largest gaps occur in ‘building automation system’ and ‘HVAC control system’, respectively. All gap values are negative (Table 5.27.). In other words, the expectations of the respondents are higher than the perceptions of the respondents in each control system. The mean values of importance and performance and gap values of the seven intelligent control systems according to Data Type 2 is shown as graphic in Figure 5.4. The largest gaps are highlighted in dark grey.

Table 5.27. Results of gap analysis for Data Type 2 (Comparison of mean values).

NAME OF THE CONTROL SYSTEM	IMPORTANCE MEAN	PERFORMANCE MEAN	GAP
Building Automation System	6,25	5,26	-0,99
Telecom and Data System	6,00	5,48	-0,52
Addressable Fire Detection and Alarm System	6,20	5,67	-0,53
HVAC Control System	5,96	5,25	-0,68
Digital Addressable Lighting Control System	5,83	5,33	-0,50
Security System	5,82	5,32	-0,50
Vertical Transportation System	5,50	5,30	-0,20

According to Figure 5.4., the largest gaps occur in ‘building automation system’ and ‘HVAC control system’. With the highest gap value, -0,99, ‘building automation system’ indicates the most important but the least satisfied service element in intelligent buildings. ‘HVAC control system’ and ‘addressable fire detection and alarm system’ with negative gap values -0,68 and -0.53 rank as the second and the third, respectively.

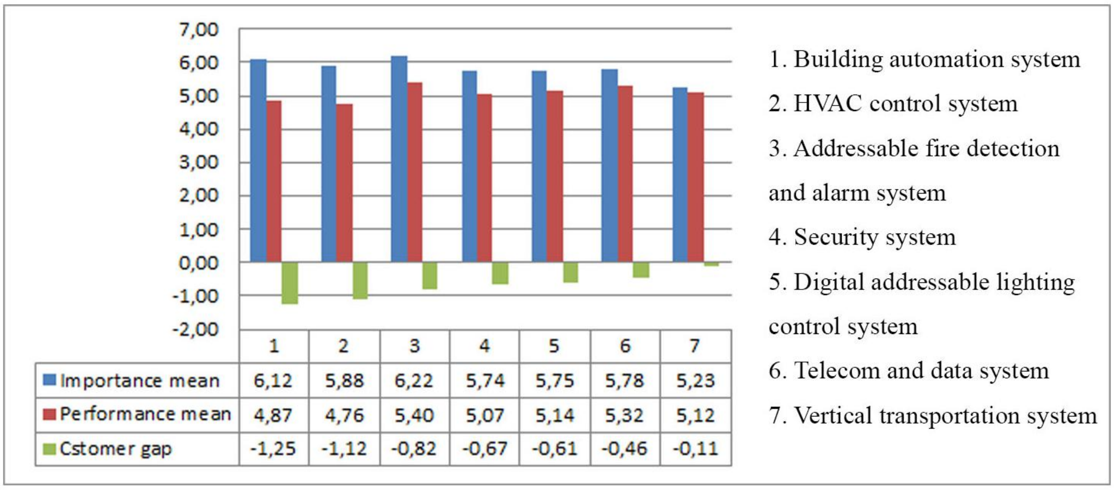
After evaluating all customer gap values including small and large scale buildings, the gaps for each scale are evaluated. The comparison of gaps for the seven control systems for small scale buildings are shown in Figure 5.5. and for large scale buildings in Figure 5.6.



	1	2	3	4	5	6	7
Importance mean	6,25	5,93	6,20	6,00	5,83	5,82	5,50
Performance mean	5,26	5,25	5,67	5,48	5,33	5,32	5,30
Customer gap	-0,99	-0,68	-0,53	-0,52	-0,50	-0,50	-0,20

Figure 5.4. Results of gap analysis for Data Type 2.

According to the mean values of Data Type 2, the largest gaps in small scale buildings occur in ‘building automation system’, ‘HVAC control system’ and ‘addressable fire detection and alarm system’, respectively. With the highest gap value, -1,25, ‘building automation system’ indicates the most important but the least satisfied service element. ‘HVAC control system’ and ‘addressable fire detection and alarm system’ with negative gap values -1,12 and -0.82 rank as the second and the third, respectively.



	1	2	3	4	5	6	7
Importance mean	6,12	5,88	6,22	5,74	5,75	5,78	5,23
Performance mean	4,87	4,76	5,40	5,07	5,14	5,32	5,12
Cstomer gap	-1,25	-1,12	-0,82	-0,67	-0,61	-0,46	-0,11

Figure 5.5. Results of gap analysis for small scale buildings in Data Type 2 (Comparison of means of small scale buildings in Data Type 2).

The gaps of the seven intelligent building control systems in large scale buildings according to the Data Type 2 are given in Figure 5.6. ‘Building automation system' with the gap value of -0,69 and 'telecom and data system' with the gap value of -0,61 have the largest gaps between the expected and perceived service quality, respectively.

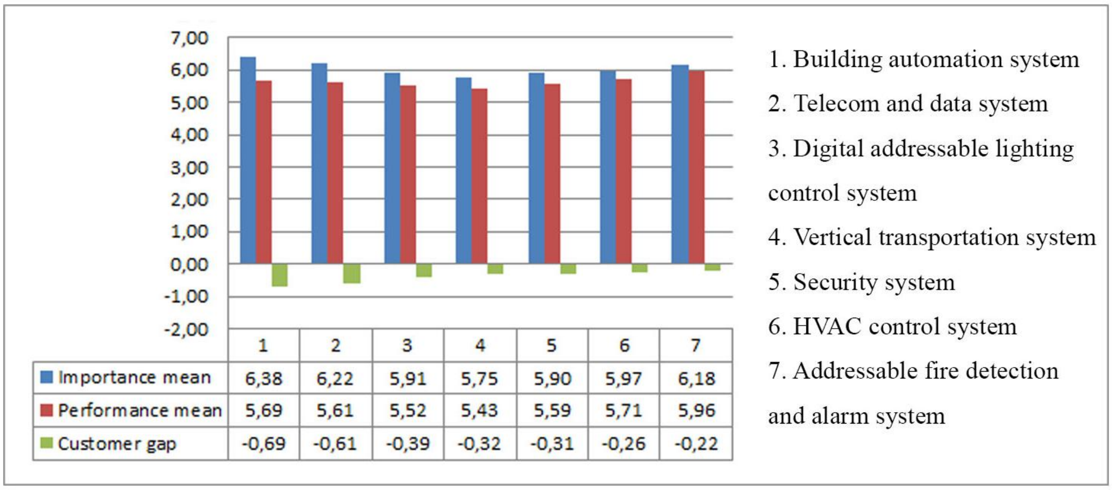


Figure 5.6. Results of gap analysis for large scale buildings in Data Type 2 (Comparison of means of large scale buildings in Data Type 2).

Table 5.28. Comparison of gaps between small and large scale buildings in Data Type 1.

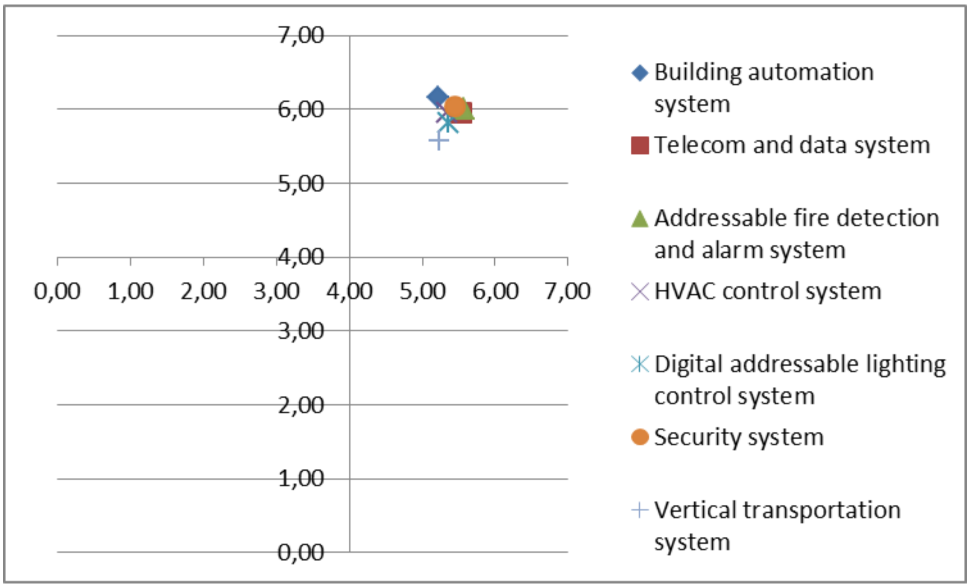
Intelligent Building Control System	Customer gap for small scale buildings	Customer gap for large scale buildings	Comparison of gaps
Building Automation System	-1,25	-0,69	0,56
Telecom and Data System	-0,46	-0,61	-0,15
Addressable Fire Detection and Alarm System	-0,82	-0,22	0,60
HVAC Control System	-1,12	-0,26	0,86
Digital Addressable Lighting Control System	-0,61	-0,39	0,22
Security System	-0,67	-0,31	0,36
Vertical Transportation System	-0,11	-0,32	-0,21

It can be detected from the comparison of the gaps of the seven intelligent building control systems, the gaps of the small scale buildings are greater than the large scale buildings except for the two attributes (Table 5.28.). These are the gaps of the 'telecom and data system' and 'vertical transportation system' and they are indicated with negative values in Table 5.28. The largest differences are found within the service attributes of 'HVAC control system', 'addressable fire detection' and 'building automation system', respectively. The 'building automation system' is the attribute which has the largest dissatisfaction gap in both small scale intelligent buildings and large scale intelligent buildings.

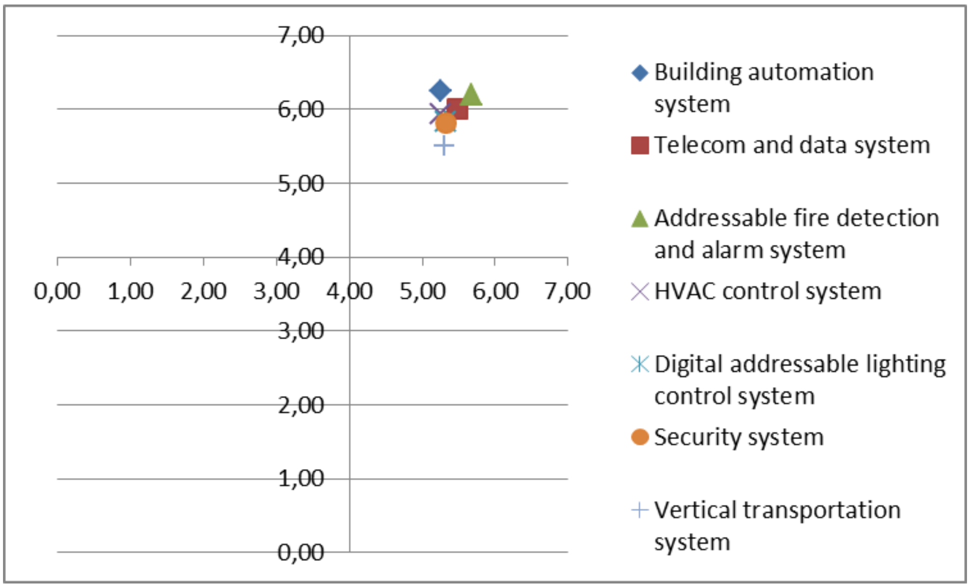
5.3. Results of Importance-Performance Analysis

In this section, Importance-Performance Analysis (IPA) is conducted. The objective of this section is to place the attributes in a prioritization map, which integrates the perspectives of the customer and the company. The attributes are discussed with regard to their place in the prioritization map. In Importance-Performance Analysis, expected and perceived services are paraphrased in importance and performance. The list of the seven control systems is given in the right sight of the Importance-Performance Analysis.

In this study, the data centered IPA is applied because in the scale centered IPA, all the attributes fall into the category of 'keep up the good work' (Figure 5.7.). Hence, the scale centered approach is not appropriate for this data set.



(a)



(b)

Figure 5.7. (a) Scale-Centered Importance-Performance Analysis with Data Type 1 (b) Scale-Centered Importance-Performance Analysis with Data Type 2.

5.3.1. Importance-Performance Analysis for Data Type 1

Importance-Performance Analysis for all buildings is given in Figure 5.8. In Figure 5.9. and Figure 5.10. the importance-performance grid for small scale intelligent buildings and large scale intelligent buildings in Data Type 1 are illustrated, respectively.

The data centered IPA is applied to Data Type 1, with intersection points of (5,39; 5,93) (Figure 5.8.). The value 5,93 is the average mean value of the importance means and the value of 5,39 is the average mean value of performance means (Table 5.1.).

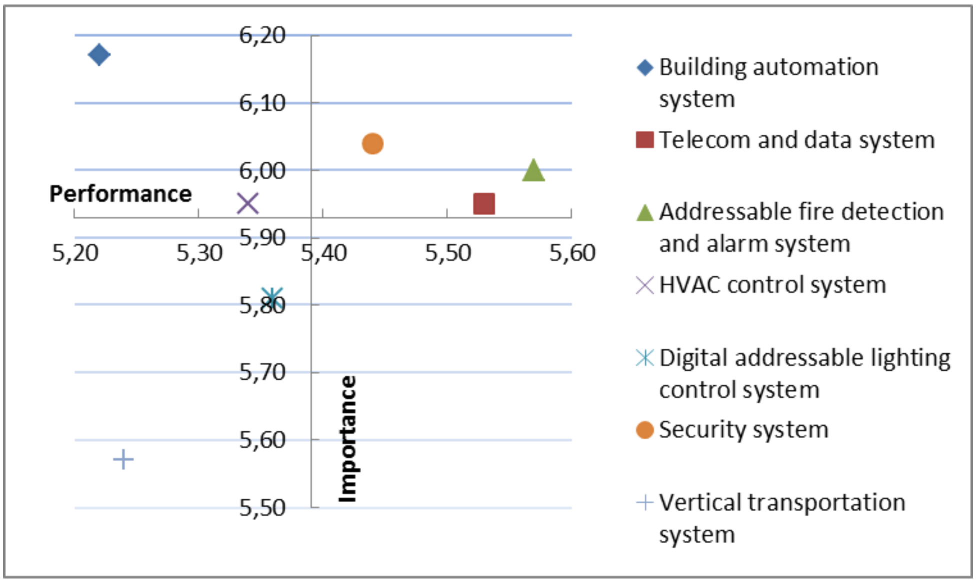


Figure 5.8. Data-Centered Importance-Performance Analysis with Data Type 1.

In the analysis of small scale intelligent buildings in Data Type 1, the intersection point is (5,10; 5,87) (Figure 5.9.). The value 5,10 is the average mean value of the importance means and the value of 5,87 is the average mean value of performance means of small scale intelligent buildings (Table 5.5.).

In the analysis of large scale intelligent buildings in Data Type 1, intersection points of (5,61; 6,00) (Figure 5.10.). The value 6,00 indicates the average mean value of the importance means and the value of 5,61 indicates the average mean value of performance means of large scale intelligent buildings (Table 5.9.).

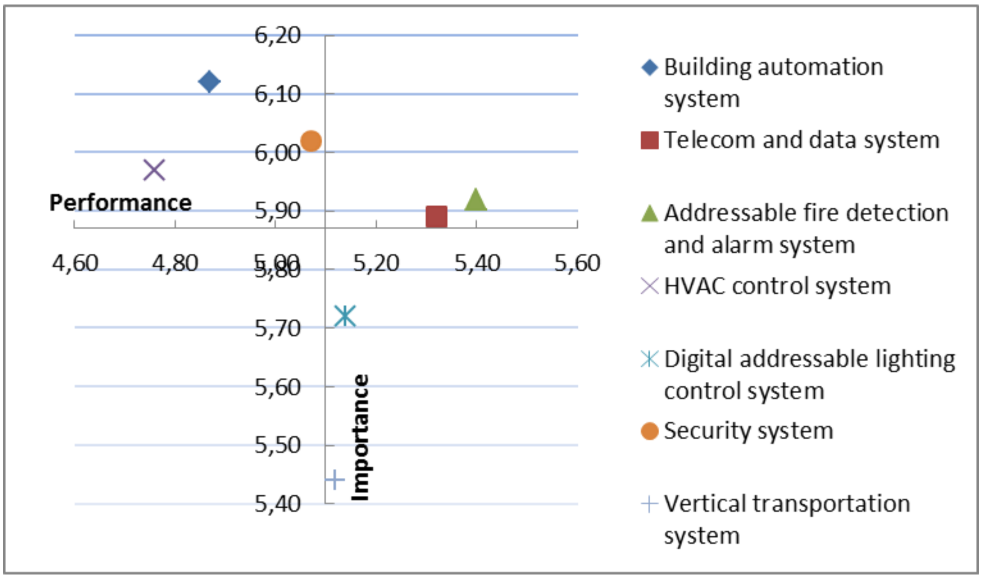


Figure 5.9. Data-Centered Importance-Performance Analysis for small scale intelligent buildings in Data Type 1.

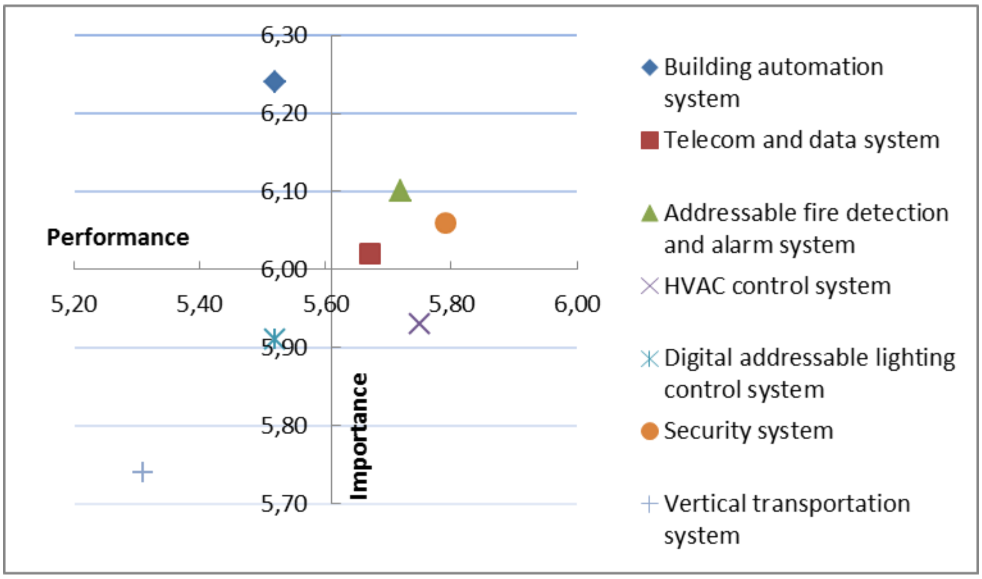


Figure 5.10. Data-Centered Importance-Performance Analysis for large scale intelligent buildings in Data Type 1.

In the following section, the attributes are discussed according to the quadrant that they take place in.

5.3.1.1. Quadrant A: “Concentrate Here” Quadrant

The general Importance-Performance Analysis is performed in Figure 5.8. The two intelligent building control systems fall within the quadrant A. The two intelligent building control systems which take place in this quadrant have the largest gaps. ‘Building automation system’ and ‘HVAC control system’ are placed in this quadrant. According to the general Importance-Performance Analysis, it can be said that the occupants and users of the intelligent buildings think that the two intelligent building control systems in this quadrant have high importance and low satisfaction level. Hence, ‘building automation system’ and ‘HVAC control system’ can be defined as the service elements of high priority. The architectural and managerial service attention and resources should be given to these control systems for higher client satisfaction. This quadrant is so important for the companies to get the appropriate message to rearrange their resources for future projects.

In Figure 5.9., Importance-Performance Analysis for small scale buildings is given and a similar pattern is seen. ‘Building automation system’, ‘HVAC control system’ and ‘security system’ show us an apparent prioritization of these control systems. In Importance-Performance Analysis for large scale buildings, only ‘building automation system’ is allocated in the ‘concentrate here’ quadrant regarding the views of the occupants and users of the large scale buildings (Figure 5.10.).

Consequently, it can be said that regardless of the scale of the building, occupants and users think that ‘building automation system’ is very important for an intelligent building service quality but it has low perceived satisfaction. The findings emphasize that the largest priority of the construction companies, automation system experts and architects must be the ‘building automation system’. For improvements in the service quality of intelligent building control systems, the attributes of the building automation system; 1) ability of integration, 2) reliability, 3) efficiency and 4) life cycle cost should be reassessed. These attributes require more attention for a higher satisfaction of the clients.

5.3.1.2. Quadrant B: “Keep up the Good Work” Quadrant

The three control systems fall within the ‘keep up the good work’ quadrant among the general Importance-Performance analysis. Although the gaps of these control systems have negative values, they are allocated in this quadrant. In spite of the respondents’ expectations are higher than their satisfaction, they are pleased with the performance of the control systems. ‘Security system’, ‘telecom and data system’ and ‘addressable fire detection and alarm system’ are the intelligent building control systems which are both important and satisfactory for the occupants and users of these buildings. The construction companies, automation system experts and architects should work to continue the performance of the control systems in this quadrant because the control systems with higher importance should keep their performance level higher too.

For small scale buildings, ‘telecom and data system’ and ‘addressable fire detection and alarm system’ are still placed in quadrant B as in general Importance-Performance Analysis. In small scale intelligent buildings, the automation system developers and architects should work to keep the current level of ‘telecom and data system’ and ‘addressable fire detection and alarm system’ performance.

In analysis for large scale buildings, the three control systems which take place in quadrant B in general analysis are allocated in the ‘keep up the good work’ quadrant. These systems are ‘security system’, ‘addressable fire detection and alarm system’ and ‘telecom and data system’. For these systems, less resources are required to reach the satisfaction level demanded by the clients.

5.3.1.3. Quadrant C: “Low Priority” Quadrant

‘Digital addressable lighting control system’ and ‘vertical transportation system’ are allocated within quadrant C. These control systems have low priority among the occupants and the users. The two control systems are the ones which are evaluated as the least important service quality attributes for intelligent building control systems satisfaction.

In small scale building Importance-Performance Analysis, the quadrant C is empty. None of the control systems is allocated in the ‘low priority’ quadrant.

In large scale buildings, as in the general analysis, the same systems are placed within the quadrant C. These findings emphasize that ‘digital addressable lighting control system’ and ‘vertical transportation system’ are low priority elements of intelligent buildings in both general and large scale buildings.

5.3.1.4. Quadrant D: “Possible Overkill” Quadrant

None of the control systems is placed in quadrant D in the entire data Importance-Performance Analysis. In small scale buildings, ‘digital addressable lighting control system and ‘vertical transportation system’ are allocated in ‘possible overkill’ quadrant. In large scale building evaluation, ‘HVAC control system’ is evaluated in the quadrant D.

The systems in quadrant D indicate that they have a good performance, even though the occupants and the users of these control systems attach slight importance to the service quality of these control systems. As a result, ‘the possible overkill’ quadrant includes different control systems in the entire data analysis and the scale-oriented analysis. For each sample of data analysis, the prioritization map gives a different message.

5.3.2. Importance-Performance Analysis for Data Type 2

Data centered IPA is applied to the entire data of Data Type 2. The intersection points for data centered IPA analysis are (5,37; 5,94). The value 5,94 is the average mean value of the importance means and the value of 5,37 is the average mean value of the performance means (Table 5.13.).

In the Importance-Performance analysis of small scale intelligent buildings, intersection point for data centered IPA is (5,10; 5,82). The value 5,10 is the average mean value of the importance means and the value of 5,82 is the average mean value of the performance means of small scale intelligent buildings (Table 5.17.).

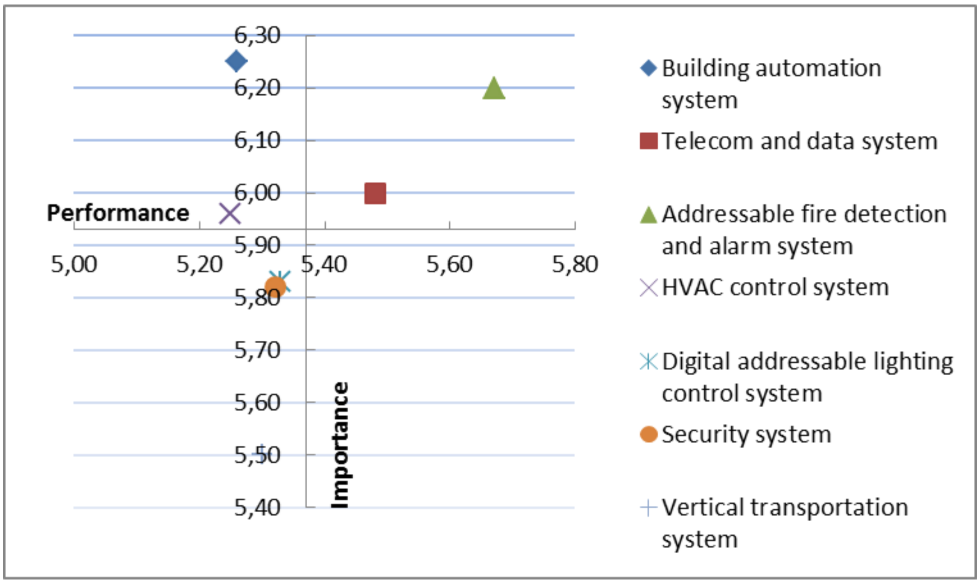


Figure 5.41. Data-Centered Importance-Performance Analysis for the entire data of Data Type 2.

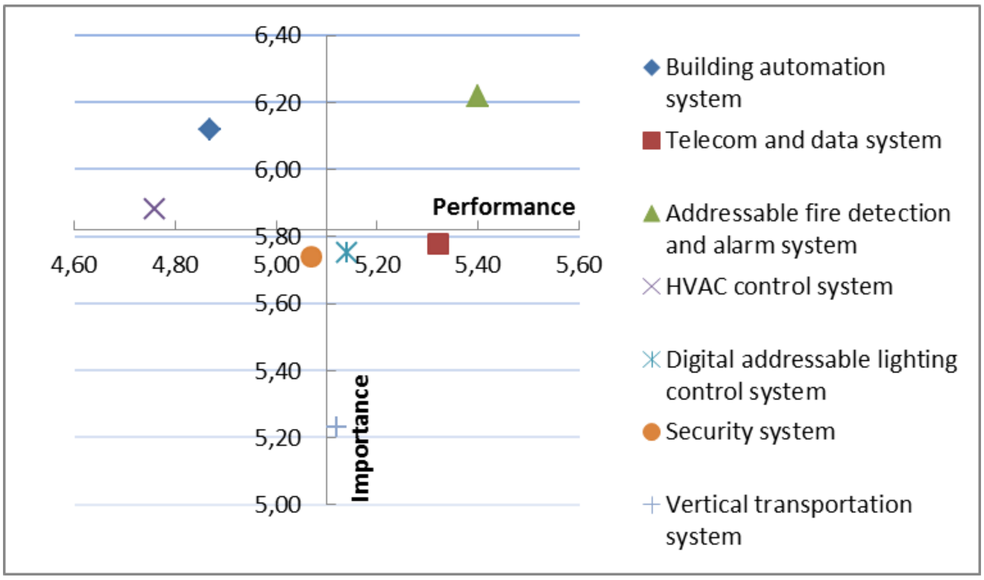


Figure 5.12. Data-Centered Importance-Performance Analysis for small scale intelligent buildings in Data Type 2.

The intersection point of (5,64; 6,04) is used in the analysis of large scale intelligent buildings. The value 6,04 indicates the average mean value of the importance means and the value of 5,64 indicates the average mean value of the performance means of large scale intelligent buildings (Table 5.21.).

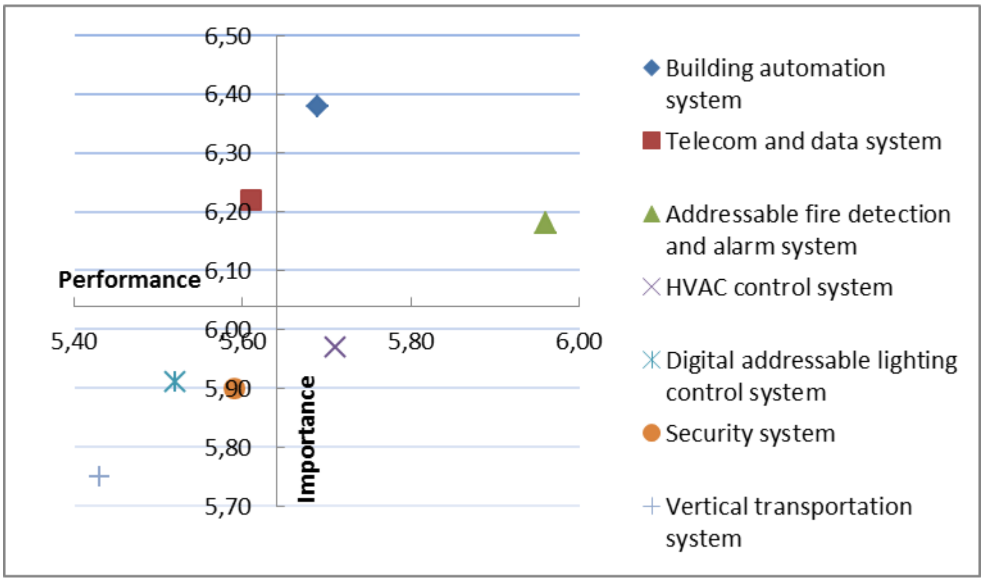


Figure 5.13. Data-Centered Importance-Performance Analysis for large scale intelligent buildings in Data Type 2.

Below given are the names of the quadrants which the indicated attributes fall and the related messages. The results of the Importance-Performance analysis for the entire data, small scale intelligent buildings and large scale intelligent buildings in Data Type 2 are illustrated in Figure 5.11., Figure 5.12. and Figure 5.13., respectively.

5.3.2.1. Quadrant A: "Concentrate Here" Quadrant

The results of the Importance-Performance Analysis applied to the entire Data Type 2 are presented in Figure 5.11. The 'building automation system' and 'HVAC control system' take place in this quadrant and the systems have the largest customer gaps. 'Building automation system' and 'HVAC control system' have high importance and low satisfaction level according to the respondents. Hence, these control systems have the highest priority for the improvement purposes of the service quality of intelligent buildings. More architectural and managerial service attention and resources should be given to these control systems for higher client satisfaction.

In Figure 5.12., Importance-Performance Analysis for small scale buildings is presented. 'Building automation system' and 'HVAC control system' takes place in quadrant A. These systems need prioritization. In Importance-Performance Analysis for large scale buildings, only the 'telecom and data system' is allocated in the 'concentrate here' quadrant among occupants and users of the large scale buildings (Figure 5.13.).

Consequently, it can be said that both in the entire data analysis and in small scale buildings, occupants and users think that 'building automation system' is a very important attribute for assessing intelligent building service quality; however, its performance is not as satisfactory as expected by the occupants and users. The systems which take place within 'concentrate here' quadrant require more attention for a higher satisfaction of the clients.

5.3.2.2. Quadrant B: "Keep up the Good Work" Quadrant

The two control systems fall within the 'keep up the good work' quadrant among the entire data Importance-Performance analysis. The occupants and users are pleased with the performance of the control systems in this quadrant. However, the expectations of the respondents are higher than their satisfaction. 'Telecom and data system' and 'addressable fire detection and alarm system' are the intelligent building control systems which are both important and satisfactory for the occupants and users of these buildings. The control systems with high importance degree should have high performance degree for keeping the service quality high. Hence, the performance level of the control systems in this quadrant should be preserved.

For small scale buildings, only the 'addressable fire detection and alarm system' is placed in quadrant B. In small scale intelligent buildings, the current level of the 'addressable fire detection and alarm system' performance should be kept.

In analysis for large scale buildings, the two control systems which take place in quadrant B in the entire data analysis are allocated in the 'keep up the good work' quadrant. These systems are 'building automation system' and 'addressable fire detection and alarm system'. For these systems, less resources are required to increase the satisfaction of the clients.

Regardless of the scale of the building, occupants and users think that 'addressable fire detection and alarm system' is very important for an intelligent building service quality and at the same time, it has high perceived satisfaction.

5.3.2.3. Quadrant C: "Low Priority" Quadrant

'Security system', 'digital addressable lighting control system' and 'vertical transportation system' are allocated within the quadrant C according to the results of the entire data analysis. These control systems have low priority for the occupants and the users.

In the Importance-Performance Analysis for small scale buildings, 'security system' is allocated in quadrant C. 'Security system', 'digital addressable lighting control system' and 'vertical transportation system' are placed within the quadrant C as in the entire data analysis. These findings emphasize that 'security system', 'digital addressable lighting control system' and 'vertical transportation system' are the low priority attributes of large scale intelligent buildings. 'Security system' is taking place in this quadrant in all Importance-Performance analysis of Data Type 2.

5.3.2.4. Quadrant D: "Possible Overkill" Quadrant

Although the control systems in quadrant D have good performance, these systems have not high importance as assessed by the occupants and users for a better service quality.

None of the control systems is placed in quadrant D in the entire data Importance-Performance Analysis. In small scale buildings, 'digital addressable lighting control system, 'telecom and data system' and 'vertical transportation system' are allocated in 'possible overkill' quadrant. In large scale building evaluation, 'HVAC control system' is placed in the quadrant D.

5.4. Discussion

All seven intelligent building control systems are plotted in each of the following quadrants on the importance–performance grid according to their importance and performance ratings of the respondents: "Keep up the Good Work," "Low Priority,"

Table 5.29. Positions of the seven control systems in importance-performance grid.

NAME OF THE CONTROL SYSTEM	Name of the IPA Quadrant					
	Data Type 1			Data Type 2		
	all buildings	small scale buildings	large scale buildings	all buildings	small scale buildings	large scale buildings
Building Automation System	Concentrate here High importance Low performance	Concentrate here High importance Low performance	Concentrate here High importance Low performance	Concentrate here High importance Low performance	Concentrate here High importance Low performance	Keep up the good work High importance High performance
Telecom and Data System	Keep up the good work High importance High performance	Keep up the good work High importance High performance	Keep up the good work High importance High performance	Keep up the good work High importance High performance	Possible overkill Low importance High performance	Concentrate here High importance Low performance
Addressable Fire Detection and Alarm System*	Keep up the good work High importance High performance	Keep up the good work High importance High performance	Keep up the good work High importance High performance	Keep up the good work High importance High performance	Keep up the good work High importance High performance	Keep up the good work High importance High performance
HVAC Control System	Concentrate here High importance Low performance	Concentrate here High importance Low performance	Possible overkill Low importance High performance	Concentrate here High importance Low performance	Concentrate here High importance Low performance	Possible overkill Low importance High performance
Digital Addressable Lighting Control System	Low priority Low importance Low performance	Possible overkill Low importance High performance	Low priority Low importance Low performance	Low priority Low importance Low performance	Possible overkill Low importance High performance	Low priority Low importance Low performance
Security System**	Keep up the good work High importance High performance	Concentrate here High importance Low performance	Keep up the good work High importance High performance	Low priority Low importance Low performance	Low priority Low importance Low performance	Low priority Low importance Low performance
Vertical Transportation System	Low priority Low importance Low performance	Possible overkill Low importance High performance	Low priority Low importance Low performance	Low priority Low importance Low performance	Possible overkill Low importance High performance	Low priority Low importance Low performance

*most consistent
**most inconsistent

“Possible Overkill,” and “Concentrate Here”. All seven control systems are discussed below in accordance with their place in the importance-performance grid (Table 5.29). There are three importance-performance analysis according to Data Type 1 and three importance-performance analysis according to Data Type 2. In both Data Type 1 and Data Type 2, three importance performance analysis are same and these are for all buildings, for small scale buildings and large scale buildings. Each system is discussed according to its place in every six of the importance-performance analysis.

In all buildings importance-performance analysis for both Data Type 1 and Data Type 2, ‘building automation system’ is located in the “concentrate here” quadrant. A similar pattern is observed for both small scale buildings of Data Type 1 and Data Type 2 and large scale buildings in Data Type 1 (Table 5.30.).

Table 5.30. Positions of the building automation system in importance-performance grid.

	Building Type	Quadrant	Message of the Quadrant
Data Type 1	all buildings	Concentrate here	Increase resources
	small scale buildings	Concentrate here	Increase resources
	large scale buildings	Concentrate here	Increase resources
Data Type 2	all buildings	Concentrate here	Increase resources
	small scale buildings	Concentrate here	Increase resources
	large scale buildings	Keep up the good work	Sustain resources

Participants think that ‘building automation system’ is very important but it is perceived as a low satisfactory control system of an intelligent building. Since this system is very important, it affects the intelligent building occupants’ satisfaction and the service quality of intelligent buildings. Hence, regardless of the data type, ‘building automation system’ requires more attention and more resources. To increase the satisfaction level of occupants, more attention should be paid and more resources should be allocated to the attributes of the ‘building automation system’. The attributes of ‘building automation system’ are: 1) ability of integration, 2) reliability, 3) efficiency and 4) life cycle cost need additional attention and resources to reach higher satisfactory.

According to the results of the thesis, ‘building automation system’ is placed in “keep up the good work” quadrant in only importance-performance analysis for large scale buildings in Data Type 2. According to this analysis, ‘building automation system’ has high importance and satisfactory level but this never means that the level of the satisfactory is high and no attention is required to this system. In such situation, attention and resources are needed to keep the satisfaction in its current level. Because the control systems with high importance have huge impact on the intelligent building service quality, to keep service quality high, the resources for the control system should be sustained.

Regardless of data type and scale of the buildings, ‘building automation system’ is perceived as the most important control system in an intelligent building and the largest gaps always occur in building automation system. To decrease the gap values the satisfaction level of the occupants and users should be increased. It is certain that in all six analysis, the highest importance values belong to the system. In the same line, Wong and Li (2006) report that the building automation system is the most important control system. In addition, they defined the system as the primary control system in an intelligent building. The reason of this finding can be explained by the fact that the building automation system controls all the control systems in an intelligent building, in other words, an intelligent building is controlled by the building automation system. It integrates all other control systems under one control system. Thus, the attribute of ability of integration plays a vital role in service quality of the building automation system. As ‘building automation system’ is the core of an intelligent building and it controls all other functions, the reliability and efficiency are also very important. By the integration between the other control systems, building automation system reduces heating, ventilating and cooling costs, while reducing the costs of other systems. Life cycle cost of the building automation system should also be low.

Finally, since it is hard to define a building as ‘intelligent building’ without building automation system, it has the highest importance in service quality of an intelligent building.

‘HVAC control system’ is perceived as one of the most important control systems in an intelligent building in all buildings and small scale buildings of Data Type 1, all buildings and small scale buildings of Data Type 2. In those analysis, the system is allocated in “concentrate here” quadrant. As reported by According to Wong and Li (2008), HVAC control system is one of the main considerations in configuring intelligent building systems. The participants reported that they give high importance to this system but they are not satisfied with its performance. The finding means that the satisfaction level of the occupants and users should be increased. To increase the satisfaction level, more attention and resources are needed for 11 attributes of the system. These attributes are 1) total energy consumption, 2) predict mean value, 3) indoor air quality, 4) amount of fresh air changes per second, 5) noise level, 6) frequency of breakdown, 7) life span, 8) compatibility with other building systems, 9) integrated with building automation system, 10) first cost and 11) life cycle cost of the system. Each attribute's satisfactory level has impact on the overall satisfaction of the system.

Table 5.35. Positions of the HVAC control system in importance-performance grid.

	Building Type	Quadrant	Message of the Quadrant
Data Type 1	all buildings	Concentrate here	Increase resources
	small scale buildings	Concentrate here	Increase resources
	large scale buildings	Possible overkill	Curtail resources
Data Type 2	all buildings	Concentrate here	Increase resources
	small scale buildings	Concentrate here	Increase resources
	large scale buildings	Possible overkill	Curtail resources

The satisfaction level of the occupants and users can be increased by the new developments in the system. The remote control which requires the integration between the internet and the control system affects the satisfaction level of the occupants and users. To conserve energy and decrease the life cycle cost, the system could work with motion and occupancy sensors. The thermal comfort according to the number of the occupants in the space should be achieved. To bring together the high importance and high satisfaction level, additional importance should be attached to new developments in the system and the 11 attributes of the system.

In importance-performance analysis for large scale buildings in both Data Type 1 and Data Type 2, 'HVAC control system' takes place in 'possible overkill' quadrant. The participants reported the system performance with high score because the participants are highly satisfied with the system. But the respondents attached only a slight importance to the system. But it should be noted that, the system is not the least important control system in large scale buildings. It can be explained by the existence of more important control systems in large scale buildings. For example, in factories, shopping malls and hospitals, building automation system, telecom and data system, addressable fire detection and alarm system are perceived more important than the HVAC control system. The resources of the control system could be curtailed.

Table 5.32. Positions of the security system in importance-performance grid.

	Building Type	Quadrant	Message of the Quadrant
Data Type 1	all buildings	Keep up the good work	Sustain resources
	small scale buildings	Concentrate here	Increase resources
	large scale buildings	Keep up the good work	Sustain resources
Data Type 2	all buildings	Low priority	No change in resources
	small scale buildings	Low priority	No change in resources
	large scale buildings	Low priority	No change in resources

The ‘security system’ is the most inconsistent intelligent building control system according to its places in all six importance-performance analysis (Table 5.29). According to the results of all three analysis of Data Type 1, participants reported that ‘security system’ is very important control system in intelligent buildings. In importance-performance analysis of all buildings and large scale buildings in Data Type 1, ‘security system’ is allocated in “keep up the good work” quadrant. The control system has high importance level, as well as a high satisfaction level. Hence, the resources belonging to the control system are needed to sustain. In the analysis for small scale buildings in Data Type 1, it is revealed that ‘security system’ has high importance but low satisfaction. The satisfaction level could be increased by paying more attention to the attributes of the system. The attributes can be listed as 1) time needed for public announcement of disasters, 2) time needed to report a disastrous event to the building management, 3) time for total agress, 4) life span, 5) allow for further upgrade, 6) compatibility with other building systems, 7) integrated with building automation system, 8) first cost and 9) life cycle cost.

On the other hand, in Data Type 2, regardless of the building scale, ‘security system’ is placed in “low priority” quadrant. Therefore, no change in the resources of the control system is needed. It should be at the bottom of the priority list for the improvement because it has low importance and low satisfaction. Nevertheless, the managers, architects and automation experts may want to increase the level of satisfaction of occupants and users. The developments in the control system should be implemented. The technological developments in access monitoring, card access control, motion detectors, networked digital closed circuit TV and person identification systems have huge impact on the service quality of security system.

Table 5.33. Positions of the addressable fire detection and alarm system in importance-performance grid.

	Building Type	Quadrant	Message of the Quadrant
Data Type 1	all buildings	Keep up the good work	Sustain resources
	small scale buildings	Keep up the good work	Sustain resources
	large scale buildings	Keep up the good work	Sustain resources
Data Type 2	all buildings	Keep up the good work	Sustain resources
	small scale buildings	Keep up the good work	Sustain resources
	large scale buildings	Keep up the good work	Sustain resources

‘Addressable fire detection and alarm system’ is the most consistent intelligent building control system according to the quadrants in all six importance-performance analysis (Table 5.29.). It is allocated in “keep up the good work” quadrant in all importance-performance analysis of the both Data Type 1 and Data Type 2 which means the system has both high importance and performance.

‘Addressable fire detection and alarm system’ is directly related to the occupants’ health and life. The safety of the occupants and users is ensured by the system. The reaction time and reliability of the system are vital for all the respondents of the questionnaire. Such a high importance level could be explained by the direct relation with the safety of the occupants. The performance of the system is reported to be high, too. The performance of the addressable fire detection and alarm system is attached to seven attributes; 1) compliance with fire protection and fighting code, 2) compliance with fire resistance code, 3) automatic sensoring and detection system for flame, smoke and gas, 4) signal transmission rate, 5) life span, 6) allow for further upgrade, and 7) life cycle cost. To keep the current level of the satisfaction of occupants and users in such an important system, reliability and response time of the sensors need more attention. No matter how the response time is short, the alarm should be reliable. Also the system must be integrated with other systems. In emergency, by this integration the safety of the occupants must be ensured. For example, HVAC system must extract the smoke, vertical transportation system must be ready to use of the occupants to exit the building and lighting control system must work for lighting the rescue pathways. Telecom and data system must give emergency messages and security system must lock the doors according to the fire codes to block the smoke and fire. The addressable fire and detection system must allow such integrations to protect the occupants and users of the building. The managers, architects, and automation engineers should sustain the resources of the control system to continue with a high level of satisfaction.

Table 5.34. Positions of the telecom and data system in importance-performance grid.

	Building Type	Quadrant	Message of the Quadrant
Data Type 1	all buildings	Keep up the good work	Sustain resources
	small scale buildings	Keep up the good work	Sustain resources
	large scale buildings	Keep up the good work	Sustain resources
Data Type 2	all buildings	Keep up the good work	Sustain resources
	small scale buildings	Possible overkill	Curtail resources
	large scale buildings	Concentrate here	Increase resources

'Telecom and data system' is allocated in "keep up the good work" quadrant in all three analysis of Data Type 1. The system is allocated in "keep up the good work" quadrant in the analysis for all buildings in Data Type 2, which shows that both importance and performance level of the system are evaluated high. That means additional attention and resources is not needed for the control system. The managers of the construction companies, architects and automation companies should work to sustain the level of satisfaction.

In the analysis for small scale buildings in Data Type 2, the system takes place in "possible overkill" quadrant with low importance and low performance. On the other hand, in the analysis for large scale buildings in Data Type 2, 'telecom and data system' is evaluated in the "concentrate here" quadrant. The place of the system emphasizes the priority for improvement in the control system. The system must have both high importance and performance. To reach high satisfaction level, five attributes of telecom and data system need more attention and resources. The attributes are 1) transmission rate, 2) reliability, 3) allow for further upgrade, 4) life span and 5) life cycle cost. In large scale buildings such as hospitals, shopping malls, airports and factories, information transfer is very important and information transfer is done by the ‘telecom and data system’. The system is responsible for all voice services, the messages of all other control systems, video and audio conferencing, electronic mails, internet access and all information services. Furthermore, while the size of the building gets larger, the importance of the system gets higher. Hence, in large scale buildings, the performance level of the control system should be increased to prevent the high values of customer gaps.

Table 5.35. Positions of the digital addressable lighting control system in importance-performance grid.

	Building Type	Quadrant	Message of the Quadrant
Data Type 1	all buildings	Low priority	No change in resources
	small scale buildings	Possible overkill	Curtail resources
	large scale buildings	Low priority	No change in resources
Data Type 2	all buildings	Low priority	No change in resources
	small scale buildings	Possible overkill	Curtail resources
	large scale buildings	Low priority	No change in resources

Table 5.36. Positions of the vertical transportation system in importance-performance grid.

	Building Type	Quadrant	Message of the Quadrant
Data Type 1	all buildings	Low priority	No change in resources
	small scale buildings	Possible overkill	Curtail resources
	large scale buildings	Low priority	No change in resources
Data Type 2	all buildings	Low priority	No change in resources
	small scale buildings	Possible overkill	Curtail resources
	large scale buildings	Low priority	No change in resources

‘Digital addressable lighting control system’ and ‘vertical transportation system’ are considered as two control systems which have minimal importance in an intelligent building. Wong and Li (2006) listed the both systems as secondary control systems in intelligent buildings according to the findings of their research. Both digital addressable lighting control system and vertical transportation system have similar patterns in importance-performance analysis of Data Type 1 and Data Type 2. In all six importance-performance analysis, the systems take place in a quadrant with low importance. In the analysis for all buildings and large scale buildings in the both Data Type 1 and Data Type 2, the control systems are allocated in “low priority” quadrant with low importance and performance rating. In the analysis for small scale buildings in both Data Type 1 and Data Type 2, they take place in “possible overkill” quadrant with low importance and high performance rating. Regardless of the data type and scale of the building, ‘digital addressable lighting control system’ and ‘vertical transportation system’ are evaluated as slightly important by the respondents. It can be understood from the results that additional attention and resources are not needed for these systems and the resources for these systems should be decreased.

The analysis indicated that ‘digital addressable lighting control system’ and ‘vertical transportation system’ have not vital role in the service quality of intelligent buildings because the participants reported that the systems have low importance level. The resources and attention that allocated for these systems are enough in consideration of low importance level of the systems. The service quality of ‘digital addressable lighting control system’ is evaluated by nine attributes. The attributes are 1) average efficacy of all lamps, 2) ease of control, 3) permanent artificial lighting average power density, 4) automatic control and adjustment of lux level, 5) life span, 6) allow for further upgrade, 7) compatibility with other building systems, 8) integrated with building automation system, and 9) life cycle cost. The service quality of ‘vertical transportation system’ is assessed by 14 attributes. They are 1) energy consumption, 2) acceleration and deceleration, 3) air change, 4) noise level, 5) vibration level, 6) maximum interval time, 7) journey time, 8) waiting time, 9) automatic and remote monitoring, 10) life span, 11) compatibility with other building system, 12) integrated with building automation system, 13) reliability, and 14) life cycle cost. The attributes has no priority for service quality improvements of an intelligent building.

CHAPTER 6

CONCLUSION

Advanced technologies are continuously integrated into newly constructed buildings in order to provide more comfortable, healthier and more secure places to live and to work in. In this line, intelligent buildings and intelligent building control systems have become very popular research topics in recent years. The most important intelligence criterion is set as whether these buildings embody the required advanced-technological control systems or not. Literature reveals that there have been numerous studies conducted to evaluate performance of intelligent buildings by utilizing various numerical methods, which mainly measure the efficiency level of intelligent building control systems. However, intelligent performance evaluation solely depending on technical merits but ignoring customer expectations is misleading. It is crucial to reveal customer needs and expectations for intelligent labeled buildings in order to attain a better intelligent design quality and to gain a greater intelligent market share. This thesis is also based on the performance of intelligent buildings however from the perspective of customers. Performance evaluation of intelligent buildings is examined within the service quality framework, which takes care of the needs, expectations and satisfaction of customers. Thus, an importance-performance and a customer gap analysis are conducted to measure the satisfaction level of customers regarding the service quality provided by the building automation system, telecom and data system, addressable fire detection and alarm system, heating, ventilating and air-conditioning system, digital addressable lighting control system, security system, and vertical transportation system integrated to an intelligent building. Customer satisfaction is measured by the gap between the expected and experienced service of each one of the intelligent building control systems. Each control system is assessed by the attributes of technical effectiveness, work efficiency, cost effectiveness, user comfort, and environmental impact. The results provided the priorities for improvement of building control systems. The findings aim to aid the designers, managers, and automation system developers and experts in improving the service quality of the under-performing control systems in order to increase the customer satisfaction level.

Data are collected by two web-based surveys designed on a seven point Likert scale to reveal both the expected and perceived service by respondents. Collected data are analyzed in two groups. Firstly, all data gathered, which refer to 53 buildings are used for statistical analysis to obtain as much information as possible for buildings indicated as intelligent. Then, 26 intelligent buildings whose both expected service rating (importance) and perceived service rating (performance) responses match up are used for further service quality analysis. The mean values for each building control system are calculated. Then t-test is used to compare their means in order to find the gaps between the customer expectations and perceptions. Customer evaluations are assessed by scale sensitive groupings and two sets are created as small and large scale intelligent buildings.

The findings of the gap analysis for both groups of data reveal that all control systems have negative values, which mean that the expected service values are greater than the perceived service values. This emphasizes that the satisfaction level perceived by the customers for intelligent building control systems could not attain the customers' expected level of service quality. The largest gaps are found between the importance and performance mean values of the building automation system and HVAC control system regarding 53 intelligent buildings. Scale oriented gap analysis indicates that customer gaps are generally larger for small-scale buildings. The largest gap difference between the small-scale intelligent buildings and the large-scale intelligent buildings is found in the HVAC control system. Then, importance-performance analysis is conducted to reflect the customers' insight and to develop proper managerial and architectural improvement priorities for future automation design and construction. Consequently, building automation system and HVAC control system should be highly prioritized. The quadrant that both systems fall in the importance-performance analysis grid combines the high importance and the low performance indicators. The results of the gap analysis also support this prioritization with higher gap values. Customer gap analysis shows that both systems have the largest gaps and have the highest priority for future improvements.

The findings of this thesis are significant in many ways. For the first time, customer perceptions about the service quality of intelligent building control systems have become a research topic. The findings do not only reveal customer expectations but also provide strategic feedback for architects, automation system providers and managers of construction companies for a better intelligent building market share. In other words, the analysis and findings are beneficial as to provide a guide to assist strategy development of sector companies for future building design and construction. The expectations and satisfaction level of the customers are primary indicators, which re-shape the future of the construction sector. The satisfaction level of the customers about the service quality of intelligent building control systems is the main parameter that constitutes the connection between the customers' expectations and the managerial act. Overall, the proposed performance evaluation analysis and the findings are vital for the welfare of the construction sector. The IPA and GAPA could be used repeatedly in time for the updated data on customer satisfaction for the upcoming intelligent building control systems.

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APPENDIX A

QUESTIONNAIRES

A-1 Expected Service (Importance) Questionnaire

1. Anketi dolduran kişinin otomasyon sistemi (kontrol paneli, otomatik ısıtma, soğutma, güvenlik sistemi) mevcut olan bina ile olan ilişkisi;

☐ Kullanıcı

☐ Mimar

☐ Mühendis

☐ Otomasyon uzmanı

☐ Yönetici

☐ Bina hakkında bilgi sahibi olan kişi (ziyaret etmiş, geçici olarak kullanmış vb.)

☐ Diğer (lütfen belirtin)

2. Önem derecesi anketini hangi tip bina için doldurmayı tercih edersiniz.

○ Villa

○ Apartman dairesi/ rezidans

○ İş merkezi

○ Alışveriş merkezi

○ Diğer (lütfen belirtin)

3. Otomasyon sistemleri mevcut olan bir binada, bütünleşik bina otomasyon sistemi ile ilgili aşağıdaki teknik özellikleri ne kadar önemli buluyorsunuz? (1'den 7'ye kadar puanlayın)

	Hiç önemli değil (1)	Önemsiz (2)	Çok önemli değil (3)	Nötr/Orta (4)	Biraz önemli (5)	Önemli (6)	Çok Önemli (7)
Sistemin binadaki, binaya entegre diğer sistemleri (asansör, aydınlatma, güvenlik, yangın vb.) kontrol etme ve izlemedeki yeterliliği	○	○	○	○	○	○	○
Sistemin güvenilirliği ve istikrarı	○	○	○	○	○	○	○
Sistemin verimliliği ve doğruluğu	○	○	○	○	○	○	○
Sistemin işletme ve bakım maliyeti	○	○	○	○	○	○	○

4. Otomasyon sistemleri mevcut olan bir binada, bilgi ve iletişim ağı ile ilgili aşağıdaki teknik özellikleri ne kadar önemli buluyorsunuz? (1'den 7'ye kadar puanlayın)

	Hiç önemli değil (1)	Önemsiz (2)	Çok önemli değil (3)	Nötr/Orta (4)	Biraz önemli (5)	Önemli (6)	Çok önemli (7)
Sistemin veri iletim hızı	○	○	○	○	○	○	○
Sistemin güvenilirliği ve istikrarı	○	○	○	○	○	○	○
Sistemin güncellenebilirliği ve iyileştirilebilirliği (gerekli altyapının sağlanması)	○	○	○	○	○	○	○
Sistemin ömrü/hizmet süresi	○	○	○	○	○	○	○
Sistemin işletme ve bakım maliyeti	○	○	○	○	○	○	○

5. Otomasyon sistemleri mevcut olan bir binada, yangın algılama ve alarm sistemi ile ilgili aşağıdaki teknik özellikleri ne kadar önemli buluyorsunuz? (1'den 7'ye kadar puanlayın)

	Hiç önemli değil (1)	Önemsiz (2)	Çok önemli değil (3)	Nötr/Orta (4)	Biraz önemli (5)	Önemli (6)	Çok önemli (7)
Sistemin alev, duman, gaz, koku, vb. uyaranları otomatik algılama becerisi	○	○	○	○	○	○	○
Sistemin tepki süresi ve tepki süresinin sürdürülebilirliği/yangın anında devamı	○	○	○	○	○	○	○
Sistemin ömrü/hizmet süresi	○	○	○	○	○	○	○
Sistemin güncellenebilirliği ve iyileştirilebilirliği (gerekli altyapının sağlanması)	○	○	○	○	○	○	○
Sistemin işletme ve bakım maliyeti	○	○	○	○	○	○	○
Sistemin yangın yönetmeliğine yangından korunma açısından uygunluğu	○	○	○	○	○	○	○
Sistemin yangın yönetmeliğine yangına dayanım açısından uygunluğu	○	○	○	○	○	○	○

6. Otomasyon sistemleri mevcut olan bir binada, ısıtma, soğutma ve klima kontrol sistemi ile ilgili aşağıdaki teknik özellikleri ne kadar önemli buluyorsunuz? (1'den 7'ye kadar puanlayın)

	Hiç önemli değil (1)	Önemsiz (2)	Çok önemli değil (3)	Nötr/Orta (4)	Biraz önemli (5)	Önemli (6)	Çok önemli (7)
Sistemin güvenilirliği ve istikrarı	○	○	○	○	○	○	○
Sistemin ömrü/hizmet süresi	○	○	○	○	○	○	○
Sistemin binadaki diğer sistemler ile etkileşimi/uyumu	○	○	○	○	○	○	○

	Hiç önemli değil (1)	Önemsiz (2)	Çok önemli değil (3)	Nötr/Orta (4)	Biraz önemli (5)	Önemli (6)	Çok önemli (7)
Sistemin Bina Otomasyon Sistemi ile entegrasyonu	○	○	○	○	○	○	○
Sistemin başlangıç maliyeti	○	○	○	○	○	○	○
Sistemin işletme ve bakım maliyeti	○	○	○	○	○	○	○
Isıl konforun (hava ve yüzey sıcaklıklarının, bağıl nemin ve hava hızının) kontrol edilebilmesi	○	○	○	○	○	○	○
Sistemin içerideki havanın kalitesini kontrol edebilmesi	○	○	○	○	○	○	○
Sistemin yeterli temiz hava değişimine izin vermesi	○	○	○	○	○	○	○
Sistemin havalandırma ve klimadan kaynaklanan gürültü seviyesini en aza indirgeyebilmesi	○	○	○	○	○	○	○
Sistemin toplam enerji tüketimi	○	○	○	○	○	○	○

7. Otomasyon sistemleri mevcut olan bir binada, aydınlatma sistemi ile ilgili aşağıdaki teknik özellikleri ne kadar önemli buluyorsunuz? (1'den /'ye kadar puanlayın)

	Hiç önemli değil (1)	Önemsiz (2)	Çok önemli değil (3)	Nötr/Orta (4)	Biraz önemli (5)	Önemli (6)	Çok önemli (7)
Sistemin sabit yapay aydınlatma gücünün yoğunluğu	○	○	○	○	○	○	○
Sistemin otomatik kontrolü ve aydınlatma seviyesinin ayarlanabilmesi	○	○	○	○	○	○	○
Sistemin ömrü/hizmet süresi	○	○	○	○	○	○	○
Sistemin güncellenebilirliği ve iyileştirilebilirliği (gerekli altyapının sağlanması)	○	○	○	○	○	○	○

	Hiç önemli değil (1)	Önemsiz (2)	Çok önemli değil (3)	Nötr/Orta (4)	Biraz önemli (5)	Önemli (6)	Çok önemli (7)
Sistemin binadaki diğer sistemler ile etkileşimi/uyumu							
Sistemin Bina Otomasyon Sistemi ile entegrasyonu							
Sistemin işletme ve bakım maliyeti							
Sistemin kontrol ve kullanım kolaylığı							
Sistemin toplam enerji tüketimi							

8. Otomasyon sistemleri mevcut olan bir binada, güvenlik sistemi ile ilgili aşağıdaki teknik özellikleri ne kadar önemli buluyorsunuz?

	Hiç önemli değil (1)	Önemsiz (2)	Çok önemli değil (3)	Nötr/Orta (4)	Biraz önemli (5)	Önemli (6)	Çok önemli (7)
Sistemin tehlikeyi bina kullanıcılarına haber verebilme süresi							
Sistemin tehlikeyi bina yönetimine haber verebilme süresi							
Sistemin kaçış planına/çıkış kapısına yönlendirebilme becerisi ve süresi							
Sistemin ömrü/hizmet süresi							
Sistemin güncellenebilirliği ve iyileştirilebilirliği (gerekli altyapının sağlanması)							
Sistemin binadaki diğer sistemler ile etkileşimi/uyumu							
Sistemin Bina Otomasyon Sistemi ile entegrasyonu							

	Hiç önemli değil (1)	Önemsiz (2)	Çok önemli değil (3)	Nötr/Orta (4)	Biraz önemli (5)	Önemli (6)	Çok önemli (7)
Sistemin başlangıç maliyeti	○	○	○	○	○	○	○
Sistemin işletme ve bakım maliyeti	○	○	○	○	○	○	○

9. Otomasyon sistemleri mevcut olan bir binada, asansör sistemi ile ilgili aşağıdaki teknik özellikleri ne kadar önemli buluyorsunuz? (1'den 7'ye kadar puanlayın)

	Hiç önemli değil (1)	Önemsiz (2)	Çok önemli değil (3)	Nötr/Orta (4)	Biraz önemli (5)	Önemli (6)	Çok önemli (7)
Asansörün çağrı anı ile terk edildiği an arasındaki zaman aralığı	○	○	○	○	○	○	○
Yolculuk süresi	○	○	○	○	○	○	○
Yolcunun bekleme süresi (asansörün çağırılmasından sonra asansörün kullanım uygunluğuna kadar geçen süre)	○	○	○	○	○	○	○
Asansörün otomatik uzaktan kontrol ve izlenebilirliği	○	○	○	○	○	○	○
Sistemin ömrü/hizmet süresi	○	○	○	○	○	○	○
Sistemin binadaki diğer sistemler ile etkileşimi/uyumu	○	○	○	○	○	○	○
Sistemin Bina Otomasyon Sistemi ile entegrasyonu	○	○	○	○	○	○	○
Sistemin işletme ve bakım maliyeti	○	○	○	○	○	○	○
Asansörün devre dışı kalma ve arızalanma sıklığı (bir ay içinde)	○	○	○	○	○	○	○
Asansörün hızlanma ve yavaşlama kontrolü	○	○	○	○	○	○	○
Sistemin yeterli hava değişimine izin vermesi	○	○	○	○	○	○	○

	Hiç önemli değil (1)	Önemsiz (2)	Çok önemli değil (3)	Nötr/Orta (4)	Biraz önemli (5)	Önemli (6)	Çok önemli (7)
Asansör kabini içerisindeki gürültü seviyesinin indirgenmişlik düzeyi	○	○	○	○	○	○	○
Asansör kabini içerisindeki titreşim seviyesinin indirgenmişlik düzeyi	○	○	○	○	○	○	○
Asansör sisteminin toplam enerji tüketimi	○	○	○	○	○	○	○

A-2 Perceived Service (Performance) Questionnaire

1. Anketi dolduran kişinin otomasyon sistemi mevcut olan bina ile olan ilişkisi;

☐ Kullanıcı

☐ Mimar

☐ Mühendis

☐ Otomasyon uzmanı

☐ Yönetici

☐ Bina hakkında bilgi sahibi olan kişi (ziyaret etmiş, geçici olarak kullanmış vb.)

☐ Diğer (lütfen belirtin)

[ ]

2. Değerlendirme yapacağınız;

Binanın/Projenin adı: [ ]

Proje hangi inşaat firmasına ait: [ ]

Projeyi nasıl tanımlarsınız (konut, villa, iş merkezi vb.) [ ]

3. Binadaki bina otomasyon sisteminin mevcut performansı ile ilgili aşağıdaki teknik özellikleri ne kadar başarılı buluyorsunuz? (1'den 7'ye kadar puanlayın)

	Hiç başarılı değil (1)	Başarısız (2)	Çok başarılı değil (3)	Nötr/Orta (4)	Biraz başarılı (5)	Başarılı (6)	Çok başarılı (7)	Mevcut değil/ Fikrim yok (0)
Sistemin binadaki, binaya entegre diğer sistemleri (asansör, aydınlatma, güvenlik, yangın vb.) kontrol etme ve izlemedeki yeterliliği								
Sistemin güvenilirliği ve istikrarı								
Sistemin verimliliği ve doğruluğu								
Sistemin işletme ve bakım maliyeti								

4. Binadaki bilgi ve iletişim ağı sisteminin mevcut performansı ile ilgili aşağıdaki teknik özellikleri ne kadar başarılı buluyorsunuz? (1'den 7'ye kadar puanlayın)

	Hiç başarılı değil (1)	Başarısız (2)	Çok başarılı değil (3)	Nötr/Orta (4)	Biraz başarılı (5)	Başarılı (6)	Çok başarılı (7)	Mevcut değil/ Fikrim yok (0)
Sistemin veri iletim hızı								
Sistemin güvenilirliği ve istikrarı								
Sistemin güncellenebilirliği ve iyileştirilebilirliği (gerekli altyapının sağlanması)								

	Hiç başarılı değil (1)	Başarısız (2)	Çok başarılı değil (3)	Nötr/Orta (4)	Biraz başarılı (5)	Başarılı (6)	Çok başarılı (7)	Mevcut değil/ Fikrim yok (0)
Sistemin ömrü/hizmet süresi								
Sistemin işletme ve bakım maliyeti								

5. Binadaki yangın algılama ve alarm sisteminin mevcut performansı ile ilgili aşağıdaki teknik özellikleri ne kadar başarılı buluyorsunuz? (1'den 7'ye kadar puanlayın)

	Hiç başarılı değil (1)	Başarısız (2)	Çok başarılı değil (3)	Nötr/Orta (4)	Biraz başarılı (5)	Başarılı (6)	Çok başarılı (7)	Mevcut değil/ Fikrim yok (0)
Sistemin alev, duman, gaz, koku, vb. uyaranları otomatik algılama becerisi								
Sistemin tepki süresi ve tepki süresinin sürdürülebilirliği/yangın anında devamı								
Sistemin ömrü/hizmet süresi								
Sistemin güncellenebilirliği ve iyileştirilebilirliği (gerekli altyapının sağlanması)								
Sistemin işletme ve bakım maliyeti								
Sistemin yangın yönetmeliğine yangından korunma açısından uygunluğu								
Sistemin yangın yönetmeliğine yangına dayanım açısından uygunluğu								

6. Binadaki ısıtma, soğutma ve klima kontrol sisteminin mevcut performansı ile ilgili aşağıdaki teknik özellikleri ne kadar başarılı buluyorsunuz? (1'den 7'ye kadar puanlayın)

	Hiç başarılı değil (1)	Başarısız (2)	Çok başarılı değil (3)	Nötr/Orta (4)	Biraz başarılı (5)	Başarılı (6)	Çok başarılı (7)	Mevcut değil/ Fikrim yok (0)
Sistemin güvenilirliği ve istikrarı	○	○	○	○	○	○	○	○
Sistemin ömrü/hizmet süresi	○	○	○	○	○	○	○	○
Sistemin binadaki diğer sistemler ile etkileşimi/uyumu	○	○	○	○	○	○	○	○
Sistemin Bina Otomasyon Sistemi ile entegrasyonu	○	○	○	○	○	○	○	○
Sistemin başlangıç maliyeti	○	○	○	○	○	○	○	○
Sistemin işletme ve bakım maliyeti	○	○	○	○	○	○	○	○
Isıl konforun (hava ve yüzey sıcaklıklarının, bağıl nemin ve hava hızının) kontrol edilebilmesi	○	○	○	○	○	○	○	○
Sistemin içerideki havanın kalitesini kontrol edebilmesi	○	○	○	○	○	○	○	○
Sistemin yeterli temiz hava değişimine izin vermesi	○	○	○	○	○	○	○	○
Sistemin havalandırma ve klimadan kaynaklanan gürültü seviyesini en aza indirgeyebilmesi	○	○	○	○	○	○	○	○
Sistemin toplam enerji tüketimi	○	○	○	○	○	○	○	○

7. Binadaki aydınlatma sisteminin mevcut performansı ile ilgili aşağıdaki teknik özellikleri ne kadar başarılı buluyorsunuz? (1'den 7'ye kadar puanlayın)

	Hiç başarılı değil (1)	Başarısız (2)	Çok başarılı değil (3)	Nötr/Orta (4)	Biraz başarılı (5)	Başarılı (6)	Çok başarılı (7)	Mevcut değil/ Fikrim yok (0)
Sistemin sabit yapay aydınlatma gücünün yoğunluğu	○	○	○	○	○	○	○	○
Sistemin otomatik kontrolü ve aydınlatma seviyesinin ayarlanabilmesi	○	○	○	○	○	○	○	○
Sistemin ömrü/hizmet süresi	○	○	○	○	○	○	○	○
Sistemin güncellenebilirliği ve iyileştirilebilirliği (gerekli altyapının sağlanması)	○	○	○	○	○	○	○	○
Sistemin binadaki diğer sistemler ile etkileşimi/uyumu	○	○	○	○	○	○	○	○
Sistemin Bina Otomasyon Sistemi ile entegrasyonu	○	○	○	○	○	○	○	○
Sistemin işletme ve bakım maliyeti	○	○	○	○	○	○	○	○
Sistemin kontrol ve kullanım kolaylığı	○	○	○	○	○	○	○	○
Sistemin toplam enerji tüketimi	○	○	○	○	○	○	○	○

8. Binadaki güvenlik sisteminin mevcut performansı ile ilgili aşağıdaki teknik özellikleri ne kadar başarılı buluyorsunuz? (1'den 7'ye kadar puanlayın)

	Hiç başarılı değil (1)	Başarısız (2)	Çok başarılı değil (3)	Nötr/Orta (4)	Biraz başarılı (5)	Başarılı (6)	Çok başarılı (7)	Mevcut değil/ Fikrim yok (0)
Sistemin tehlikeyi bina kullanıcılarına haber verebilme süresi	○	○	○	○	○	○	○	○
Sistemin tehlikeyi bina yönetimine haber verebilme süresi	○	○	○	○	○	○	○	○
Sistemin kaçış planına/çıkış kapısına yönlendirebilme becerisi ve süresi	○	○	○	○	○	○	○	○
Sistemin ömrü/hizmet süresi	○	○	○	○	○	○	○	○
Sistemin güncellenebilirliği ve iyileştirilebilirliği (gerekli altyapının sağlanması)	○	○	○	○	○	○	○	○
Sistemin binadaki diğer sistemler ile etkileşimi/uyumu	○	○	○	○	○	○	○	○
Sistemin Bina Otomasyon Sistemi ile entegrasyonu	○	○	○	○	○	○	○	○
Sistemin başlangıç maliyeti	○	○	○	○	○	○	○	○
Sistemin işletme ve bakım maliyeti	○	○	○	○	○	○	○	○

9. Binadaki asansör sisteminin mevcut performansı ile ilgili aşağıdaki teknik özellikleri ne kadar başarılı buluyorsunuz? (1'den 7'ye kadar puanlayın)

	Hiç başarılı değil (1)	Başarısız (2)	Çok başarılı değil (3)	Nötr/Orta (4)	Biraz başarılı (5)	Başarılı (6)	Çok başarılı (7)	Mevcut değil/ Fikrim yok (0)
Asansörün çağrı anı ile terk edildiği an arasındaki zaman aralığı	○	○	○	○	○	○	○	○
Yolculuk süresi	○	○	○	○	○	○	○	○
Yolcunun bekleme süresi (asansörün çağırılmasından sonra asansörün kullanım uygunluğuna kadar geçen süre)	○	○	○	○	○	○	○	○
Asansörün otomatik uzaktan kontrol ve izlenebilirliği	○	○	○	○	○	○	○	○
Sistemin ömrü/hizmet süresi	○	○	○	○	○	○	○	○
Sistemin binadaki diğer sistemler ile etkileşimi/uyumu	○	○	○	○	○	○	○	○
Sistemin Bina Otomasyon Sistemi ile entegrasyonu	○	○	○	○	○	○	○	○
Sistemin işletme ve bakım maliyeti	○	○	○	○	○	○	○	○
Asansörün devre dışı kalma ve arızalanma sıklığı (bir ay içinde)	○	○	○	○	○	○	○	○
Asansörün hızlanma ve yavaşlama kontrolü	○	○	○	○	○	○	○	○
Sistemin yeterli hava değişimine izin vermesi	○	○	○	○	○	○	○	○
Asansör kabini içerisindeki gürültü seviyesinin indirgenmişlik düzeyi	○	○	○	○	○	○	○	○
Asansör kabini içerisindeki titreşim seviyesinin indirgenmişlik düzeyi	○	○	○	○	○	○	○	○
Asansör sisteminin toplam enerji tüketimi	○	○	○	○	○	○	○	○