Evaluating Smart House Adaptability Potentials of Residential Buildings in Famagusta, North Cyprus

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ABSTRACT

Future of buildings and the built environment is a predictable term. Predicting the future of building design is mainly related to the developments in Internet of Things (IT) and new developing technologies. Users of buildings demand to update their living spaces with new technologies to ease their daily life, this process makes changes in the function of building, architectural spaces, facilities, home automation gadgets and devices. Adaptability is known as an environmentally friendly answer to the mentioned changes, adaptability extends the useful age of building and it delays the need to construction a new building and lowers the rate of building demolitions and obsolescence. According to the previous academic literature, the future of building will be related to 'Smart' and 'Intelligent' terms. As a result, in this thesis the adaptability of buildings is going to respond to the new needs from smart and intelligent upgrades of a future building. There is a lack of literature over discovering adaptability potentials of an existing building which is going to be smart house in the future. This thesis researched 12 different smart and intelligent features through the literature review over the topic. The aim of this thesis is to categorize the definitions and features of smart house and then evaluate the potential of smart house adaptability of an existing building, the source of change is considered as the future developments of technology in building. This study reviews recent literature over the building adaptability and smart houses. At the end a case study evaluates the adaptability potential of residential buildings in Famagusta, North Cyprus.

Keywords: adaptable building, residential building, house, smart house, technology

ÖZ

Binaların ve yapılı çevrenin geleceği tahmin edilebilir bir terimdir. Bina tasarımının geleceğini tahmin etmek esas olarak Nesnelerin İnterneti (Nİ) ve yeni gelişen teknolojilerdeki gelişmelerle ilgilidir. Binaların kullanıcıları günlük yaşamlarını kolaylaştırmak için yaşam alanlarını yeni teknolojilerle güncellemek isterler, bu süreç bina, mimari mekanlar, tesisler, ev otomasyon alet ve cihazlarının işlevinde değişiklikler yapar. Uyarlanabilirlik, bahsedilen değişikliklere çevre dostu bir cevap olarak bilinir, uyarlanabilirlik binanın yararlı yaşını uzatır ve yeni bir bina inşa etme ihtiyacını geciktirir ve bina yıkım ve eskime oranını düşürür. Önceki akademik literatüre göre, inşa etmenin geleceği "Akıllı" ve "Zeki" terimleriyle ilişkili olacaktır. Sonuç olarak, bu tezde binaların uyarlanabilirliği, gelecekteki bir binanın akıllı ve zeki yükseltmelerinden gelen yeni ihtiyaçlara cevap verecektir. Gelecekte akıllı ev olacak mevcut bir binanın uyarlanabilirlik potansiyellerini keşfetme konusunda literatür eksikliği var. Bu tez, konu üzerine literatür taraması yoluyla 12 farklı akıllı ve zeki özelliği araştırdı. Bu tezin amacı, akıllı evin tanımlarını ve özelliklerini kategorize etmek ve daha sonra mevcut bir binanın akıllı ev uyarlanabilirlik potansiyelini değerlendirmektir, değişimin kaynağı yapıdaki teknolojinin gelecekteki gelişmeleri olarak kabul edilir. Bu çalışma, bina uyarlanabilirliği ve akıllı evler hakkındaki son literatürü gözden geçirmektedir. Sonunda bir analiz çalışması, Kuzey Kıbrıs'ın Gazimağusa kentindeki konutların uyarlanabilirlik potansiyelini değerlendiriyor.

Anahtar kelimeler: uyarlanabilir bina, konut binası, ev, akıllı ev, teknoloji

To My Family...

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I would like to express my great appreciation to my supervisor Assoc.Prof.Dr. Afet Çelıker Coşkun for her notable patience and incredible support at every stage of this thesis.

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Chapter 1

INTRODUCTION

The building developments are growing fast through recent decades and the building industry is about to answer the new needs of users, both users and employers are looking for new trends and as a result the building design and functions are changing. Every aspect of the built environment is involved, both interiors and exteriors are changing rapidly as a result of building design developments. In this case it is important to find and predict the changes.

Technological development is one of the main factors that cause change in the building sector. Modern society has more experience of working with new technologies and gadgets in their daily life, so they often try to improve their living quality with installing new gadgets or devices, they get more advantage from technological devices, which are designed or programmed to ease user’s daily life.

Smart house and smart cities are known as the future of the built environment, they demand more functionality and accelerated technologies to increase the performance of the building (Buckman, Mayfield, & Beck, 2014). There are various available studies trying to define a clear definition for smart buildings, smart gadgets and smart devices are used widely inside the building industry, according to Kamel and Memari (2018) there are various aspects which made smart houses such as data processing systems, control, communication and sensing or measuring tools.

Architecture pays attention to the new needs of users to ease their daily life and improve it, while building costs are high in modern societies and constructing a new building is not the reasonable idea to cover the new needs. it’s not sustainable and the high cost of living is an issue. The answer is to design a flexible building which can be adaptable to future changes, while technology development plays an important role in this issue the future of houses can be predicted and buildings can be adaptable to their further needs.

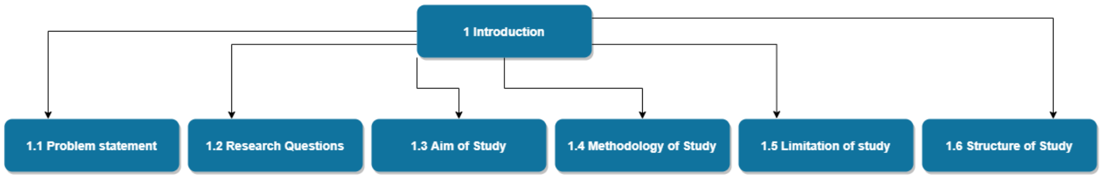


Figure 1: Summary of chapter one

1.1 Problem Statement

In modern societies, when somebody wants to find a new building there are many reasons behind the customer’s basic decision, to use or build a new building or to use an existing building.

Usually when a building is not answering the new needs of the user, building a new one will be the answer. It’s better to avoid the rebuilding process, since it’s not sustainable and also not economically acceptable.

Thinking about the future of building industry can provide a solution for the problem. If the further needs of users are considered, the building will be adaptable to changes for a longer period of time. Wong & Wang (2005) researched over definitions of intelligent buildings and found that there is a high risk of demolition, obsolescence or significant refurbishment for those buildings which are not responding to new changes in the occupants who are using them or in the technologies that users used.

In general, predicting the future of building is involved with the developments of technology. researching over the future of technology may help to predict the future of buildings, according to related literature the future of houses will be smart. According to Buckman et al. (2014), “Smart cities are commonly seen to be the future of the built environment” (p. 93).

In order to design a building with the ability of upgrading to smart, spatial and functional needs of a smart building should be considered. With the development of technology, new definitions, new devices and new spaces will affect the building’s usage and interior elements may be changed in order to support the new technological equipment and new space functions.

In interior architecture design, adaptability and flexibility are the keywords which will cover the design process for this issue. Adaptability is known with different types. Each of them is involved with different elements or aspects of a building. To design a flexible building, first it’s necessary to define the purpose of design, changes can happen through a long or short period of time.

By reviewing various academic literature on the subject, it would be observed that there is a lack of research over the adaptability potentials of an existing building which will get smart in the future. In order to find the answer, the needs and features of a smart house should be defined and then finding the effective adaptability types to cover the future needs, would be discussed in this study.

1.2 Research Questions

However, to be able to generate the appropriate data required for this study, the following questions are important to this study; The primary research question of this study is:

What are the smart features which turns a building to smart house? How these features can affect the space and functions of an existing building? How can an existing residential building be evaluated in terms of smart features adaptably?

The other research question of the study are as follows:

- What is the future of the building industry?
- What is the definition of smart house?
- What type of adaptability will be effective to fulfil the future smart house needs?

In this study the spaces of residential buildings will be analyzed to find adaptability potentials for future changes, which can upgrade to a smart house. The main purpose is to predict the future of building and find adaptable potentials for smart future upgrades in order to reduce the rebuilding process and make the current buildings reusable in the future. With the aim of answering the research questions, the title of this thesis is going to be: Evaluating smart house adaptability potentials of residential buildings in Famagusta, North Cyprus.

1.3 Aim of Study

This study seeks to review various academic researches on this related discourse, to be able to define smart house and categorize definitions and features of smart houses, hence providing a categorization of smart features, which can be evaluated in terms of adaptability potentials for the future changes from them. thereby presenting method to evaluate adaptability of an existing building for the future smart upgrades. It is the hope of the researcher that this study can help the designers to have an understanding of smart house feature needs and using adaptability in their designs which can attend to future needs of smart houses. This study also may help to increase the chance of adaptable reusing instead of rebuilding process in the future of the building industry.

The future of the buildings will be discussed through the related literature, the most arguable option will be considered as the future of the built environment. Then, the smart features of buildings will be categorized in order to find the future probable spatial and functional needs of a residential buildings. Meanwhile, Adaptability and flexibility will be discussed in order to find adaptable types and definitions. Therefore, case studies would involve the evaluation of current buildings potentials and their adaptable capability to the categorized list of smart features.

The main aim of this study is to generate adequate information of smart houses that would categorize the smart features of a future residential building and researching over adaptability, both will be used to find adaptability potentials of an existing building for future changes. This may cover the problem of the research to reuse and existing building and avoid demolitions and related environmental risks which revert from obsolescence. The study may help both designers and clients to find related data for their future residential projects.

1.4 Methodology of Study

The method of this study would involve the analysis of a wide range of data, and employment of both qualitative and quantitative approach, hence, data collection from relevant sources like books, papers, journals, thesis and other written materials.

This study employed a mixed method to fill the gap of research, which is a lack of information about smart house adaptability and how to design an adaptable building with respect to the future of the residential buildings which are going to be smart as next generation houses. A wide range of previous studies was analyzed to find related literature of adaptable building design and smart house features, the case studies will help to examine adaptability potentials for smart upgrades of new residential buildings and compare them inside tables to analyze.

1.5 Limitation of Study

The study is limited to the analysis of the smart house adaptability potentials of residential buildings. In this study the future of the built environment is limited to smart and intelligent buildings and their related features. The analysis of residential buildings is going to be limited to functional and spatial features of the selected buildings in terms of smart house features, the smart features are limited to fire detection, fire protection, occupant detection, activity recognition, communication network, smart security, smart lighting control, smart lift, smart heating, smart solar panels, kinetic façade and double-skin façade. Of course, more smart features were researched during the literature review like entertainment areas or facilities for elderly and disable people and etc. But they were not related to adaptability evaluation and not included in this study. The spaces of residential buildings for adaptability evaluation are limited to interior spaces of each flat type such as: entrance, bedrooms, living room, kitchen, Bathroom, balcony and façade of the building. The adaptable types of both interior and exterior architecture will be analyzed and. The adaptability types for the evaluation are limited to 6 main types which are: adjustable, versatile, refit-able, convertible, scalable and movable. To have better understanding of adaptability of cases, material durability and height of floors were recorded in the case study observation.

1.6 Structure of Study

The structure of this thesis is divided into 5 main chapters. The problem statement, aim of study, methodology, limitation of study and structure is discussed in the first chapter. The second chapter is based on literature review of related data for the future of building industry and definition of intelligent and smart houses. The third chapter will focus on the Interior design features of smart houses and defines adaptability to achieve the selected method of this thesis. The fourth chapter method of study will collect and analyze information from a case study and finally, the fifth chapter will conclude and summarize the study and discuss case study results. The structure of study presented at the end.

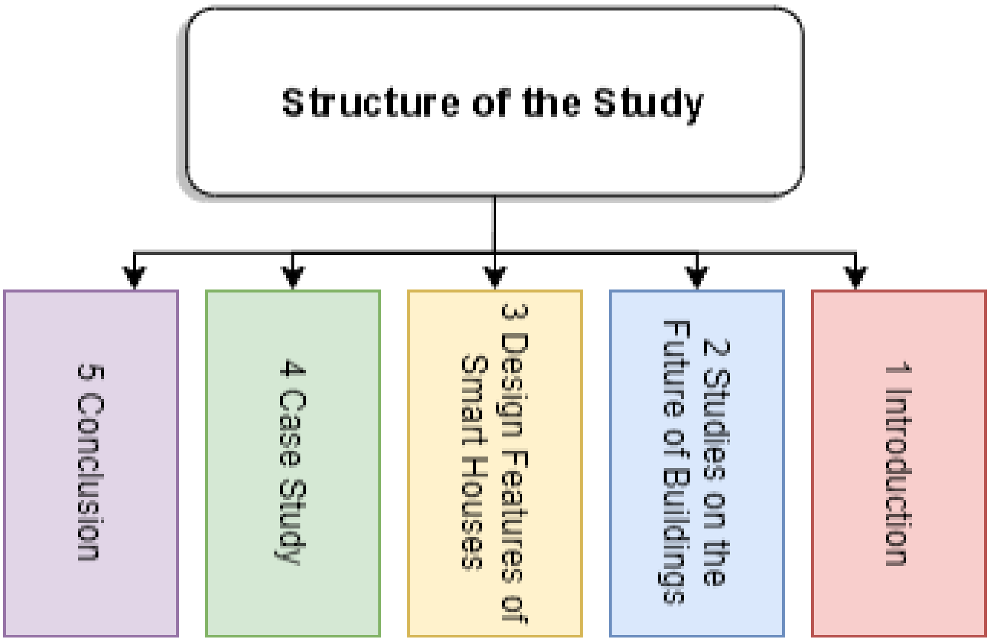


Figure 2: Structure of the study

Chapter 2

STUDIES ON THE FUTURE OF BUILDINGS

This chapter is researching over available definitions of smart and intelligent houses. By considering the most recent academic literature and data about the future of buildings, it is evident that the most researchers divided the future of the built environment into smart and intelligent houses. Academic data for the smart and intelligent houses are going to be reviewed in this chapter in order to have an understanding about the definition and general features of these buildings. literature review also talked about instances of smart houses, to have a better insight about the smart house finished projects, at the end of this chapter the instances of smart houses are selected and researched.

By reviewing the data from literature review, the future of the built environment, the definition of smart and intelligent houses and instances of smart houses will be reviewed in this chapter, the outcome of this literature review is necessary for selecting the interior design based smart features, which will be discussed in chapter3.

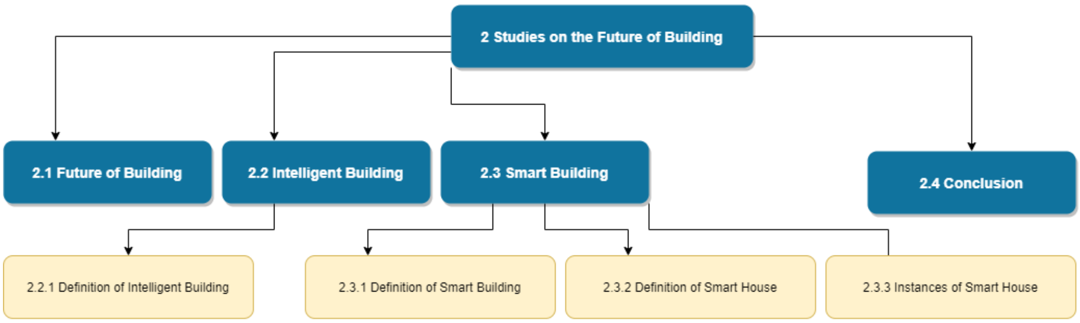


Figure 3: Summary of chapter two

2.1 Future of Building

The building industry has changed through the last 100 years. The buildings were made from basic materials such as bricks and stones with primary systems for water dispensing, gas and electrical equipment, in contrast to modern buildings which are designed with more complex design and they are built dynamically (Buckman, et al., 2014). Recent building design is demanding to add more functions to the buildings in any building category, for example technological developments in recent years have changed the daily lives of buildings users and which have led to considerable energy consumption issues in contemporary buildings. However, buildings of the future would have the ability to provide predominant modern services e.g., communication, health, electricity, utility, leisure, and security. People spend a significant amount of time in their houses, which attracts potential investors to promote the integration of all possible services into traditional houses. There are a variety of reasons and progress behind changing the buildings. Smith argued that there are drivers behind this change in building design and these drivers are known to add value to the building (Buckman et al., 2014). Through the recent academic literature, it is evident that researchers are illustrating the differences between the term “smart” and “intelligent” while sometimes these two meanings are getting confused. (Buckman et al., 2014).

2.2 Intelligent Building

Intelligent building concept was made from the user demands for more comfortable living and this term is highly related to the technologies that help users to have better control over their living environments. Through the literature the concept of intelligent building is mainly discussed with the developments of technology and Information technology. first usage of “Intelligent” word was in 1980 to mark out buildings which were located in the United States of America (Wong & Wang, 2005). The difference between intelligent building and smart building is mostly discussed in literature which aims to define separate definitions for each type. According to Buckman et al. (2014), in some academic perspectives the smart building is a subclass inside intelligent building, intelligent buildings are mostly recognized with the process of gathering data and responding to them, in the future of building design the term intelligent will play an important role. The smart buildings are known as a potential name for the future of intelligent buildings. Buckman et al. (2014) also discussed smart buildings as a part of intelligent building but with adaptable futures. Definitions of intelligent buildings are very diverse in the academic literature and most related ones to this study will explained further in this chapter.

2.2.1 Definition of Intelligent Building

Intelligent building definition is mainly related to the users and their needs, users are looking for a house which offers helpful services and they want to bring more comfort to their houses. Wigginton & Harris stated that the “Intelligent” building concept was encouraged by the increasing need from occupants to control and comfort their living environments and there are more than 30 different definitions for intelligent buildings (Wong & Wang, 2005). However, in support of the above argument Powell (1990), defined intelligent building as that dominate its environment completely, which can be seen from the technological domination of the building’s air conditioning and heating, telecommunication, fire prevention and protection, lift, lighting, security, and data service, with other systems of the building that are critical. The management computer system is in charge of the domination of the operations of the building just started.

This definition of intelligent buildings was mostly around the impact of building operation and decreasing the interaction between users and building with automation

(Buckman et al., 2014). This is also reinforced by Wong & Wang (2005) reviewed the literature over intelligent building definitions and stated that early explanations of intelligent buildings were concentrated on technological terms and user interaction was omitted. The lack of user interaction in early explanations of intelligent buildings was also mentioned as Omar (2018) states that the early definitions of IBs (Intelligent Buildings) did not study user interactions, but it changed through the recent definitions and the user interactions in the interior space of a building, started to mention in the new definitions. Through the literature it is evident that intelligent buildings have to answer users' needs (Wong & Wang, 2005).

The Conseil International du Batiment working Groups in 1995 gave a definition of intelligent building as an architecture that are vigorous and sensitive, which avail the inhabitant with a more productive, cost efficient and ecological validated situations, which are done within the four primary elements through which they have constant communication within themselves (Everett, 2008). As started by Everett (2008), the primary elements of intelligent Building are places, processes, people and management.

Furthermore, for defining an intelligent building, researchers have also concentrated on the needs of users. Clements-Croome (2011) defined intelligent building as the building that is sensitive to the needs of the inhabitants, community and society.

Intelligent buildings have advantages of sustainability of energy and water consumptions, with a shortcoming of emissions and waste. Different early approaches to define an intelligent building make it difficult to present a design framework for these buildings. However, Wong & Wang (2005) argued that so many present definitions of intelligent buildings are not clear enough to provide a framework that would be critical for the design of the intelligent building, which might result in a whole focus on the technological aspect of intelligent building or even going against the culture of the host community. Hence the need for a clear definition of intelligent building is very critical for the optimal design that would meet all the needs of this rapid changing world. In regards to this, Wong & Wang (2005) adopted the recommendation of So et al (2001), who proposed a two-stratum approach to create an efficient intelligent building definition. The first one is made up of nine 'Quality Environment Modules' (QEM) and the second one has three sectors of vital features that are functional technologies, functional spaces and functional requirements. Despite that Chow (2004) recommended an extra one to the nine proposed by So et al (2001), which is the health discourse of the building. Therefore, the ten QEM proposed by both So et al 2001 and Chow 2004 are stated below:

- Environmental friendliness
- Space utilization and flexibility
- Cost effectiveness
- Human comfort
- Working efficiency
- Safety and security measures
- Culture
- Image of high technology
- Construction process and structure
- Health and sanitation.

Configuration of Intelligent Buildings

As stated by Yang and Peng (2001), the configuration of an intelligent building has been seen in two parts which are as follows:

- Physical building intelligence
- Intelligent building operation and management.

The physical building intelligence is made of the structure, skin (facade), electrical systems, information technology, internal partition, and mechanical systems. While the Intelligent building operation and management involves the processing of data from the physical building intelligence, for the organization, automation, communication and monitoring of the building system to promote optimal management and operation.

Energy Consumption

In some of the previous literature the intelligent buildings are defined with an introduction to energy consumption in the building industry. In the developed countries the energy consumption portion of the building sector is known as 20% up to 40% of the overall energy consumption and in countries such as the United States and Europe the energy consumption of buildings is more than industry usage and transportation energy usage (Perez-Lombard, Ortiz, & Pout, 2007). Climate change is now a critical issue and the usage of energy in buildings plays an important role to control the negative effects of climate change on human life. According to Omar (2018), by increasing the intelligent usage of buildings it is possible to save costs and decrease the energy consumption. In recent academic literature Intelligent buildings are expected to have ability to learn from its users and the building environment besides the ability to make change and react in response to the users and environment (Wong & Wang, 2005).

2.3 Smart Building

Future of the built environment was discussed and between the possible scenarios the most accurate is to consider smart house as origin of services, equipment and design of future houses. According to previous literature the future will be smart in the next generation houses. This is a result of a demand of users to ease their life. Smart and Intelligent buildings are two terms which have been treated in the previous academic literature as separate terms but they have some overlaps in their definition and samples. At this part, the literature review of the study will collect data for definition of smart and intelligent houses to have better understanding about the needs of houses in the future.

2.3.1 Definition of Smart Building

In the last 30 years, definition of intelligent buildings has been investigated unlike the smart definition which has been developed in more recent literature (Buckman et al., 2014). In the definition of smart houses, a variety of services and objectives are considered and they all work to facilitate the users (Kamel & Memari, 2018). In the criteria of smart house, definitions are very diverse and there is not a standard and unit definition of smart houses, in the literature review of academic papers and literature, each researcher covers a part of the services or goals of smart houses. The smart technologies are consisting of a variety of devices and are defined in a wide range of building criteria. According to Buckman et al. (2014), “This seems to be the case in all aspects of the built environment sector; smart sensors, smart materials and smart meters” (p. 92). There are different features defined for a smart house such as: energy saving, energy consumption, efficiency, sustainability, security, safety, health care, entertainment, monitoring, facilities for elderly and disable people which are not included in the limitation of this study. On the other hand, researchers also recognized a smart house with consideration of aspects such as: adaptability, multi-functionality and automation (Kamel & Memari, 2018). Labonnote and Holyland researched over the published papers concentrated over the smart house criteria and states that the most papers were mentioned Health services with the highest number of approximately 80 papers in 2010, after that safety, security and wellness were the researched area in smart houses with the peak of nearly 50 papers in 2010 and just less than 10 papers focused on entertainment and energy management between 2003 and 2013 (Kamel & Memari, 2018). Some potential importance of smart buildings is stated by Eugeny (2015) as:

- Inhabitant comfort: the activities of the behavior of those that occupy the house, using the data derived to maximize the indoor comfort.
- Energy savings: with the decrease in the usage of energy in smart housing is high, this would reduce the cost of running the building by those that own the building.
- Time saving: with the automation of everyday activities of the house the smart buildings can save a lot of time for those that occupy it.
- Assistive Domotics: smart building can provide immense assistant to the people of the society in need of support like the elderly and also the physically challenged individuals, with alerting the love ones and authorities responsible for them, thereby improving the quality of life of the inhabitant.
- Safety: smart buildings have a system that runs a diagnostic analysis on itself to prevent gas leaks, fire and water in the building; therefore, the inhabitants are alerted of an issue within the building.

- Health and Care: with the right level of light intensity, temperature, and air condition, is among the highest focus of smart building.

Eugeny 2015 also stated Smart building have various constituent parts which make it distinct from normal buildings can be seen through the following features:

- Software Component: a smart building should be able to general relevant information, analyze this information, and be able to make predictions and decisions concerning the nature of environment and individual activities; this is done by meters and sensors which extract this unprocessed information.
- Hardware Component: smart buildings are fitted with meters and sensors to be able to know what is going on in the building both the indoor and outdoor, which works like the human senses. Such conditions like light intensity, temperature, the level of carbon dioxide, with that of water and gas leak.
- Network Component: In order for the building to perform as a body, the building would need a communication network, which would provide connection for all the devices among them. Nevertheless, this communication is done alongside artificial intelligence, it can be said that this is the center nervous system of the building.

Buckman et al. (2014) argues that design and fabrication of modern buildings has changed in contrast to the buildings were designed 100 years ago and the buildings are more dynamic and complex, he also presented three drivers behind the building progression listed as: longevity, comfort and energy efficiency. These drivers are working to achieve the best performance of a new building.

2.3.2 Definition of Smart House

Smart houses can now be defined as the incorporation of services, which technology made them possible in the house through linking the smart devices, users are using them for higher quality of life (Robles & Kim, 2010). according to Ameena et al., (2013) a smart house can be said to be a house that consists of sensors, regulating devices and middle waves as well as a network. In a smart house the two main communication elements are smart load and smart Network. they went on to state that the core objective of the smart house is to give automation, enhance energy consumption and decrease environmental emission at houses. Balta-ozkan et al. (2014) also stated that Inhabitants of a smart house can regulate the energy usage more efficiently and still be able maintain a high level of comfort for several activities within the house through the capacity to regulate gadgets from a specific regulation point remotely. Therefore, Nazimye et al. (2014) defined smart house as a residence remotely tracked and regulated, which is fitted with communication link connecting sensors house gadgets, which offer services that meet the requirement of its occupants. However, the link networking various technological elements like sensors and gadgets as well as information that is critical to the notion of smart house, it is the presence of the links in the house that makes the smart house different from the normal house that is fitted with high-tech features. The link in the smart house connects with the smart city in order to offer good services. There are other researchers who present the differences between smart house and normal houses in their researches, as Scotts (2007) states that smart house is distinct from a house that is fitted with enhanced technology devices like smart meters and smart gadgets. However, in particular through the means of linked networks of gadgets and senses, smart house permit inhabitants to regulate the energy utilization in an efficient manner, while still improving the comfort for several activities within the house.

Popscu, (2018) and Acampora et al., 2013 proposes basic characteristics of smart house:

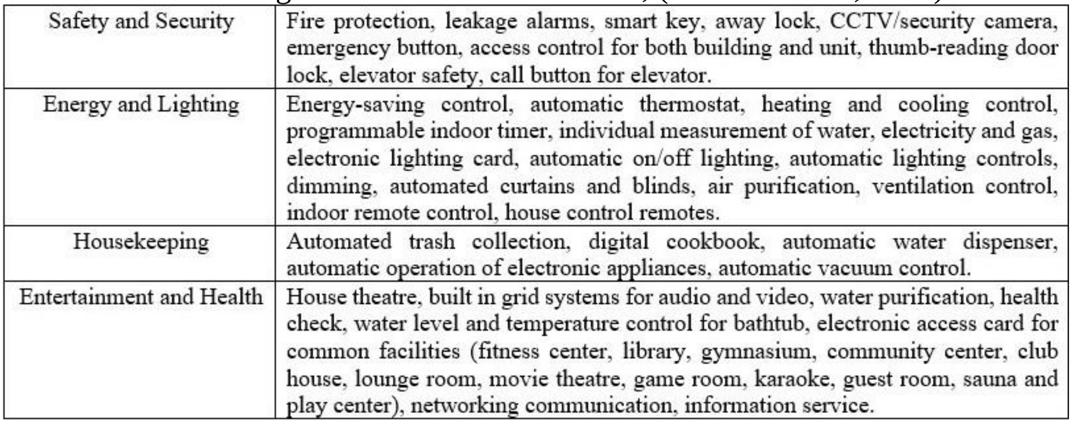
- Context Aware: this the characteristics of a smart house that focuses on the contextual details of the building.
- Personalized characteristics: this the characteristics of a smart house that centers on the individual needs.
- Anticipatory characteristics: these are the characteristics of a smart house that majors on presuming the personal needs, that might out the need for intentional intervention.
- Adaptive characteristics: this is the feature of the smart house that centers adaptive capacity of the space, which is being able to adjust to prevalent changing needs of the individual.
- Ubiquitous characteristics: it is the capacity of the smart house to be integrated into the everyday environment.
- Transparency characteristics: the characteristics of the smart house that embodied in the inconspicuous method in daily life.

It is widely attested that smart houses offer a life of ease and the reduction of inconveniences, which results in peace of mind. According to cook (2010), smart house technologies can be made of several monitors, sensors, interfaces, equipment and gadgets interconnected together to give way to automation of localized and remote management of residence give away to automation of localized and remote management of settings. Manageable gadgets and equipment comprise washing machines, fridges, heating, lighting, windows, doors, curtains and TVs (Robbles and Kim, 2010). Nevertheless, sensors and monitors spot the features of the environment like humidity, temperature, motion as well as light. Furthermore, regulated functionality is offered by the software within the computer gadgets as well as devoted hardware interfaces (Aldrich, 2003). However, being away from house, one can still be enabled to know the happenings within their house, even smart house covers security systems for any case of emergency.

Services of smart houses are advantages that are made available to inhabitants, the system manages demand of the smart house users which works by technological features of the smart house network. The services of the smart house can be classified according to the inhabitants’ needs that they focus on, which can be communicating, entertaining, energy management, health, comfort and assisted living (Nazimye et al., 2013). However, the security services of smart houses, with the aid of sensors, might provide the capacity to track movement within the house, thereby the occupant will be aware and spotting unwanted visitors. Also, the user can be aware of any window or door that is left open or closed. employment of sensors to track location of inhabitants help the occupants to have services depend on their action and their location in house. Other items such as collecting the data of temperature, will help the utilization of energy. Furthermore, services of energy efficiency of smart houses are instrumental to the users in cutting down energy consumption in the house. With employment of technology that automates energy saving or with the use of centralized energy consumption data and cost.

Yeunsook Lee (2007) categorized the digital functions of a smart house into 4 domains which are safety and security, energy and lighting, housekeeping and entertainment and health (table1). Each of the domains show how diverse are the technologies and services of a smart house.

Table 1: Available digital function in smart house, (Yeunsook Lee, 2007)



Safety and Security	Fire protection, leakage alarms, smart key, away lock, CCTV/security camera, emergency button, access control for both building and unit, thumb-reading door lock, elevator safety, call button for elevator.
Energy and Lighting	Energy-saving control, automatic thermostat, heating and cooling control, programmable indoor timer, individual measurement of water, electricity and gas, electronic lighting card, automatic on/off lighting, automatic lighting controls, dimming, automated curtains and blinds, air purification, ventilation control, indoor remote control, house control remotes.
Housekeeping	Automated trash collection, digital cookbook, automatic water dispenser, automatic operation of electronic appliances, automatic vacuum control.
Entertainment and Health	House theatre, built in grid systems for audio and video, water purification, health check, water level and temperature control for bathtub, electronic access card for common facilities (fitness center, library, gymnasium, community center, club house, lounge room, movie theatre, game room, karaoke, guest room, sauna and play center), networking communication, information service.

In this study, a limited number of these features are selected in the next chapter. The selected features will be researched in advanced and used for the method of study.

2.3.3 Instances of Smart House

Smart house definitions are discussed widely in the academic literature. While, there are number of smart house examples which have already developed and finished. These smart house examples are mostly made with the aim of experiment and research. Chan, Esteve, Escriba & Campo (2008) gathered a great number of smart house examples and noted that these smart houses are made with the aim of adding comfort and also leisure for the users. Most of them use neural networks to control different factors without any foregoing programming for the users. In all the cases the house and its different electrical devices are suited with monitors, sensors and networks to be connected to a data center for collecting and processing the data from the house. In this study a limited number of these examples are going to be presented in order to have feasible and realistic understanding of the smart house theories and services which discussed before in this chapter. The examples practically show the sensors and services and the architectural responses for these devices. Photographs and explanation of a real example of sensors, control panels, and other equipment will help the method of this study in the further chapters because, these smart features could be design and construct in majority of future residential interior spaces.

Adaptive Control of Home Environment

An adaptive house known as “ACHE” (Adaptive Control of Home Environment) (Figure 4) in Boulder, Colorado, was designed to utilize a neutral network to regulate the heating, lighting, temperature and water heating within the building which did not have a prior programming by its occupant. In the figures 5 and 6 the equipment of ACHE thrives to optimize energy resources at the same time in adapting with the occupants' needs and comfort. ACHE does this by having a distinct regulation system for each function (Mozer, 2004). The following are images of the house, sensors and network employed in the ACHE project.

Figure 4: The adaptive house, (Mozer, 2004)

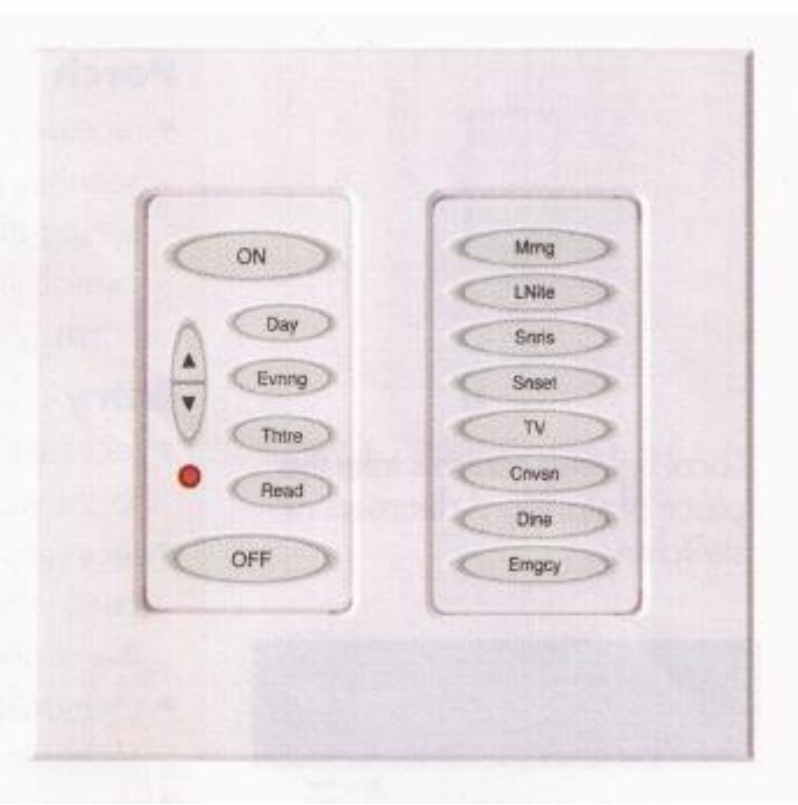


Figure 5: The lighting control panel for the adaptive house, (Mozer, 2004)

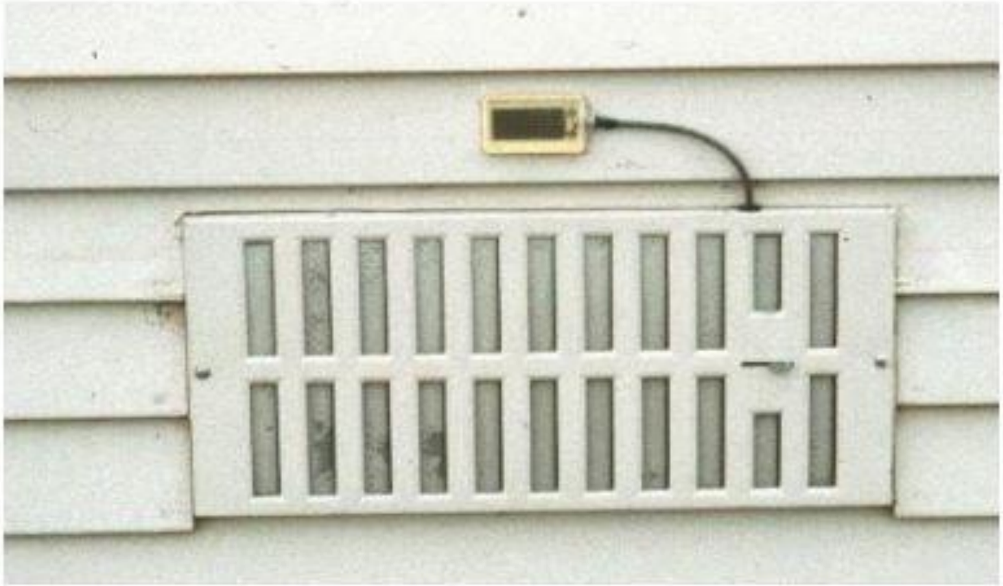


Figure 6: The outdoor temperature sensor of the adaptive house, (Mozer, 2004)

Gatortech Smart House

The GatorTech Smart house is a project created in Florida (Figure 7); it is developed to maximize comfort and safety for users. The GatorTech Smart House is designed around specific smart devices. All the devices are equipped with a sensor and actuator which is linked to an operational hub. The smart house utilizes a high-precision ultrasonic tracking system to find the inhabitants, which analyze the movement of the occupants' pattern and optimize the regulation of the environment (Urdiales 2015).

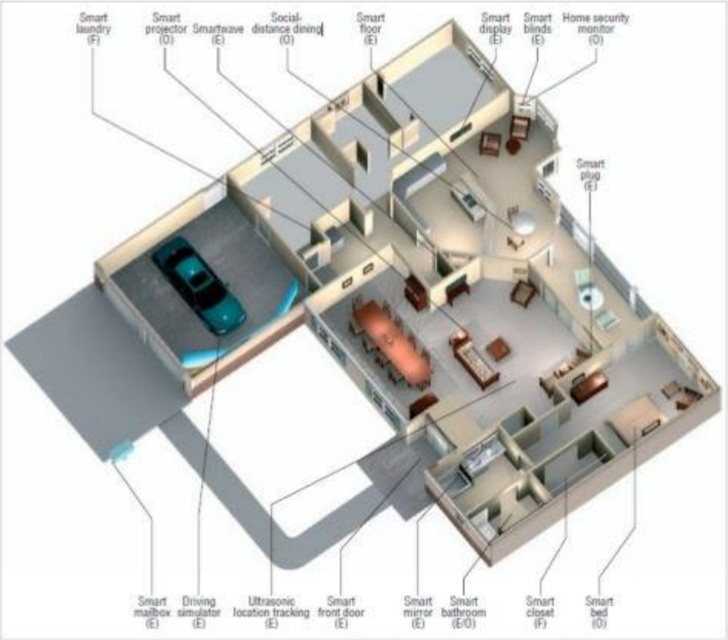


Figure 7: The GatorTech smart house, (Urdiales, 2015)

Aware House Research Initiative

A three-story building was constructed by a team of researchers from different fields at the Georgia Institute of Technology known as the Aware House Research Initiative, in which the building served as a laboratory that is alive for the purpose of development, design, and the analysis of domesticated technologies of the future. (Figure 8). The smart building adopts some mathematical aids utilized for the development and analysis of the behavioral pattern. The core aim of the project is to facilitate a higher quality of life and elongate the life span for the elderly by providing an environment that is familiar to them. The research team of the project was also able to create tracking and sensing technologies, and would assist in the finding of frequently displayed items in the house. LCD touch screens would be the medium through which the occupant would interact with the building.

Figure 8: The Aware Home (AHRI) (Aware home research initiative)

Ubiquitous Home Project

The sensor-implanted house known as the Ubiquitous Home project is an experimental center for the development of latest services aimed at connecting sensors, appliances and mechanisms via digital networks. It is an actual house with a master's bedroom, Japanese style room, kitchen, living room, study, bathroom, dining room, and a washroom; it also has a computer room that serves a computer coordination hub. There are so many sensors in The Ubiquitous Home project to track the activities of the inhabitants, in which each space is fitted with cameras and microphones to collect data that is both visual and audio (Figure 9). The aim of the project is to aid inhabitants to harness the benefits of user-adaptation mechanisms.

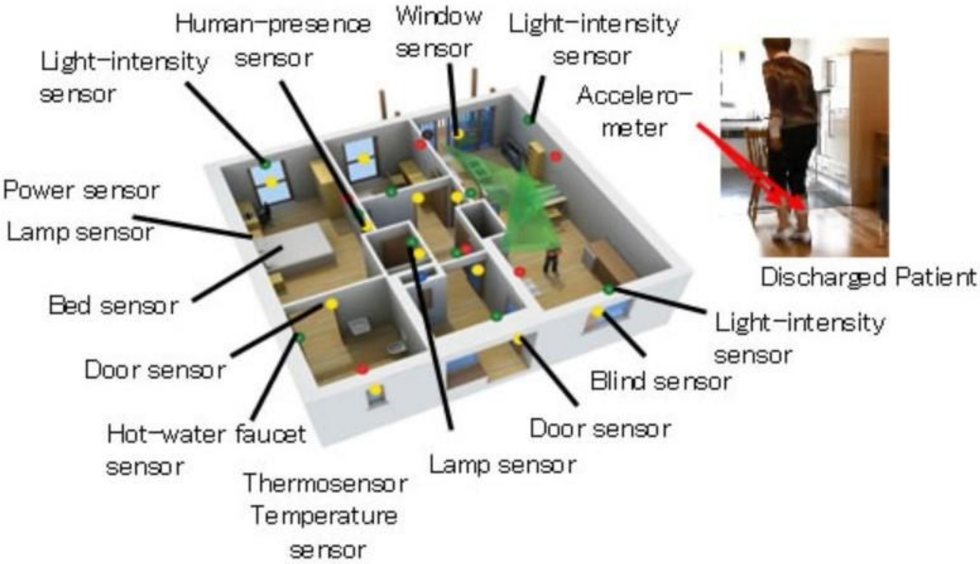


Figure 9: Ubiquitous Home project sensors, (Fujitsu Laboratories, 2015)

Self

The SELF (system named sensorized environment for life) project was created by Nishida et al. in Ibaraki Japan, that is an intelligent environmental structure. Through critical data an individual is capable of sustaining their health via a system of SELF-communication evaluation. The SELF- bedroom model assists the occupants with a physiological data status; in which the bed is fitted with pressure sensor order, as well as the ceiling light being fitted with microphone to spot the audios of the occupants breathing. Some many visual physiological qualities can be evaluated using the data generated. The SELF system banks and evaluates these physiological data, thereby aiding the occupants with information on sustaining a healthy lifestyle or correction that is pinned on everyday life (Figure 10).

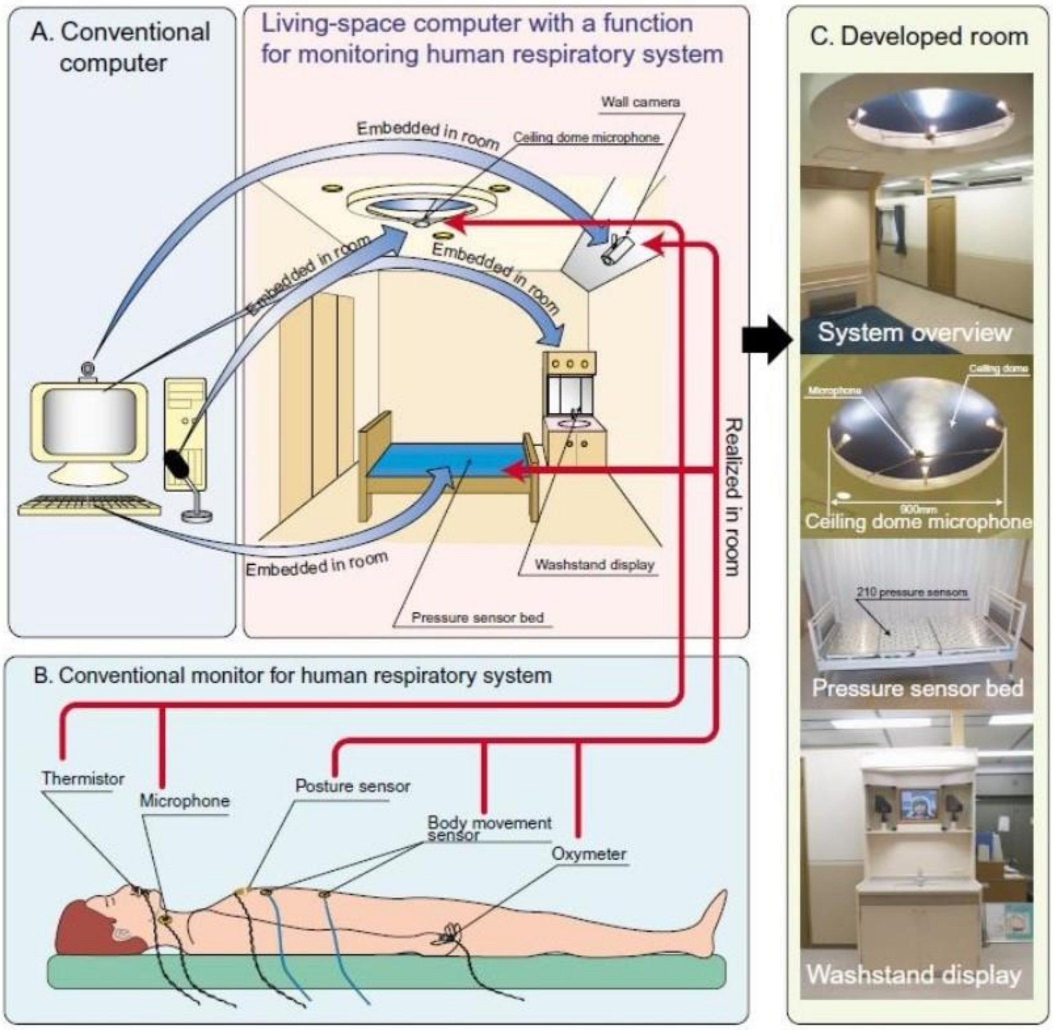


Figure 10: Environment sensorization, (Everyday life computing)

2.4 Conclusion

To conclude, the smart and intelligent buildings are defined in this chapter. The terms ‘smart’ and ‘intelligent’ have similarities in their definition, while in some features there are differences between these terms. the term smart is considered as a newer term than intelligent buildings made from functions and equipment which are made to ease the user’s life and add comfort to the occupant’s daily life. The definition of smart and feature houses and their features and services were fully reviewed in this chapter. The definitions can help to have a general understanding of this buildings.

Among all these features which researched through the academic literature, the smart features which are related to the interior space of the existing buildings are selected and researched in the next chapter to fulfil the aim of study.

Chapter 3

DESIGN FEATURES OF SMART HOUSES

The following chapter presents information about the design of intelligent and smart buildings. The future of built environment was researched in the previous chapter. According to literature review in chapter 2, smart and intelligent buildings will be considered as the future of buildings. Each of these terms covers a variety of technologies, devices and services. These smart and intelligent features are used to add comfort and ease the daily life of the occupants.

Features of smart buildings are collected and explained based on the academic literature which were presented in previous chapter. Among the smart and intelligent features, a limited number of 12 smart features were gathered and explained in this chapter. The aim of this chapter is to fully explain the selected features, selected features are those that can affect the interior space of residential buildings and those that can be evaluated and observed for adaptability evaluation. These smart features will be categorized in tables for the case study to evaluate adaptability potentials of an existing building for future changes and will fulfil the aim and problem of the study. The last part of this chapter which contains adaptability and flexibility definitions, can help to find adaptability types and strategies for future houses and will be also used to achieve the outcome of study in next chapter.

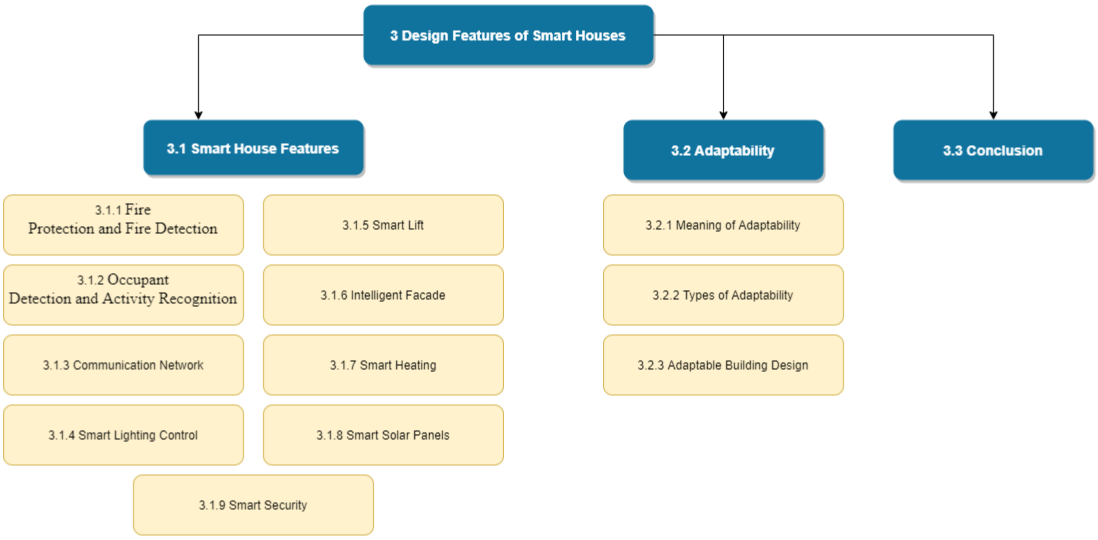


Figure 11: Summary of chapter three

3.1 Smart House Features

Smart house is an adaptive house which reacts to user needs. In the academic literature smart houses are discussed mainly with their features and systems. shauai et al., (2019) state that a smart house environment contains the integration of a sophisticated automation system that supports the occupants of the building with smart services which optimizes the comfort of the inhabitants and decreases the running cost, while providing a good security. Smarts houses can be said to be a building that is automated, which possesses installations that can detect and control appliances like lighting, HVAC system, various hardware, as well as the security system of the building (Zaidan et al., 2017). In the advancement of latest smart devices, there has been an upturn in its demand in recent years, in which these devices can be linked to the internet, as it has been remotely managed. However, the internet of things is made up of appliances fixed with sensors, software and connectivity as well as the link between devices (Mocrii and Musilek, 2018).

A smart house contains items that are not really smart on their own, that is the role of the sensor is the produce data (figure 12), still not contributing value to the house on its own. so, with the inhabitants regulating the temperature of the thermostat using the external temperature and humidity as well as the bench lines, so it regulating it temperature is just automation and which is not smartness. So now an environment can be said to be smart only when the available data concerning the environment is communionly preserved, evaluated, patterns are identified, leading to decision making without the interference of the occupants of the building (Mocrii and Musilek, 2018).

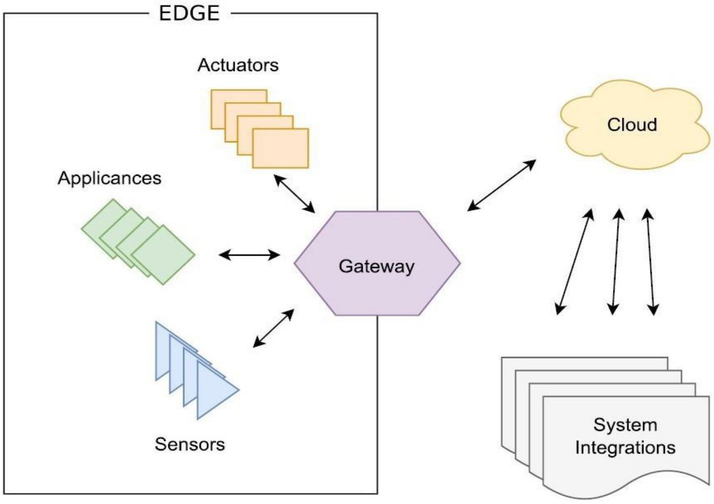


Figure 12: Cloud-based architecture of a smart house, (Mocrii & Musilek, 2018)

Gateways can be seen as control mechanisms that also include user interface that communicate with devices like mobile phone, electronic tablets, or computer, with a connectivity connection system that is managed with internet of things. In addition, the modern system of a smart house is made of sensors and switches that networks with the main nerve known as Gateway (Galinina et al., 2015; Zaidan et al., 2017).

3.1.1 Fire Protection and Fire Detection

According to Wu & Zhao (2019), fire has been reported as one of the most critical accidents that might result in significant manufacturing losses, facility and equipment destruction and worse significant human harm. In addition, Bu and Gharajeh (2019) stressed that fire accidents contribute a huge challenge to safety and health of humans as well as their properties, with damages recorded both in the fatalities and financial terms, which have gained some upturn over recent years. The causes of these fire accidents have resulted from numerous unpredicted reasons. Furthermore, fire is among the top list of disasters globally, therefore it critical that there is a fire detection system with a vital role of noticing fire at the shortest time to be able to decrease the damage to both human and monetary sense, these fire detectors can be place in several places like buildings, forest and even rural community. Individuals in these environments with fire detectors are provided with early warning signs of fire with the aid of fire sensors, in conjunction with normal point sensors like smoke and heat detectors. Their fire sensors detect fire accidents much faster than point sensors by employing the aid of a camera in addition to image analyzing methods. In addition to the merits of fire sensors to the normal detector is that they provide information concerning the size, flow of the fire and the development of the fire Bu and Gharajeh (2019). Wu & Zhao (2019) went further to stress that an interior environment with conventional systems of fire detection have some limitations.

Moreover, a critical part of a surveillance system is the fire detection system. As a central component of the early cautioning structure, the fire detection tracks and reports fire preferably before it begins. However, the present fire detection systems employ sensors that analyze smoke, sampling of both particles and temperature for tracking fire. The prevailing fire detection system measures fire possibilities in a slow manner, which might fall within minutes; therefore, it has limited utilization outside the building. The smoke and heat detection system are activated, when a good quantity of smoke particles move to the devices (detectors), as well as the increase in temperature detected, thereby reducing the damage that might be caused by the fire. Nevertheless, the response time by the detection time has to be brought down to increase the likelihoods of putting off the fire, which in turn decreases the financial and human losses (Qureshi et al., 2016; Bu and Gharajeh, 2019). Moreover, within the last ten years researchers have tried to gain great thrives in slowing down the response time for point detection systems, an instance of this challenge is seen in the fire sensor centered computing, which provides a substitute for a fire detection system, which is spontaneous in nature. However, the researchers have concluded vision sensors with videos and images in conjunction with point detection systems (smoke and heat detectors) can be among the efficient approaches to fire detection (Mahdipour, & Dadkhah, C, 2014; Bu and Gharajeh, 2019).

Therefore, vision sensors that execute the fire detection system predominantly consist of three components, which are smoke/flame blob detection, motion detection as well as candidate object segmentation. Therefore, in the fire detection system, image deduction and contextual modelling methods, provide the variation for the first motion as the camera is often considered to be static (piccardi, 2004; Gharajeh, 2019). Moreover, Bu and Gharajeh, 2019, went ahead to state that a vision-based sensor approach can decrease the reaction time, thereby increasing the possibility of detection, providing it services even for a huge environment.

In some industries, fire detection techniques that employ advanced intelligent video, digital camera and computer vision technology have been developed fast and have been utilized. The video fire detection advancement has undergone two stages; First the utilization of color model as well as hand –designed components for fire detection, which is centered on color alongside the characteristically shape of the frame. This is sorted out by traditional video fire detection techniques, by subtracting a multi-dimensional vector as well as grouping character of the vector to be fire or no- fire group (Wu & Zhao, 2019). The (figure 13) shows the fundamental flow of the fire detection system via the sensor. Figure shows how alarm systems and alerts which has been used in fire detection and fire protection systems and how they work with image analyzing sensors and communication equipment as a whole system.

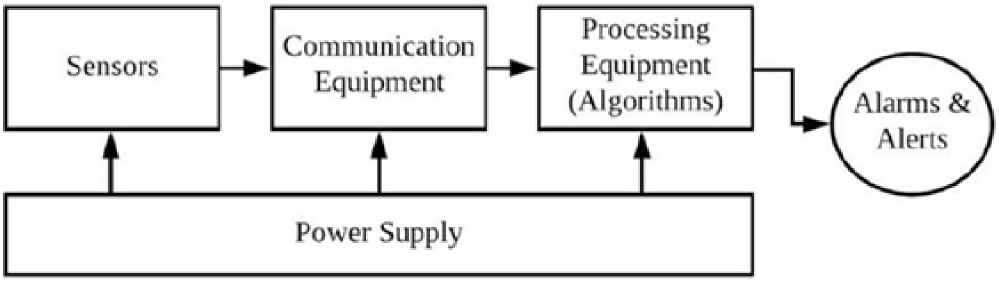


Figure 13: Integration of fire detection system with IOT and image analyzing methods for smart cities, (Sharma & Kumar, 2020)

3.1.2 Occupant Detection and Activity Recognition

Building occupancy is very critical to the building for energy optimization control. However, occupancy prediction-oriented study has attracted thrives in the field of smart Domestic Energy (Chung & Cho, 2017; Jiang & Xie, 2018). Thereby decreasing the energy utilization in the building to cut down on the use of fossil fuel, thereby reducing operational cost of the building thereby boosting the affordability of the building (Wang et al., 2019). In addition, in comparison to traditional HVAC systems, smart HVAC systems can prevent a huge amount of energy consumption in buildings, in order words the terminology demand has to do with real-time occupancy needs inside the buildings' air quality alongside the thermal comfort (Zhao et al., 2015). However, in developed countries, HVAC systems presently account for about half of the total energy consumption of buildings (Lombard-Perez, et al., 2007; Pedersen et al., 2017).

However, with many applications and possible advantages building occupancy detection, has become a thriving research field. This would be seen in the management of space and time distribution in smart houses services which include the HVAC system and lighting. The idea of a smart building can be seen as the combination of machine learning technology with that automation of cost and energy and still reducing emission level (Sara et al., 2019).

Occupant Detection

Nevertheless, according to Zhao et al., (2015) tools like carbon dioxide sensors, wireless sensors links, passive infrared sensors, cameras as well as radio frequency identification sensors were utilized in several kinds of occupancy detection techniques. With sensor data mining employed in a more situation- awareness modelling, in recent studies conducted, for context like estimating the interior occupancy rate employing several sensors in buildings like residential buildings, commercial buildings, and industrial buildings alongside context like indoor air quality tracking (Jeon et al., 2018).

According to Cook et al., (2013) Techniques in occupancy detection can be can be classified into two classes, which are:

- Image-centered technique (image centered technique depends on digital cameras technology to track occupancy).
- Data-centered technique (presently the data centered sensor detection of occupancy is the most used, especially the passive infrared sensor, which are

fixed fundamentally for energy efficiency control of the operation of lighting in buildings).

However, Cook et al., (2013) went on to state that in smart houses it is critical that there is a system that tracks and analyses the activities of the inhabitants, so that smart houses are designed to boost the living standard of the inhabitants of the building. In addition, Wang et al., (2018) stressed that data from occupancy detection alongside the inhabitant's behavioral pattern could be utilized to manage the buildings' HVAC system and energy efficiency more intelligently.

Moreover, Zou et al., (2017) broke down the status of occupancy sensing into three, which are:

- Occupancy detection: this level determines if the stated space is occupied, it is the most fundamental level of occupancy inference.
- Occupancy counting: the aim of this level of detection is to determine the number of inhabitants in a stated space; it is the second level occupancy inference which is centered on counting the individual in that space.
- Occupancy tracking: the aim of this level is to predict in real-time the specific position of the inhabitants; it possesses the top most level of occupancy inference.

For many houses' automation systems, there is a fundamental need to determine the occupancy rate of the building. For instance, when there is an individual presence in a house the lighting system as well as the HVAC system is activated, alongside a situation when there is no one in the housing, the HVAC is managed intelligently; thereby energy consumption is managed considerably. In addition, it is critical to know when the house would be occupied, to activate the HVAC system, to optimize the comfort of the occupants and also save energy in the building. Therefore, the automation of the house depends on the occupancy detection and prediction for fundamental services of the house (Kleiminger et al., 2014).

Energy consumption conservation has received an upturn in audience in the past year, with buildings needing a good management and comprehension of the activities of the occupants with the energy needs as well as the building needs (Wang et al., 2018). They went further to state that the energy consumption of the buildings' occupants is determined by the following ways:

- The release of body heat of the occupants which stabilities with the partaking indoor heat.
- Extracting occupancy needs, which involves thermal comfort and interior air quality.
- Interacting with the various systems of the buildings' management and services.

Moreover, the data of occupancy are generated from surveys, lab simulation and experiment, as well as data sensing, thereby with the knowledge of the data of occupancy the right energy estimation alongside proper flexibility of the building (Wang et al., 2018).

According to Zou et al., (2017), a huge pull of studies has supported the clamp that the comprehension of specific occupants' activities could aid in the building control system, thereby decreasing energy consumption, increasing the comfort of the inhabitants in the context of thermal comfort and acoustic management.

Activity Recognition

Activity recognition and prediction facilitates the smart system to respond to the activities occupants. However, a critical part of an individual activating monitoring is the activity discovery itself, as sensors like motion detectors with cameras, would constantly generate data as well as the algorithms required to spot nature of activities, which could be utilized for recognition and prediction (Mocrii et al., 2018).

Zou et al (2017) stressed that leveraging the availability of Wi-Fi within the buildings, signals of occupancy sensing, like localization, detection, and counting of occupancy becomes possible. The reason behind this argument is that the mobility of the inhabitants can alter the production of the signals of the Wi-Fi, which are noticed from its receiving stations. In addition, with the upturn in the advancement in Wi-Fi enabled IoT gadgets in house, it is becoming possible to install them in the interior environment. However, Wang et al (2019) argued that the number of individuals connected to Wi-Fi and the number of gadgets connected are not consistent, which might be altered whether spatially or periodically, making the number of individuals connected to the Wi-Fi alone, as not being a reliable occupancy data collection.

However, Mocrii et al (2018) stated mediums through which activity recognition are done are floor pressure sensors, heat sensor cameras, digital video cameras. They went further to state that the activity recognition should be done in real-time, in order for the smart house to respond and adapt accordingly instantly, while occupancy prediction can take place by modelling the data of frequent patterns of the everyday activities of the occupant, with the aid of several sensors. Furthermore, environmental sensors are good solutions because of their non-intrusive nature (Zhu et al., 2017).

Zou et al (2018) went further stated that pin sensor is among the most employed sensors for occupancy detection, it does this by spotting the presence of individuals by estimating the variation in emitted radiation. Its merits are the lower energy consumption thereby having a low cost, but with a demerit of failing to spot static occupants as well as possessing a low detection span.

Another device employed for occupancy detection is the camera, which is critical for knowing the number of crowds, by evaluating the image frame taken by the cameras, providing the specific number of occupancies. Moreover, between the occupant and the cameras a station point is needed, as well as lighting might be needed (Zou et al., 2018).

In addition to the above is the smart meter, which measures the energy consumption in the building, which is also seen in the interaction between the inhabitants with the appliances. The utilization of smart meter merit is that it is low cost as well as not being intrusive, having a demerit of solely provision of binary data and not being able to state the number of occupants (Zou et al., 2018).

A carbon dioxide sensor has been said to be a critical environmental sensor, for occupancy detection (Luis & Feldheim, 2016). The demerit of the carbon dioxide sensor is that it takes time to estimation in occupancy detection, as the co 2 in indoor environment is slow (Zou et al., 2018).

Environmental sensors which are besides the carbon dioxide sensors are other environmental sensors like temperature, light, humidity, as well as pressure can be adopted to detect occupancy. It is employed in crowding counting and detection. The limitation of the environmental sensors is also the time delay affecting the estimation (Zou et al., 2018).

According to Zou et al., (2018) Wi-Fi has been seen widely as a substitute for the GPS system for indoor situation-awareness as well as position-centered services, as the framework of the Wi-Fi is available widely within the built environment.

3.1.3 Communication Network

With the IoT (internet of thing) which has become a model for the smart house, it has provided an avenue for occupants to manage smart devices remotely through the aid of the internet. However, as the interaction between the occupants and smart devices through a network that is not secure, personal data might be collected by unauthorized individuals (Shuai et al., 2019).

Smart objects possess a number of options for its utilization, it is useful for interconnection among sensors and devices. Therefore, this interconnection is known as Internet of things (IoT), IoT permits the establishment of large as well as needed to get group intelligence via analyzing the smart objects' data. In addition, IoT provides a network between the physical and virtual objects. The interconnection takes place at any time, it could be human to human connection or machine to machine, as well as human to machine connection, both outdoor and indoor. In the smart house, centered on the WSAN individual can manage different smart objects, which are handling various activities, which could be called upon or automatically done with a smart device or remote control. Here doors and windows can be controlled by smart devices, even lighting, so in order to get the best out of the smart object, they have to be interconnected to each other. Nevertheless, a central system is needed like a brain, which can control and alert the smart objects (Garcia et al., 2017). (Figure 14).

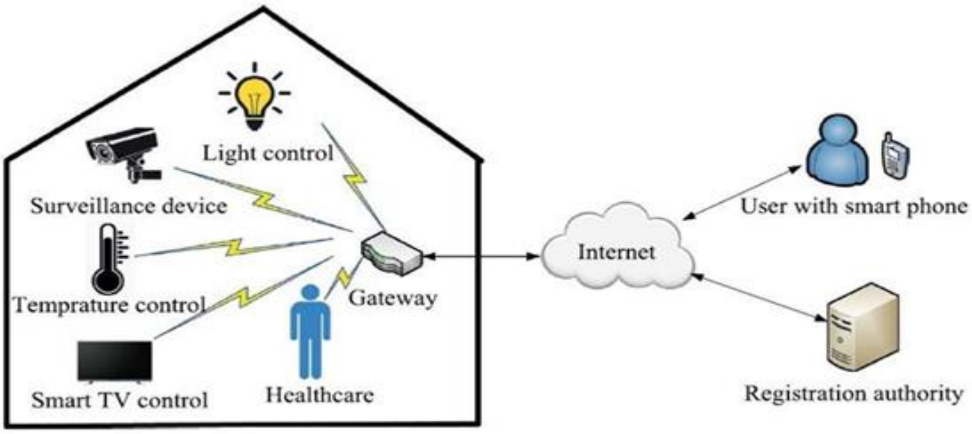


Figure 14: Framework of a smart environment, (Sahuai et al., 2019)

However, Mocrii et al (2018) stated that communication protocols are categorized into three which are wired, wireless, and hybrid. The choice on which to use depends on the users' situation, in which some provide longer range, lower power consumption as well as high security. Figure 10 shows framework of a smart environment and how different smart devices should be communicating data with the user and processors.

3.1.4 Smart Lighting Control

A critical aspect of the smart building/city/house is the intelligent lighting system. The lighting output of the system is managed and controlled from its temperature, color to its brightness by the sensing of the mobility of its occupants as well as the ambient lighting environment. The major focus of this intelligent lighting system is to meet the satisfaction of the visual comfort of the inhabitants and still decreasing consumption of energy in the building (Sun & Yu, 2020).

With the aid of reasonable design of a lighting management system, the intake of lighting can be decreased. The conservation of energy in the light management system can be achieved by employing two vigorous types in the environment which is different degrees of daylight as well as the alteration in the occupancy. In the intelligent lighting system, the systems under focus are the numerous intelligent luminaries. However, as each luminary possesses a lighting sensor alongside occupancy sensor. Within its boundaries each of the sensors measures the binary occupancy as well as the sum illumination degree respectfully. Each luminaire possesses its communication section. However, the dimming degree of each of the luminaires is defined by the corresponding controllers, in which the daylight contribution in combination with the net artificial light output is equal to the total luminance (Meugheuvel et al., 2014). With the employment of LED, management luminaires, it is now possible for the brightness of the light to decrease (dim) a particular luminaire with the consideration of the light sensing input as well as local presence. It is critical that the illumination needs of the occupants are taken into consideration, even as it lowers the cost of energy (Rossi et al 2015). The merits of the LED luminaires are how they are flexible to changes of lighting system to environment (Pandhariquande & Caicedo, 2015).

Lowry (2016) stated that Lighting has the bigger chance than other features of internal environmental management system for producing emissions of carbon as lighting energy is obtained fully from electrically means, therefore it is critical that the occupants needs are critically controlled, these can be done through the following methods for lighting for decreasing energy consumption:

- Adoption of LED lamps.
- Management to decrease the amount of time space is not utilized.
- Management to decrease the illumination when there is daylight.

However, this management can be automated or manual control or the combination of both.

According to Chew et al., (2017) Despite the huge merit of the smart lighting, it still has some challenges it suffers from, like the capital cost is not justified by the regular energy saving returns as well as the lack of a vigorous light quality management. However, smart lighting systems can be classified into the following:

- Commercial smart lighting system: this classification of smart lighting system can be gotten from counter shelves of stores, which are aesthetics, mobility management as well as incorporation of the occupants’ needs, and data (Chew et al., 2017).
- Energy saving smart lighting systems: this classification of smart lighting system with an incorporation of energy conserving arrangements designed to capitalize on energy consumption efficiency via executing a robust energy conserving management system (Chew et al., 2017).
- Advanced smart lighting control systems: this classification of smart lighting systems maximize an important lighting metric further than the illuminance to add to a bigger level of management over the created light output. These lighting management systems are regularly advanced on lighting mechanisms that are two or more adjustable core emitters (Chew et al., 2017).

3.1.5 Smart Lift

According to Zhou et al (2018) with urban land being stressed, buildings have been developed to become a trend. As a result, the lifts are now very vital to the vertical mobility within the building for people and goods. Furthermore, with development in sensors in smart environments, lift scheduling has become another critical service that has employed a sensor for its services (Figure 15). An elevator management system can sense the approach of individuals before they press the call button, this due to sensors like camera, audio and sensors on the floor. With the data derived from the sensors the lift can prepare scheduling, thereby decreasing energy consumption.

For decreasing the waiting duration, travelling duration and energy consumption are the different performance considerations for scheduling systems of elevators. However, if the elevator knows the level in which the individual would stop, the management of its scheduling can be efficient, giving it an advantage over the traditional elevator system, which cannot predict the individual destination (Kwon et al., 2014).

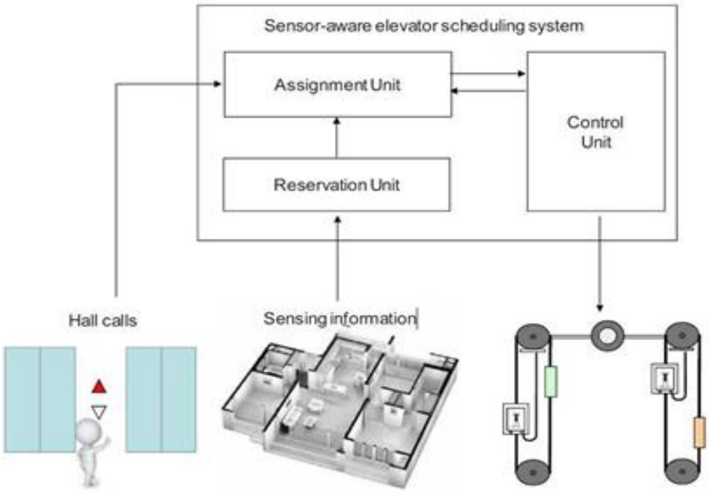


Figure 15: Fundamental architecture of the sensor-aware elevator, (Kwon et al., 2014)

3.1.6 Intelligent Façade

According to Johnsen and Winther (2015) the façade is a way of symbolizing the representation of prestige and power. The design of the façade has several significances which are vital to both the climate of the interior as well as the consumption of energy. Here energy flow is noticed over their boundaries (indoor and outdoor environment). The critical function of the façade is to provide protection for the interior environment as well as maximize the management function of the following:

- The management of thermal transmission from the outdoor to the indoor
- Management of solar energy weight from outdoor to indoor
- High optimization of passive solar energy
- High optimization of delighting
- Provision of glare protection
- Management of airflow from outdoor to indoor
- Permission of visual connection to the outdoor
- Adequate privacy.

The level of the complexity of the design of a façade has attained the point where it is feasible to call some façade intelligent façade. Here it can be said to be a façade that responds dynamically to the needs posed by the exterior environment as well as the interior occupants, and still being energy conscious. This intelligent façade adopts a principle of energy conservation and the maintenance of indoor comfort (Ochoa, & Capeluto, 2009).

In modern buildings glazed facades are predominately adopted, due to their huge light transmittance as well as aesthetics for passer-by. In addition, these glazed facades have good indoor comfort and energy conservation for the building properties (Figure 16). Intelligent facades possessing several management technologies have been studied to improve the indoor comfort degree, energy conservation requirement of buildings. Several features of a façade can be dynamic and managed to fix the needs of both the interior environment and adjustment of the exterior climate or weather situations (Liu, et al., 2015).

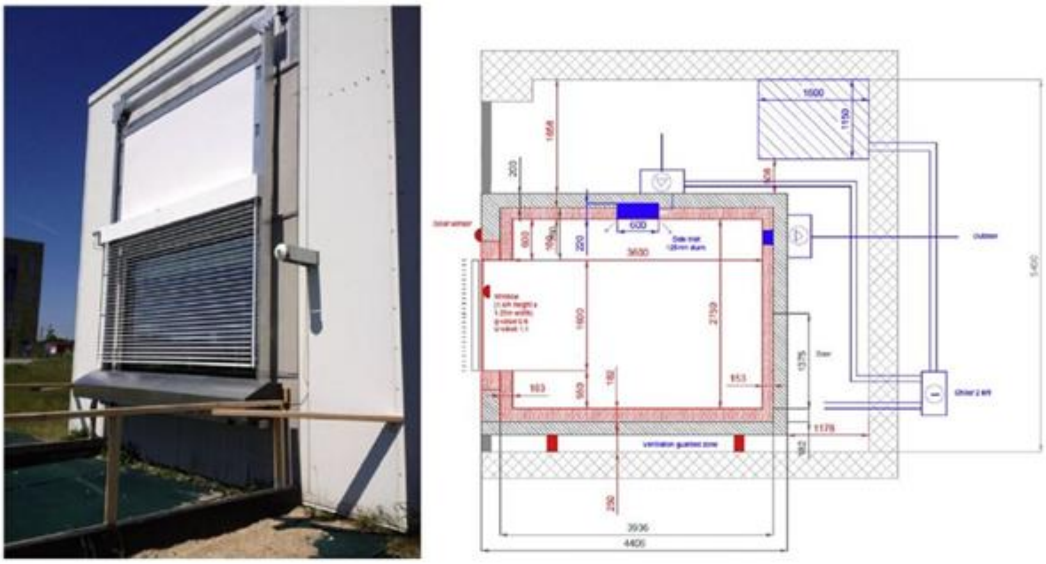


Figure 16: Full-scale test facility in Aalborg University-cube, (Liu et al., 2015)

The image above shows the full scale of the cube in Aalborg University comprising a south elevation facing experiment room, having interior measurement as 2.76 by 2.7 by 3.65m3. The south elevation has the glazed façade systems which are covered by a protected zone to reduce the heat transfer through the coverings. Intelligent façade can be employed to increase the indoor comfort of the building and reduce the energy consumption with manageable facades. The right management of technologies adopted for the façade like night shutter, natural ventilation as well as solar shading can go a long way in reducing energy and heat consumption, improve cooling and provide visual connection to the outdoors and improve thermal comfort of the interior (Liu, et al., 2015).

However, with the development of smart materials and automation management, façade now have terms like adaptive, smart and intelligent façade. Here they can vigorously change their properties in reaction to adjusting interior needs and outdoor situations (Luna-Navarro et al.,2020). In order to meet the requirements of an intelligent façade, the design should begin from the architectural stage, where concepts and notions can be experimented on, produced using simple graphical representation and gradually moves to the level where more details would be required (Pranovich et al., 2003).

Kinetic Façade

According to kensek & Hansanuwat, (2011) there are several types of intelligent facades which are:

- Double skin façade
- Double glazed façade
- Ventilated façade
- Kinetic façade
- Solar façade.

Among the mentioned intelligent façades, the most famous is the Kinetic Façade. It is preferably critical to design as well as to develop facades that become responsive and interactive to various environmental conditions. The kinetic façade responds to environmental conditions like humidity, temperature and wind automatically by opening, even adapting its shape, orientation alongside its form (Ghaffarian Hoseini et al., 2012, kensek & Hansanuwat, 2011).

It can be argued that Kinetic façade can be used to create low energy and eventually zero energy buildings towards the line sustainable development of the made- made environment. Therefore, facades with shading devices that are interactive and movable can be seen as variation for a good performance of kinetic facades (Ahmed et al., 2015). However, Ghaffarian Hoseini et al., (2012), show that the incorporation of double skin façade, ventilated façade, double glazed façade alongside solar with kinetic façade can be come together to give energy conservation, improve environmental performance, provision of visual connection to the outdoor, improve thermal comfort, whiling limiting the environmental menaces.

To conclude, the intelligent faced types and examples are working mostly to reduce the energy usage of house. With the usage of kinetic and double-glazed façade, energy consumption reduction can be observed and serves to the smart house definition of houses with low rate of environmental risks, pollutions and low energy usage.

Double Skin Façade

The employment of double-skin facades is a well-known solution in the topics towards advancement in solar heat gain management, thermal shield zone, energy conservation and pleasing to the eye (Ahmed et al., 2015; Qahtan, 2019). The type of intelligent façade known as the double skin façade is multi-strata structure that comprises two skins (façade) which set the in-between hollow airflow between the interior and exterior (figure 17). It is a building skin method which is a solution for decreasing the heating and cooling weight of the building (Eom et al., 2019). In previous years, the double-skin façade has been employed in modern high-rise buildings because of the high-tech aesthetic appearance and energy conservation ability. It functions as the structure's envelope of the buildings, which is made up of inner and outer glass and air hallow midway for ventilation (Su et al., 2017).

Figure 17: Example of double skin façade, (Pomaranzi et al., 2020)

3.1.7 Smart Heating

Ahn et al (2017) stressed that several practical and theoretical methods to HVAC systems have advanced to give way for more energy to keep the indoor thermal comfort condition of the building. They went on to state that a traditional PID algorithm with its management system can be adopted when checking HVAC controls, with the goal of optimizing the quantity of energy expense in the boiler or fan motor. It is critical that cities as well as utilities create a group of smart energy strategies that permit the best use of energy while still decreasing the jobless investments within the infrastructure. However, the issues that are normally encountered in the field of heating management are the cost of heating as well as the poor customer attitude (Bourelos et al., 2020).

The idea of a smart energy system argues that all energy grids should be smart, not just the individual energy grids. These smart grids would give way for better cooperation among several systems of energy grids (lund et al., 2017).

For many years now, the research into the idea whether to utilize the information and communication technology to automate as well as intelligently manage the heating system has been ongoing. However, according to Kleiminger et al (2014) a smart energy system has to meet two core needs where are:

- It has to decrease the quantity of energy on heating a traditional heating system
- It should guarantee sufficient thermal comfort.

Nevertheless, house automation should not just determine if the house is occupied, but should go a step further in predicting when the house would be occupied, which would give the heating system time to heat the space to a preferred condition that would be comfortable for the occupants. This would allow the heating system to be set off at the right time that would ensure the optimal comfort of the occupants. Moreover, the capacity for the system to adapt to prevailing environmental conditions is what gives the system its smartness, which is modeled from specific activities or behavior of the inhabitants. Therefore, a heating management system that is automated is now seen as the controller that makes sure that the air temperature measured within the house is adequately enough to provide a specific value (Kleiminger et al., 2014).

Several technologies have been adopted for the purpose of heating both water and space. For combined or district heating technologies huge power plants provide the heat as well as power the boilers or heat pumps for large areas, while individuals employ heating mechanisms like small gas or electric boilers, in combination to round or air medium through which heat is pumped into the space. Water is heated with various means and with the utilization of air derived heat pump water heaters. The utilization of a hybrid heating system (Figure 18) could provide more advantages through a much better flexibility through the employment of multiple sources of energy for the heating of the water and space (Wang et al., 2020).

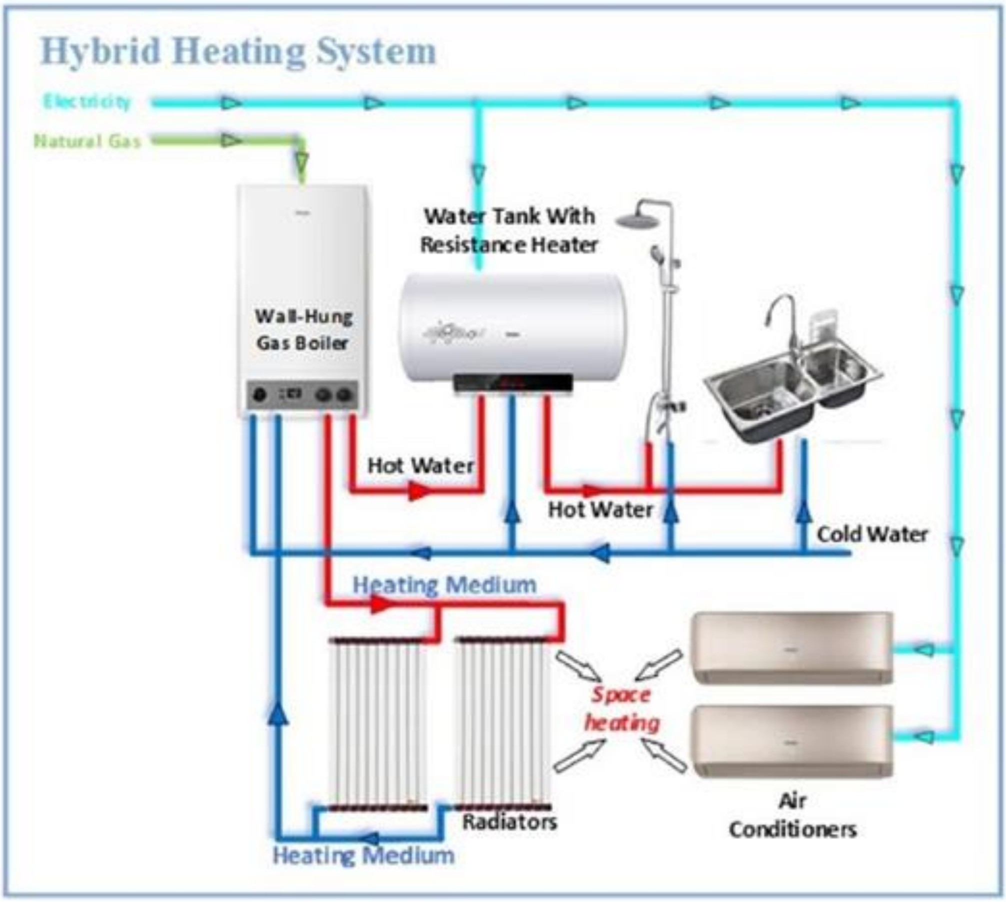


Figure 18: The architecture of the hybrid heating system, (Wang et al., 2020)

3.1.8 Smart Solar Panels

Renewable energy has stated to be a substitute energy source for developing countries of the world, which have high deficits on power generation, and still provide sustainable energy in the long run for people (Thakur & Chakraborty, 2015). However, according to Papageorgas et al (2013) stressed that the electric grid of many nations is in most extent aging, centralized, but are not renewable energy sources. Solar is stated to be the largest renewable energy source, which has collected so much interest to its development and implementation around the world. Moreover, with government policies and the decrease in the cost of the solar cells, these can result in rapid utilization of solar tried systems for various uses. Despite further advancement in the manufacturing technology of the solar cell, the utilization of optimization methods for photovoltaic production, tracking and control are not on the same pace (Papageorgas et al., 2013). Qiu et al (2019) argued that photovoltaic energy technologies that are distributed at places such as rooftop or ground-placed solar are becoming a much critical way in which the society can decrease dependence on fossil-fuels sourced electricity.

The smart solar photovoltaic blinds (SPB) that was developed by Kang &Lee (2019) has the combination of both the blinds and solar cell panel, which has the dual functions decreasing the indoor cooling load by serving as a barrier for solar heat (blinds) and also the production of electricity (photovoltaic system) (Figure 19). Their design can be place on a green buildings window or a brown building window as blinds, thereby boosting the building energy conservation as well as producing electricity (Jeong et al., 2017).

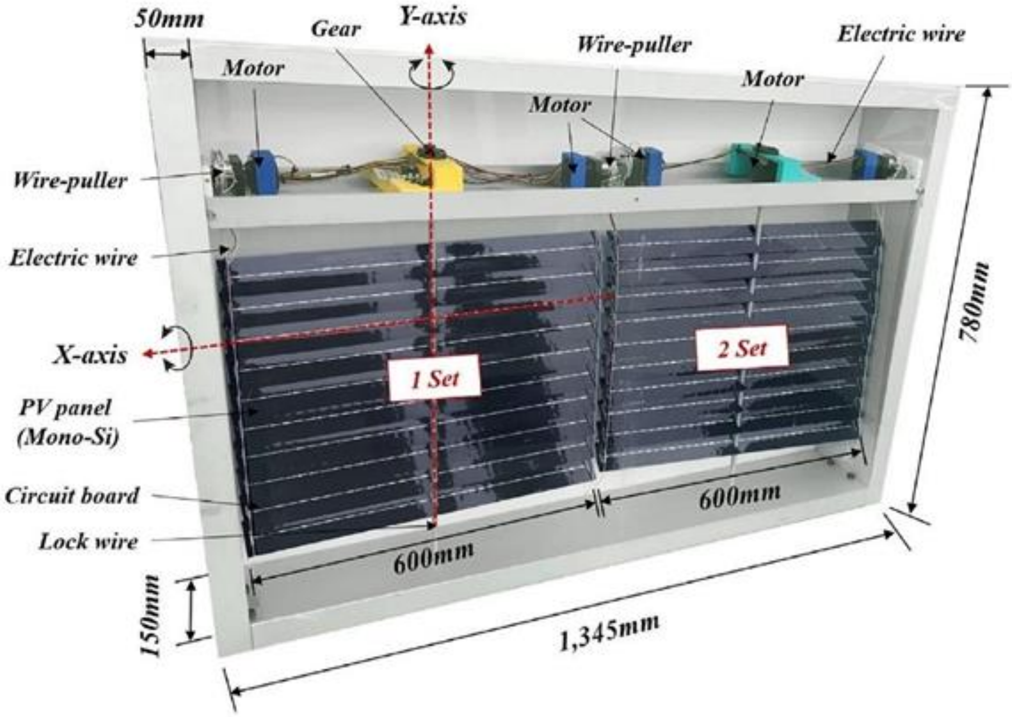


Figure 19: Smart solar photovoltaic blinds, (Kang et al., 2019)

Kang et al., (2019) stated that the smart SPB study was enacted for the building facades to attain almost zero-energy buildings (Figure 20) The smart SPB as stated early is a blind system (window) that also has a photovoltaic module which can manage the solar energy gaining entrance into the room, while decreasing the energy utilized in the building as it generates its power. The smart SPB is made up of the following:

- A real time tracking and analyzing system; Here data on electricity is produced in real time with the aid of network sensors.
- A real time automation management system; here based on the date produced from the electricity, the tilt angle that would be optimal for the smart SPB is known from the initial data of electricity.

Figure 20: Real-time tracking, analyzing and automated management of the smart SPB, (Kang et al., 2019)

3.1.9 Smart Security

With the aid of IoT it has become possible for smart devices to be connected remotely, in which door, windows, lights, even items used in feeding pets can be managed by smartphone and an app. IoT has also made it possible for tracking house from any point in the world. Smart security systems can be highly personalized, which is made available in DiY kit, or it can be set up by professionals (URL 5). Another fascinating adoption of the IoT would be the acknowledgment of people utilizing computer vision. The incorporation of computer vision into an IoT framework could increase the security system to smart building, due to their ability to point individuals in the places that they are not supposed to be within odd hours like a thief (Garcia et al., 2017).

The idea of a smart house would not be feasible without the aid of sensors spread across the house. However, with these devices connected to the internet of the building resulting in their exposure to cybercrime and hacks, thereby exposing the privacy of people's smart houses. However, in the context of a smart house, security is concerned with the security and privacy of data, thereby ensuring the privacy of the occupants.

Another aspect is the physical security of the building as well as safety of the inhabitant, is very critical. According to Mocrii et al (2018), security system employed has to deal with the following:

- Prevent data breaches
- Authorization
- To make sure there is privacy for the users.

According to Surantha and wicaksono, (2018) It has become very critical to keep the house safe, as it is a place where assets are kept, therefore it becomes a must to keep it safe. A more conventional approach to the security of the building is the employment of CCTV (closed circuit television). CCTV is a device that tracks the situation within the building or its exteriors. CCTV is very important, which tracks the situation within the house, which could be when occupants could be in the building or not. Some common limitations to CCTV are as follows:

- It does not alert the occupant when this is an intruder or suspicious items.
- It is still streaming to capture the entire programs that are going on in the house, thereby leading to consumption of a very high bandwidth as well as storage media.

Surantha and Wicaksono, (2018) went further to state that some researchers have created a security tracking system centered on IoT concept 2.3. These security tracking systems use the ability of the sensor like the passive infrared motion sensor, which monitors the happening of any unwanted activities. The system is fixed with feedback to alert the occupants of an intruder in the house. The security monitoring system is much better than conventional CCTV. In addition, each device has to possess an authentication stack for access into security sensitive zones (Chifor et al., 2018).

3.2 Adaptability

Changing is a part of human’s life and natural environment. changing may have advantage or disadvantage on human life and it depends on how the results of a possible change are considered. From a long time ago, humans tried to predict the possible changes in the future and now it’s evident that humans are unable to predict different results or types of a possible change in the future and as a result it is better to think about adaptation instead of prediction. The word ‘change’ is known as a key to understanding adaptability through the very diverse previous academic literature without considering the type of building. (Pinder et al., 2017) nowadays adaptability is used as a design strategy in building sector and it is applied to a wide range of architecture design types such as office design, residential houses and hospital buildings (Pinder et al., 2017).

There are different types of change that can happen to a building during the time of use. Kincid (2000) introduces developments in certain technologies as a reason of change in the usage of a building. Ross et al. (2008) noted that: ‘‘There is value in adaptability in large part, because it is difficult to predict the changes that necessitate adaptation’’.

The development of technology as a reason for change is introduced as one of the important reasons for considering adaptability in this study because a smart house is made from the new technologies in the building industry.

3.2.1 Meaning of Adaptability

Adaptability is known as an ability to change to answer new needs. Adaptability has been used in a diverse variety of fields such as business, biology, ecology and education (Heidrich, et al., 2017). Furthermore, Brand (1994) defined adaptability as alteration that cannot only be seen as in building, but can be seen as individuals and groups which conceive the change. In addition, Sinclair et al. (2012) explained adaptability as the adaptive degree of a structure as the capacity to meet the alteration of the future with a limited demolition, as well as the cost, with optimal efficiency, good condition and the tendency to change, thereby resulting in the 'building' resilience.

Manewa et al., (2015), defined adaptability of building as the active system that possesses the ability to meet a group of changing requirements concerning space, usage, and features. they went further to stated that a maladaptable building is the one that would not meet the new requirements that us required of it, which might be as result of cost complication or technological non viability. Nevertheless, the connection between the adaptability and maladaptabilty is most time not obvious which relies on the group of external and internal factors of demands which can be assessed through critical evaluation (Heidrich, et al., 2017).

In all definitions it's evident that adaptability is defined as an ability to cope with further changes. Adaptability in architecture is mostly essential investments in a building which make a building be able to answer the change.

Nevertheless, the infrastructural system that makes the building what it is, is susceptible to several changes over their life cycle. These can comprise the ability to adapt to the prevalent needs of the occupants of the building: adjusting up to meet trending market situations, regulation requirements, currents issues with climate change as well as other environmental issues (measurable with the goal of decreasing the contributing elements that leads to climate change as well as changes to control the impacts and decrease the potential harm associated with climate change). Other issues include advances in technological and functionality permanence. (Heidrich et al., 2017).

However, studies in the adaptability of building through the years have led to several models and ideas that have provided the foundation for the comprehension and development of the ability to be adapted. Therefore, one of the critical concepts of the recent studies is that buildings are made up of stratus, which possess several degrees of adaptation. furthermore, as stated in Duffy (1990) classification as cited by Heidrich et al., 2017, various building status can include the following:

- shell (structure)
- services (heating, plumbing)
- scenery (fitting)
- set (furniture).

3.2.2 Types of Adaptability

with a good example of a space possessing more than the minimum is relevant for scalability and versatility as well as convertibility. In addition, it would be also important to point that adjustability does not only look at how the occupants make changes to the space, but the building elements that would allow the process of adaptation to be easier for the occupant in agreement to the action of the user (Heidrich, et al., 2017).

According to Arge (2005), there are three concepts that are concerned with adaptability primarily about the physical configuration of the building, in still does to concern the monetary or agreed in a contract of flexibility, nevertheless, these concepts and their definition are seen below:

- Generality can be seen as the capacity of the building to adjust to the evolving function and needs of the occupants, still not altering the properties, thereby resulting in the building to having a multifunctional use.
- Flexibility is the capacity of the building to adjust to the evolving function and needs of the occupants, still altering its properties, which shows that the building is constructed with the ability to rearrange when the occupants need the change.
- Elasticity can be defined as the capacity of the building to be elongated or divided based on the evolving needs of the users or occupants, thereby dividing the building into several cells of functions and even might require extension of the building.

In contribution to the type of adaptability, Manewa et al., (2013) cited the strategies that were employed in the Adaptable Future Project in 2012 known as the Frame cycle that integrated various design approach to adaptable buildings which are as follows:

- Adjustable strategy can be seen as the capacity of the building to alter its tasks, including concerns for changes in furniture type, alongside modular systems and planned links.
- Versatility strategy covers the capacity of the building to alter its internal spaces of the building, thereby focusing easy links, modular cells, alterable planes, fitted or demountable cells, out of size volume of space, and up to date services of the systems.

- Refitability here covers the capacity of the building to alter its components, which pays attention to the dismountable, degradable, ability to move, and foldable components of the building.
- Convertible refers to the capacity of the building to adjust along several functions, however it might need the internal and external changes of the building, with special focus on management of large volume of space, open spaces as well as materials that are renewable, ceilings, that would promote suit change.
- Scalability covers the capacity of the building to change its size, still terms like Extendible', 'expandable', and 'elasticity' can be seen as having the same definition with scalability.
- Movability covers the capacity of the building to be able to alter its location, thereby promoting prefabrication systems, linear processes, systems buildings and product families.

The figure below describes aforementioned strategies for adaptability in buildings with their characteristics.

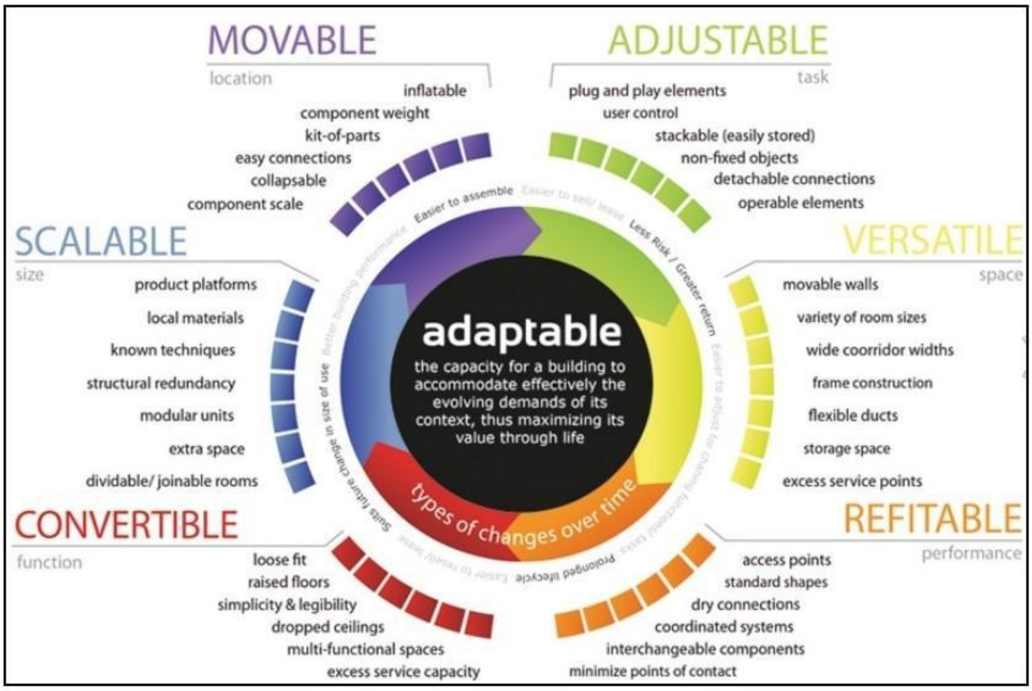


Figure 21: Types of adaptability strategies, (Manewa et al., 2013)

Nevertheless, types or characteristics of adaptability can be achieved in several ways, with factory or commercial building spaces can be scale either in the increase of floor gross area or in the increase of floor number due to structural modularity and services, the buildings mentioned above are designed to be adjustability in mind with the aid of infill that are movable, spaces that are shared, as well as spaces that are much larger to its minimum. it is important to note that, there is no layed down strategy, but a group of characters that would enable the meeting of the needs of the occupants of the building (Heidrich, et al., 2017).

3.2.3 Adaptable Building Design

Adaptable building definitions which were discussed in the previous part were mostly concentrate on the types of adaptability. Strategies were presented to recognize the new needs of the building and finding the suitable the adaptability types to fulfil the new demands of occupants. Searching for the design tactic designing adaptable houses, may lead to some features which can help the adaptability of buildings at design stage.

These design tactics are affecting the space organization of the interior spaces, circulation patterns, furniture arrangement and approaches for construction with consideration of structural issues and their effect on the form and volume of the building.

According to John et al (2017) floor to ceiling height can be said to be a significant aspect that has a huge role to play in the process of adaptation. Structures with a higher floor to ceiling height possess the potential for several uses. They cited Gregory (2006) who stated that buildings with the best chance for adaptation are buildings with adequate ceiling height. However, they went to stress that building with excess floor height is wasteful in a longer time as well as a short term. In design and building codes, some regulations and codes have limited the designer to design within fixed height limitation, which also in turn limits the chances for adaptation.

John et al (2017) stress the conflict that does arise for instance the utilization of suspended ceiling or a floor that is raised, that is good for changes of the services within the building usage, but however decreases the building capacity for interior utilization of height, that is a critical feature of the building. Fundamentally, the owner has to make the decision before time, concerning which part or approach of adaptability they would prefer, because there is no building that can take the whole adaptability aspects.

According to the work of Manewa, Siriwardena, Ross & Madanayake (2015) buildings that have undergone adaptability decreases the life cycle cost of the building, particularly its maintenance and continuous utilization. However, the capital cost might be much more than the conventional maladaptive building, still adaptive building takes the lead when the issue of durability of material is involved as well as the energy conservation of the building, thereby reducing the need for more maintenance, making them more attractive to tenants. Therefore, quality of the material is a critical aspect of the building of adaptability. However, as adaptive building pushes chances for the capacity to be refit-able, it also gives way for high flexibility where aging materials can be changed; this is factored on the nature of the adaptation (Manewa et al., 2015).

3.3 Conclusion

In this part of the study the selected smart features from the chapter 2 were fully described. These features were selected from the variety of smart features. Fire protection and fire detection systems, occupant detection, activity recognition mainly work with sensors, in between, a communication network is needed to transfer data along sensors, devices and users. There are features which work in order to save energy, like smart lighting control, smart lift, smart heating and smart solar panels. Each of them has their equipment and sensors to transfer and process data.

Security issues will answer with the help of smart security systems which also works along sensors, cameras and processors. Alarm systems notify the user in case of any threads. This chapter explains 2 features which are used in both smart and intelligent buildings which are kinetic façade and double-skin façade. Energy saving issues is the main reason behind using them. The literature review of this chapter shows how each of these feature works, their technical and spatial requirements can be understood from the explanations in this chapter. It can be possible to evaluate an existing building with consideration of upgrades to the smart features. Adaptability has also been explained and characteristics of each adaptability type and their borders were presented, so that the potentials for future upgrades in chapter 4 will be considered in the frame of adaptability types.

Chapter 4

CASE STUDY: DATA COLLECTION FOR EVALUATING THE POTENTIALS OF ADAPTABILITY FOR FUTURE CHANGES IN RESIDENTIAL BUILDINGS (CASE OF: FAMAGUSTA, NORTH CYPRUS)

The case study of this thesis is analyzing the smart features along the new residential buildings. The new residential projects are going to be selected in the city of Famagusta, North Cyprus and the architectural elements and current situation of these buildings are going to be analyzed according to the smart building features. The case study is going to analyze these buildings according to literature survey which is extracted from literature review. Case study is based on the which is gathered from a variety of previous academic literature over the topic and limited to smart features, which were researched in chapter3, these features were limited, listed and researched in order to be used for data collection with observation. This chapter will collect data in order to answer the aim and main questions of the thesis, the method which has been used is observation and literature survey.

The smart features of the building and adaptability types in chapter 3 are used in order to examine the buildings currents status and for proposing future potentials of adaptability to new changes. The diagram of this chapter can be seen in figure 22.

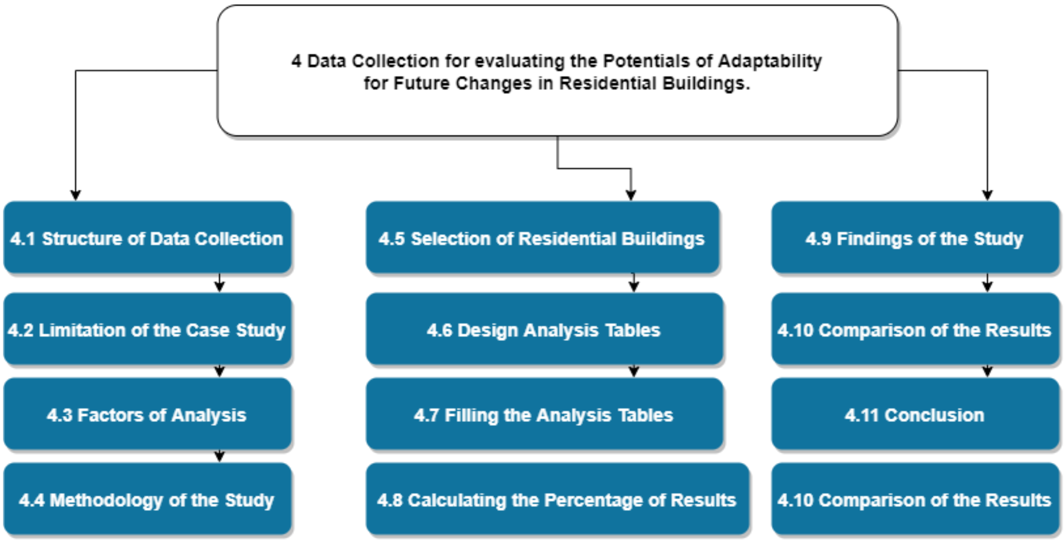


Figure 22: Summary of chapter four

4.1 Structure of Data Collection

In this thesis, a data collection method is developed to analyze the adaptability of residential buildings for the future upgrades with new smart features.

At the beginning of the methodology a number of construction companies in Famagusta, North Cyprus were selected, next step was to limit the companies and their project, tables are going to be ready for categorizing the smart features and evaluating the buildings adaptability for the future changes. The tables of case analysis were designed and developed by the author during the different stages of this research. All the information inside the tables based on the related literature review of the study in chapter 2 and chapter 3. At the next step photographs and building information were gathered inside the tables. At the end, the results of study will be estimated and concluded.

4.2 Limitation of Case Study

The Limitations of this methodology is going to apply to both case studies and features of smart houses. The features are limited to 12 features which were researched before in chapter 3 and buildings also selected between the alternatives. At first the limitation was applied in order to limit the buildings more than 4 years of age and then as a result of coronavirus shut downs and public quarantine, the researcher of this study decided to limit the selected list into those buildings which have accurate data of their projects in their websites in order to reduce the unnecessary transportation and observation. The residential buildings are going to be analyzed which:

- Located at Famagusta, North Cyprus
- Located at City Centre and do not contain suburbs
- Buildings which finished during 2016-2020
- Future and under construction projects are not included
- Residential apartments and not villas
- The selected construction companies are those which have accurate architectural project data in their websites.

4.3 Factors of Analysis

The information from chapter 3 is going to make a table of smart features which were collected from various academic resources over the smart and intelligent building with different approaches. These smart features were researched through the most recent literature in chapter 2 and explained in chapter 3. Adaptability types are collected from literature review in chapter 3 and will cover the probable changes as a solution to analyze the buildings spaces and abilities for being adaptable to new conditions. Data collection methods of this thesis are literature review and observation, data is collected in tables and summarized in this chapter.

Analyze tables were designed in order to gather information from previous chapters, information of the residential building was collected by authors observation and resources from the internet and the company website.

Factors of the study were researched through the most recent literature in chapter 2 and 3 and selected buildings are going to be analyzed according to designed tables. for some buildings with different flat types (1+1, 2+1, 3+1, Studio) these factors are analyzed separately. Factors of the study can be categorized as follows:

1. Floor plan space organization (Entrance, Kitchen, Bedroom, TV-Lounge, Bathroom, Balcony and facade of the building). These spaces are going to be analyzed for the table of adaptability potentials.
2. Height of floor and Durability of materials of the current status of building will be observed and recorded in their tables. These terms explained under the adaptability heading in chapter 3 and will help for evaluation of the adaptability potentials.
3. Smart features (see chapter 3) which are categorized into 12 features, they are listed as:
    - Fire detection
    - Fire protection
    - Occupant detection
    - Activity recognition
    - Communication network
    - Smart security
    - Smart Lighting control
    - Smart Lift
    - Smart Heating

- Smart Solar panels
- Kinetic facade
- Double-skin façade.

4. Adaptability types are shown as a table to analyze the potentials of the building for answering the changes for smart features in the future. From the adaptability types discussed in chapter 3, 6 types were selected for the case study:

- Adjustable
- Versatile
- Refit-able
- Convertible
- Scalable
- Moveable.

Other types of adaptability and other smart features of smart/Intelligent buildings are not included in this limitation.

4.4 Methodology of the Study

In this chapter of the thesis the methodology of the study will collect data about adaptability potentials of residential buildings to become smart house in the future. The data collection is going to be used for finding the potentials and limitations for adaptability in the selected buildings.

4.5 Selection of Residential Buildings

Method of the case study is to collect information from residential apartments in Famagusta, North Cyprus (Figure 23). The city is located at eastern side of the island and is known for being a destination for tourists and a great number of students living inside the residential apartments in this city. The demand for building new residential housing is growing in this city. There are many construction companies in this city and they have projects in both city center and suburban areas. For this study the new residential projects from these companies are going to be analyzed.

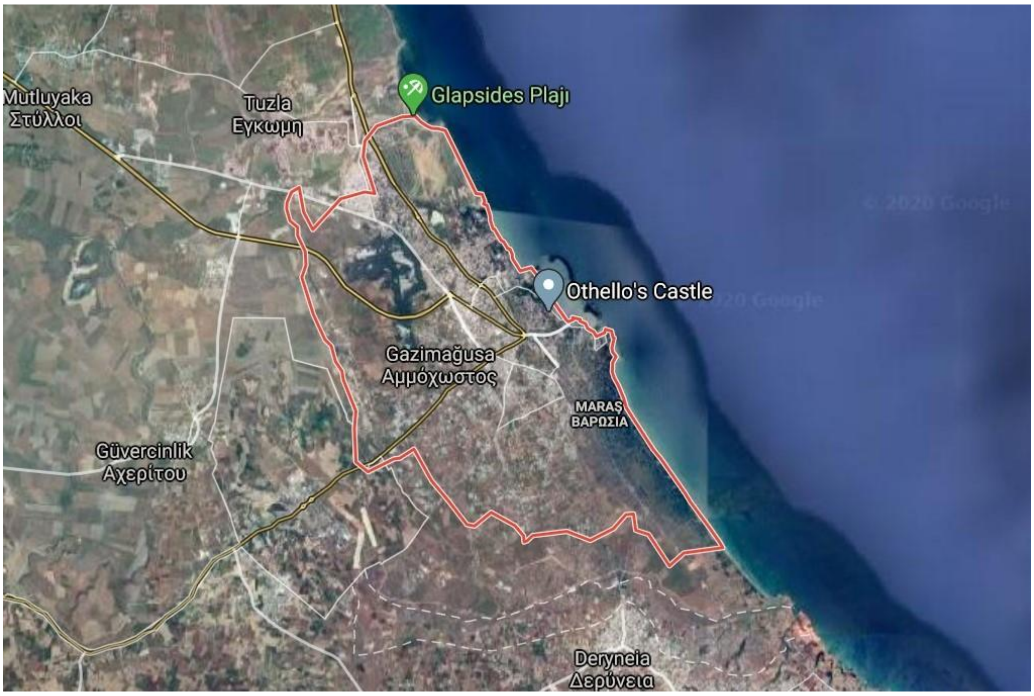


Figure 23: Location of Famagusta (Gazimagusa) in North Cyprus map, (Google maps, 2019)

In the figure above shows the map of Famagusta City can be seen and Mediterranean Sea is located on the right side. The selected buildings located at different parts of city and rural parts are not included in this research. With the analyzing tables which were designed by the researcher, Different aspects and adaptability potentials of this building will be observed and evaluated according to smart features. The results of the data collection will be presented in percentages and they will be used to finalize the findings at the end.

4.6 Design Analysis Tables

In this part, the analysis tables are designed by the author to fulfil this chapter case study, the columns and rows based on the literature review from chapter 2 and 3 and there is general information about the floor types and location and photographs of each building in a separate table. All the projects from the selected companies were categorized in order to analyze the projects which are included in this research according to the case study limitation. The list has parts as below:

- Projects by the construction company names.
- Type of plan.
- Name of building.
- Name of the smart features (from the chapter 3 literature review).
- Adaptability potentials.
- Materials durability & Height of floor (discussed before in chapter 3).
- schematic plan and name of interior spaces.
- Overview of space organization.
- Photographs or renders.
- Current status of the building for each smart feature.

An example of the case study analysis table is shown in the table 2.

Table 2: Example of case study analysis table

Name of Building / Type of Plan

Logo of Company

Name of Company:
Name of Building:
Name of Plan Type:

			Adaptability Potential for Future Upgrades						
	Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
SMART BUILDING FEATURES	Fire Detection								
	Fire Protection								
	Occupant Detection								
	Activity Recognition								
	Communication Network								
	Smart Security								
	Smart Lighting control								
	Smart Lift								
	Smart Heating								
	Smart Solar Panels								
	Kinetic Facade								
	Double-skin Facade								

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall					
	Floor					
	Ceiling					
Kitchen	Wall					
	Floor					
	Ceiling					
Bedroom 1	Wall					
	Floor					
	Ceiling					
Bathroom	Wall					
	Floor					
	Ceiling					
Living Room	Wall					
	Floor					
	Ceiling					
Balcony	Wall					
	Floor					
	Ceiling					
Bedroom 2	Wall					
	Floor					
	Ceiling					
Bedroom 3	Wall					
	Floor					
	Ceiling					

Floor Plan of Plan Type	Space Organization of Plan Type	Photographs

4.7 The Analysis Tables

Analyzing the selected companies was carried out by limited site visits and also according to information from the company's websites. The corona virus shut downs and social distancing change the process of filling tables. For some cases such as Northern Land new residential buildings. The researcher employed observation and site visits, and for some cases the information gathered from the website of the companies. The information is used to analyze the current adaptability of these buildings. The photographs of the buildings also searched over the company's websites to collect accurate data for the buildings which were analyzed with online materials, during coronavirus shut downs. Below, all the case study tables are presented.

UZUN Group of Companies

Explanation

Logo of company

Uzun Group of Companies

The Uzun Group of Companies was established by Gürsel Uzun in 1980 in the nicosia. The companies first started as a family business. The company is working on different projects along the island and the company has also other companies in the areas such as: construction company, contracting, project design, real estate services, furniture of projects, & rental car services.The company is known for its seriousness and meticulousness in the fields it operates. The aim of the company is to design permanent living spaces which add quality to user lifestyles, & helps the users to adapt themselves to the city and environment, the company is looking forward to changing the building concepts rather than building a simple shelter.The projects of Uzun group of companies, spread along different locations of the island, in many sector such as residential & commercial buildings in North Cyprus. Uzun is one of the top companies which make quality projects in the country (Uzun website).

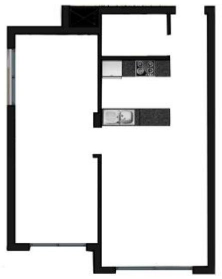
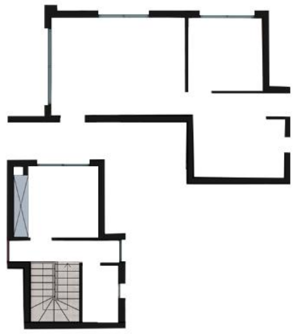
Example of projects

Selected projects: Vanora

Figure 24: Explanation of Uzun Group

Vanora

Plan Organization

Names	2+1 Penthouse A	2+1 Penthouse B	2+1 Duplex
Plan			
Space Schema			

Floor Plan Organization

Photographs

Map

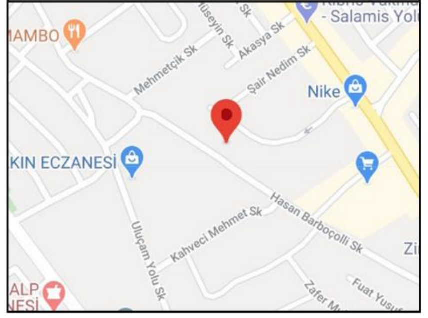


Figure 25: Uzun, Vanora project

Vanora / 2+1 Duplex

Name of Company: Uzun Group
Name of Building: Vanora
Name of Plan Type: 2+1 Duplex

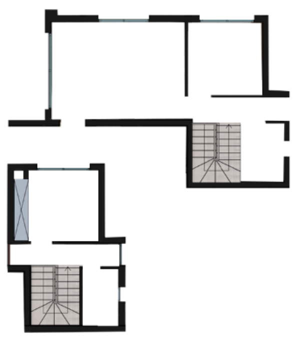
SMART BUILDING FEATURES

Adaptability Potential for Future Upgrades

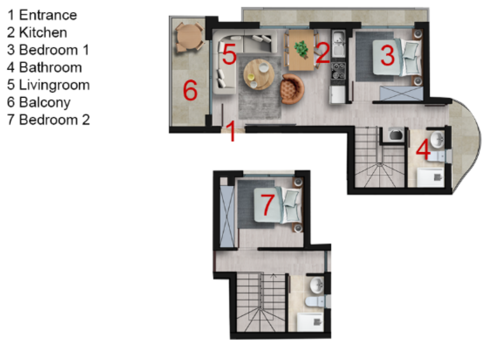
Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Basic fire protection		*					Changing the space & services
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Central satellite system		*					Changing the space & services
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Lighting sensors			*				Easily improving the space
Smart Lift	Not found			*				Easily improving the space
Smart Heating	Not found		*					Changing the space & services
Smart Solar Panels	Solar water heating system			*				Easily improving the space
Kinetic Facade	Not found					*		Changing the size of building
Double-skin Facade	Double glass PVC windows					*		Changing the size of building

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Kitchen	Wall	Ceramic		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Bedroom 1	Wall	Paint		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Bathroom	Wall	Ceramic		*		2.35
	Floor	Marble		*		
	Ceiling	Paint		*		
Living Room	Wall	Paint		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Balcony	Wall	Paint	*			2.64
	Floor	Marble		*		
	Ceiling	Paint		*		
Bedroom 2	Wall	Paint		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Bedroom 3						

Floor Plan of Studio



Space Organization of Studio



Photographs

Figure 26: Uzun, Vanora 2+1 duplex

Vanora / 2+1 Penthouse A

Name of Company: Uzun Group
Name of Building: Vanora
Name of Plan Type: 2+1 Penthouse A

SMART BUILDING FEATURES

Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Basic fire protection		*					Changing the space & services
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Central satellite system		*					Changing the space & services
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Lighting sensors			*				Easily improving the space
Smart Lift	Not found			*				Easily improving the space
Smart Heating	Not found		*					Changing the space & services
Smart Solar Panels	Solar water heating system			*				Easily improving the space
Kinetic Facade	Not found					*		Changing the size of building
Double-skin Facade	Double glass PVC windows					*		Changing the size of building

Adaptability Potential for Future Upgrades

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Kitchen	Wall	Ceramic		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Bedroom 1	Wall	Paint		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Bathroom	Wall	Ceramic		*		2.35
	Floor	Marble		*		
	Ceiling	Paint		*		
Living Room	Wall	Paint		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Balcony	Wall	Paint	*			2.64
	Floor	Marble		*		
	Ceiling	Paint		*		
Bedroom 2	Wall	Paint		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Bedroom 3						

Floor Plan of Studio

Space Organization of Studio

1 Entrance
2 Kitchen
3 Bedroom 1
4 Bathroom
5 Livingroom
6 Balcony
7 Bedroom 2

Photographs

Figure 27: Uzun, Vanora 2+1 penthouse A

Vanora / 2+1 Penthouse B

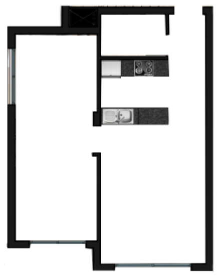
Name of Company: Uzun Group
Name of Building: Vanora
Name of Plan Type: 2+1 Penthouse B

SMART BUILDING FEATURES

Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
		Adaptability Potential for Future Upgrades						
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Basic fire protection		*					Changing the space & services
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Central satellite system		*					Changing the space & services
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Lighting sensors			*				Easily improving the space
Smart Lift	Not found			*				Easily improving the space
Smart Heating	Not found		*					Changing the space & services
Smart Solar Panels	Solar water heating system			*				Easily improving the space
Kinetic Facade	Not found					*		Changing the size of building
Double-skin Facade	Double glass PVC windows					*		Changing the size of building

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Kitchen	Wall	Ceramic		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Bedroom 1	Wall	Paint		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Bathroom	Wall	Ceramic		*		2.35
	Floor	Marble		*		
	Ceiling	Paint		*		
Living Room	Wall	Paint		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Balcony	Wall	Paint	*			2.64
	Floor	Marble		*		
	Ceiling	Paint		*		
Bedroom 2	Wall	Paint		*		2.6
	Floor	Laminate			*	
	Ceiling	Paint		*		
Bedroom 3						

Floor Plan of Studio



Space Organization of Studio

Photographs

Figure 28: Uzun, Vanora 2+1 penthouse B

NorthernLAND Construction

NorthernLAND

Explanation

NorthernLAND Construction

The NorthernLAND company was established in 2003, NorthernLAND construction is a famous company and one of the biggest companies in the island. NorthernLAND is famous between local people and immigrants in North Cyprus for Its high rise residential buildings and the company's other brands such as “ Fit-plus GYM” and fitness club and “Cyprus Ways” car rentals. Recently, the company established Thrones club as another brand of NorthernLAND. Projects of this group are built on both urban and rural sides of Famagusta, North Cyprus, and the company is successful in answering the needs of all local citizens, Students and TouristsThe NorthernLAND company aims to be the most successful construction company in the north side of Cyprus island. The company presents itself as a prouded company which has more than the Cypriot standards in their projects, the company aims to have unique designs and quality of services and building. The company principles are considered in transparency, honesty and reliability. Customer satisfaction is known as one of the reasons behind the success of a company (Northernland website).

Selected projects: Uptown Park, Subway Park & Center

Logo of company

NorthernLAND

Example of projects

Figure 29: Explanation of Northernland construction

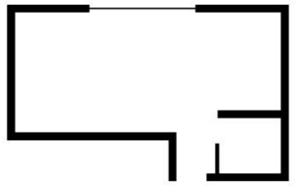
NorthernLAND Center Building

Plan Organization

Names

Studio

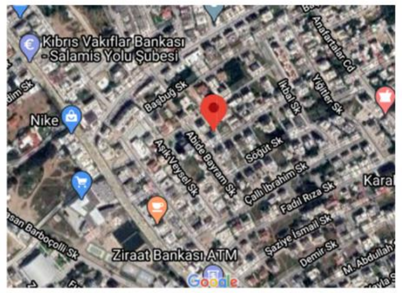
Plan



Space Schema

Photographs

Map



Floor Plan Organization

Figure 30: Northernland, Center project

Center Building / Studio

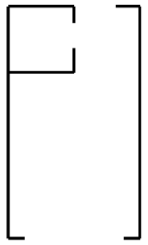
Name of Company: Northern land
Name of Building: Center
Name of Plan Type: Studio

SMART BUILDING FEATURES

Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Basic fire protection		*					Changing the space & services
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Central access & internet				*			Changing the function
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Lighting sensors			*				Easily improving the space
Smart Lift	Card lift			*				Easily improving the space
Smart Heating	Not found		*					Changing the space & services
Smart Solar Panels	Not found				*			Changing the function
Kinetic Facade	Not found					*		Changing the size of building
Double-skin Facade	PVC double glazing					*		Changing the size of building

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint		*		2.6
	Floor	Laminate		*		
	Ceiling	Paint		*		
Kitchen	Wall	Ceramic			*	2.6
	Floor	Laminate		*		
	Ceiling	Paint		*		
Bedroom	Wall	Paint		*		2.6
	Floor	Laminate		*		
	Ceiling	Paint		*		
Bathroom	Wall	Tile Panel		*	*	2.3
	Floor	Marble		*		
	Ceiling	Paint		*		
Living Room						
Balcony	Wall	Paint		*		2.6
	Floor	Stone Tile			*	
	Ceiling	Paint		*		
Bedroom 2						
Bedroom 3						

Floor Plan of Studio



Space Organization of Studio

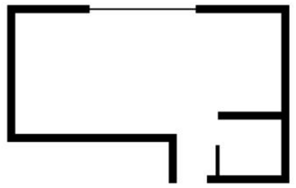
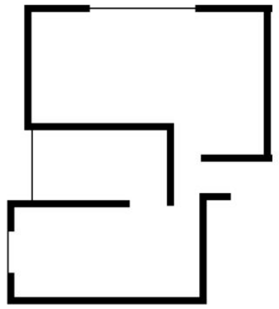
Photographs

Figure 31: Northernland, Center studio

Subway Park Building

NorthernLAND

Plan Organization

Names	Studio	2+1
Plan		
Space Schema		

Floor Plan Organization

2+1 Floor	
Studio Floor	

Photographs

Map

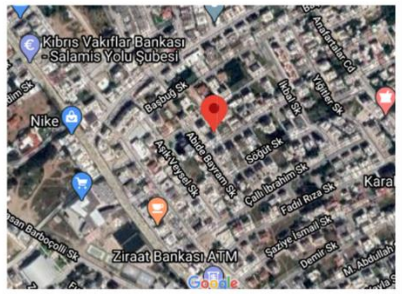


Figure 32: Northernland, Subway park project

Subway Park Building / Studio

Name of Company: Northern land
Name of Building: Subway Park
Name of Plan Type: Studio

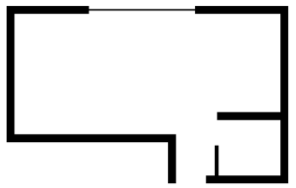
SMART BUILDING FEATURES

Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Basic fire protection		*					Changing the space & services
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Low-end network		*					Changing the space & services
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Lighting sensors			*				Easily improving the space
Smart Lift	Card lift			*				Easily improving the space
Smart Heating	Not found		*					Changing the space & services
Smart Solar Panels	Not found			*				Easily improving the space
Kinetic Facade	Not found					*		Changing the size of building
Double-skin Facade	PVC double glazing					*		Changing the size of building

Adaptability Potential for Future Upgrades

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint		*		2.6
	Floor	Laminate		*		
	Ceiling	Paint		*		
Kitchen	Wall	Paint	*			2.6
	Floor	Laminate	*			
	Ceiling	Paint		*		
Bedroom	Wall	Paint		*		2.6
	Floor	Laminate		*		
	Ceiling	Paint		*		
Bathroom	Wall	Ceramic		*		2.3
	Floor	Marble		*		
	Ceiling	Paint		*		
Living Room						
Balcony						
Bedroom 2						
Bedroom 3						

Floor Plan of Studio



Space Organization of Studio

Photographs

Figure 33: Northernland, Subway park studio

Subway Park Building / 2+1

NorthernLAND

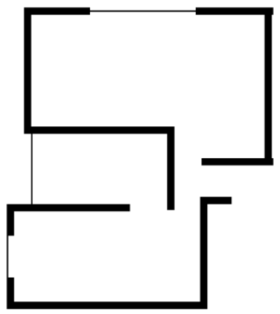
Name of Company: Northern land
Name of Building: Subway Park
Name of Plan Type: 2+1

SMART BUILDING FEATURES

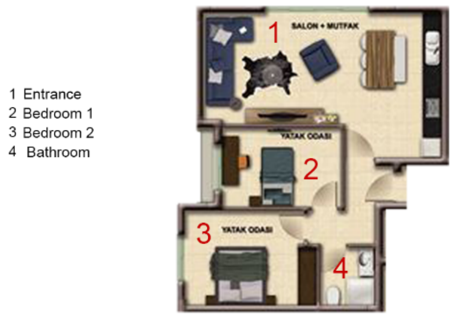
Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
		Adaptability Potential for Future Upgrades						
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Basic fire protection		*					Changing the space & services
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Low-end network		*					Changing the space & services
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Lighting sensors			*				Easily improving the space
Smart Lift	Card lift			*				Easily improving the space
Smart Heating	Not found		*					Changing the space & services
Smart Solar Panels	Not found			*				Easily improving the space
Kinetic Facade	Not found					*		Changing the size of building
Double-skin Facade	PVC double glazing					*		Changing the size of building

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint		*		2.6
	Floor	Laminate		*		
	Ceiling	Paint		*		
Kitchen	Wall	Paint	*			2.6
	Floor	Laminate	*			
	Ceiling	Paint		*		
Bedroom 1	Wall	Paint		*		2.6
	Floor	Laminate		*		
	Ceiling	Paint		*		
Bathroom	Wall	Ceramic		*		2.3
	Floor	Marble		*		
	Ceiling	Paint		*		
Living Room	Wall	Paint	*			2.6
	Floor	Laminate		*		
	Ceiling	Paint		*		
Balcony	Wall	Paint	*			2.6
	Floor	Marble		*		
	Ceiling	Paint		*		
Bedroom 2	Wall	Paint		*		2.6
	Floor	Marble		*		
	Ceiling	Paint		*		
Bedroom 3						

Floor Plan of Studio



Space Organization of Studio



Photographs

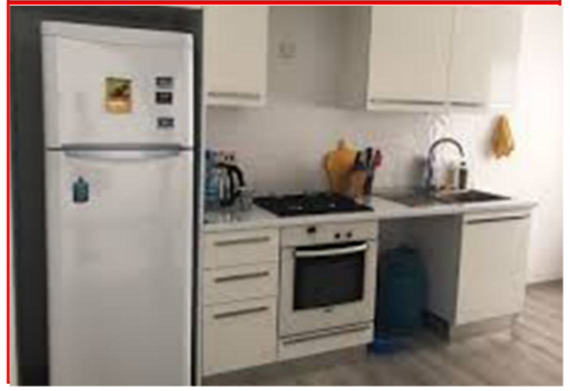
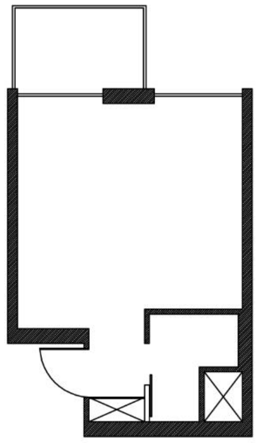
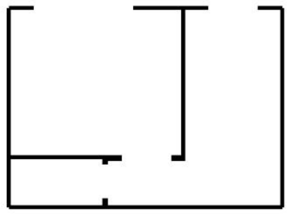
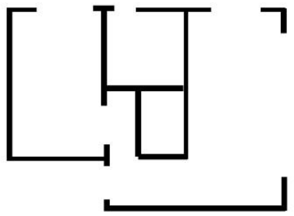


Figure 34: Northernland, Subway park 2+1

Uptown Park Building

NorthernLAND

Plan Organization

Names	Studio	1+1	2+1
Plan			
Space Schema			

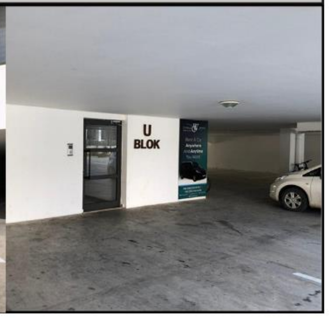
Floor Plan Organization

1 Entrance
2 Kitchen
3 Bedroom 1
4 Bathroom
5 Livingroom
6 Balcony
7 Bedroom 2

1 Entrance
2 Kitchen
3 Bedroom 1
4 Bathroom
5 Livingroom
6 Balcony

1 Entrance
2 Kitchen
3 Bedroom 1
4 Bathroom
5 Livingroom
6 Balcony

Photographs



Map

Figure 35: Northernland, Uptown park project

Uptown Park Building / 1+1

NorthernLAND

Name of Company: Northern land
Name of Building: Uptown Park
Name of Plan Type: 1+1

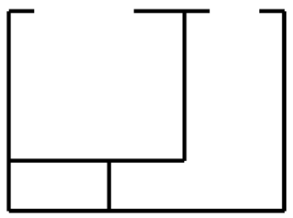
SMART BUILDING FEATURES

Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Fire protection for each floor			*				Easily improving the space
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Advance communication room	*						Changing the task
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Responsive lighting sensors			*				Easily improving the space
Smart Lift	Card lift			*				Easily improving the space
Smart Heating	Not found		*					Changing the space & services
Smart Solar Panels	Not found			*				Easily improving the space
Kinetic Facade	Not found							Not Adaptable
Double-skin Facade	PVC double glazing							Not Adaptable

Adaptability Potential for Future Upgrades

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint		*		2.65
	Floor	Laminate		*		
	Ceiling	Paint		*		
Kitchen	Wall	Ceramic			*	2.65
	Floor	Laminate		*		
	Ceiling	Paint		*		
Bedroom 1	Wall	Paint		*		2.65
	Floor	Laminate		*		
	Ceiling	Paint		*		
Bathroom	Wall	Ceramic		*		2.34
	Floor	Marble		*		
	Ceiling	Paint		*		
Living Room	Wall	Paint		*		2.65
	Floor	Laminate		*		
	Ceiling	Paint		*		
Balcony	Wall	Paint	*			2.68
	Floor	Marble			*	
	Ceiling	Paint		*		
Bedroom 2						
Bedroom 3						

Floor Plan of Studio



Space Organization of Studio

Photographs

Figure 36: Northernland, Uptown park 1+1

Uptown Park Building / 2+1

NorthernLAND

Name of Company: Northern land
Name of Building: Uptown Park
Name of Plan Type: 2+1

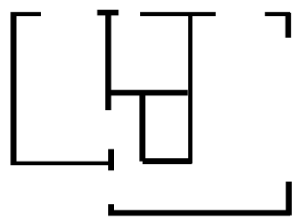
SMART BUILDING FEATURES

Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Fire protection for each floor			*				Easily improving the space
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Advance communication room	*						Changing the task
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Responsive lighting sensors			*				Easily improving the space
Smart Lift	Card lift			*				Easily improving the space
Smart Heating	Not found		*					Changing the space & services
Smart Solar Panels	Not found			*				Easily improving the space
Kinetic Facade	Not found							Not Adaptable
Double-skin Facade	PVC double glazing							Not Adaptable

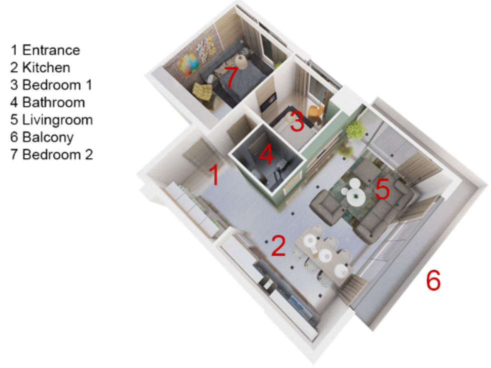
Adaptability Potential for Future Upgrades

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint		*		2.65
	Floor	Laminate		*		
	Ceiling	Paint		*		
Kitchen	Wall	Ceramic			*	2.65
	Floor	Laminate		*		
	Ceiling	Paint		*		
Bedroom 1	Wall	Paint		*		2.65
	Floor	Laminate		*		
	Ceiling	Paint		*		
Bathroom	Wall	Ceramic		*		2.34
	Floor	Marble		*		
	Ceiling	Paint		*		
Living Room	Wall	Paint		*		2.65
	Floor	Laminate		*		
	Ceiling	Paint		*		
Balcony	Wall	Paint	*			2.68
	Floor	Marble			*	
	Ceiling	Paint		*		
Bedroom 2	Wall	Paint		*		2.65
	Floor	Laminate		*		
	Ceiling	Paint		*		
Bedroom 3						

Floor Plan of Studio



Space Organization of Studio



Photographs

Figure 37: Northernland, Uptown park 2+1

Uptown Park Building / Studio

NorthernLAND

Name of Company: Northern land
Name of Building: Uptown Park
Name of Plan Type: Studio

SMART BUILDING FEATURES

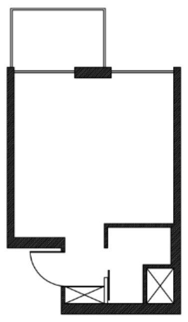
Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Fire protection for each floor			*				Easily improving the space
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Advance communication room	*						Changing the task
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Responsive lighting sensors			*				Easily improving the space
Smart Lift	Card lift			*				Easily improving the space
Smart Heating	Not found		*					Changing the space & services
Smart Solar Panels	Not found			*				Easily improving the space
Kinetic Facade	Not found							Not Adaptable
Double-skin Facade	PVC double glazing							Not Adaptable

Adaptability Potential for Future Upgrades

Materials | Durability | Height

Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint		*		2.65
	Floor	Laminate		*		
	Ceiling	Paint		*		
Kitchen	Wall	Ceramic			*	2.65
	Floor	Laminate		*		
	Ceiling	Paint		*		
Bedroom 1	Wall	Paint		*		2.65
	Floor	Laminate		*		
	Ceiling	Paint		*		
Bathroom	Wall	Ceramic		*		2.34
	Floor	Marble		*		
	Ceiling	Paint		*		
Living Room						
Balcony	Wall	Paint	*			2.68
	Floor	Marble			*	
	Ceiling	Paint		*		
Bedroom 2						
Bedroom 3						

Floor Plan of Studio



Space Organization of Studio

Photographs

Figure 38: Northernland, Uptown park studio

DOVEÇ Construction

Explanation

DÖVEÇ Construction

Dovec construction company is a well known and trusted construction company in North Cyprus The company has built more than 1000 projects for families and businesses. They are between a few number of companies which have a First Class Construction Building Licence from the Northern Cypriot Government. The Arredo production kitchen and home furnishing and alfam dormitories in the Eastern Mediterranean University are known as the sub parts of the dovec company.

Another brand from dovec company is Döveç Fitness Centre which is a chain fitness club with some branches in the city. The company was established by the founder Muharrem Döveç, during the establishment of Döveç company he already had 20 years of experience. He is a member of the Turkish Cypriot Builders and Construction Association. Today the company is one of the remarkable examples of quality construction in the island (Dovec website).

Selected projects: Golden Residence, Terrace Park & Corner Park

Logo of company

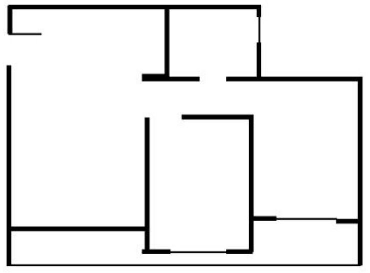
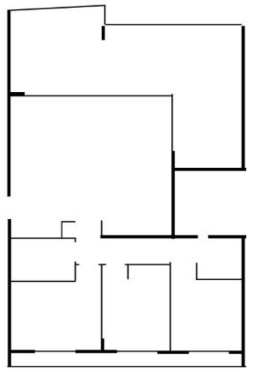
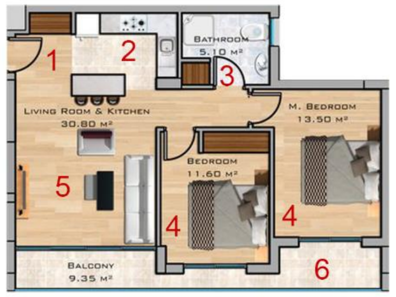
Example of projects

Figure 39: Explanation of Dovec construction

Corner Park Building

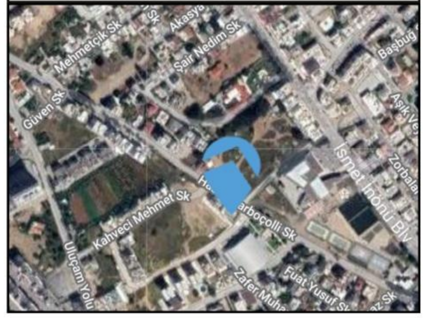
DÖVEC CONSTRUCTION

Plan Organization

Names	2+1	3+1
Plan		
Space Schema	1 Entrance 2 Kitchen 3 Bathroom 4 Bedroom 5 Living Room 6 Balcony 	1 Entrance 2 Kitchen 3 Bathroom 4 Bedroom 5 Living Room 6 Balcony 

Photographs

Map



Floor Plan Organization

Floor Type 2

Floor Type 1

Figure 40: Dovec, Corner park project

Corner Park Building / 2+1

DÖVEC CONSTRUCTION

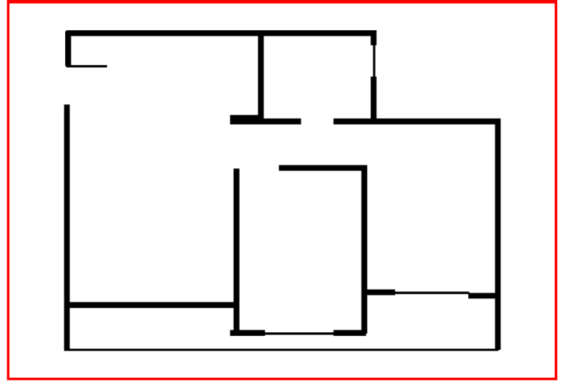
Name of Company: Dovec
Name of Building: Corner Park
Name of Plan Type: 2+1

SMART BUILDING FEATURES

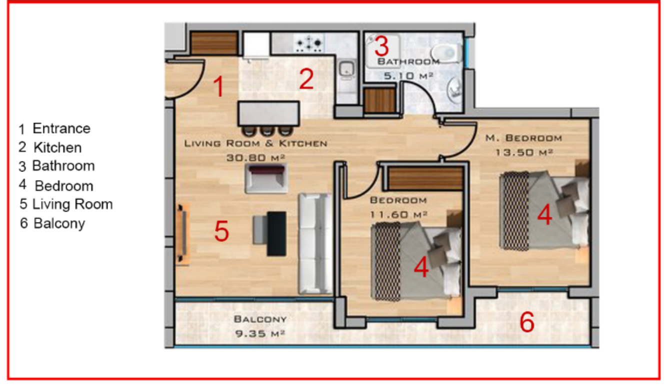
		Adaptability Potential for Future Upgrades						
Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Not found		*					Changing the space & services
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Central satellite system				*			Changing the function
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Photocell stair lighting			*				Easily improving the space
Smart Lift	Card lift			*				Easily improving the space
Smart Heating	Central generator system		*					Changing the space & services
Smart Solar Panels	Not found				*			Changing the function
Kinetic Facade	Not found					*		Changing the size of building
Double-skin Facade	PVC double glazing					*		Changing the size of building

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint			*	2.67
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Kitchen	Wall	Tile Panel			*	2.67
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Bedroom 1	Wall	Paint			*	2.67
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Bathroom	Wall	Ceramic			*	2.35
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Living Room	Wall	Paint			*	2.67
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Balcony	Wall	Paint			*	2.67
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Bedroom 2	Wall	Paint			*	2.67
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Bedroom 3						

Floor Plan of 2+1



Space Organization of 2+1



Photographs

Figure 41: Dovec, Corner park 2+1

Corner Park Building / 3+1

DÖVEC CONSTRUCTION

Name of Company: Dovec
Name of Building: Corner Park
Name of Plan Type: 3+1

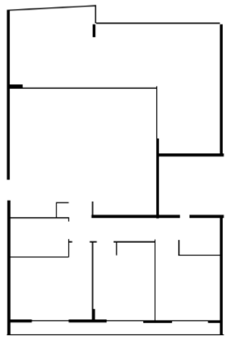
	Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
SMART BUILDING FEATURES	Fire Detection	Smoke detectors			*				Easily improving the space
	Fire Protection	Not found		*					Changing the space & services
	Occupant Detection	Not found		*					Changing the space & services
	Activity Recognition	Not found		*					Changing the space & services
	Communication Network	Central satellite system				*			Changing the function
	Smart Security	Camera system			*				Easily improving the space
	Smart Lighting Control	Photocell stair lighting			*				Easily improving the space
	Smart Lift	Card lift			*				Easily improving the space
	Smart Heating	Central generator system		*					Changing the space & services
	Smart Solar Panels	Not found				*			Changing the function
	Kinetic Facade	Not found					*		Changing the size of building
	Double-skin Facade	PVC double glazing					*		Changing the size of building

Adaptability Potential for Future Upgrades

Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint			*	2.67
	Floor	Laminate			*	
	Ceiling	Paint		*		
Kitchen	Wall	Tile Panel			*	2.67
	Floor	Laminate			*	
	Ceiling	Paint		*		
Bedroom 1	Wall	Paint			*	2.67
	Floor	Laminate			*	
	Ceiling	Paint		*		
Bathroom	Wall	Tile Panel			*	2.35
	Floor	Marble			*	
	Ceiling	Paint		*		
Living Room	Wall	Paint			*	2.67
	Floor	Laminate			*	
	Ceiling	Paint		*		
Balcony	Wall	Paint			*	2.67
	Floor	Stone Tile			*	
	Ceiling	Paint		*		
Bedroom 2	Wall	Paint			*	2.67
	Floor	Laminate			*	
	Ceiling	Paint		*		
Bedroom 3	Wall	Paint			*	
	Floor	Ceramic			*	
	Ceiling	Paint		*		

Materials — Durability — Height

Floor Plan of 2+1



Space Organization of 2+1

Photographs

Figure 42: Dovec, Corner park 3+1

Golden Residence

Plan Organization

Names

2+1

3+1 type1

3+1 type2

Plan

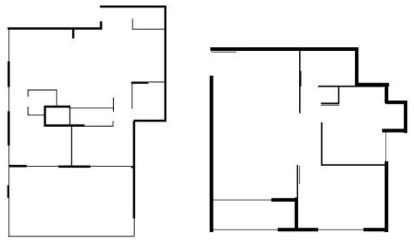
1 Entrance
2 Kitchen
3 Bathroom
4 Bedroom
5 Living Room
6 Balcony

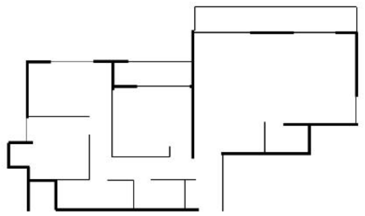
1 Entrance
2 Kitchen
3 Bathroom
4 Bedroom
5 Living Room
6 Balcony

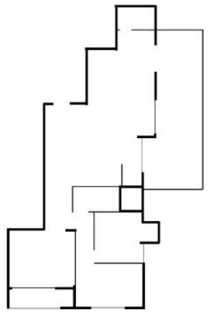
1 Entrance
2 Kitchen
3 Bathroom
4 Bedroom
5 Living Room
6 Balcony

1 Entrance
2 Kitchen
3 Bathroom
4 Bedroom
5 Living Room
6 Balcony

Space Schema







Photographs

Map

Floor Plan Organization

Figure 43: Dovec, Golden residence project

Golden Residence / 3+1 - Type 1

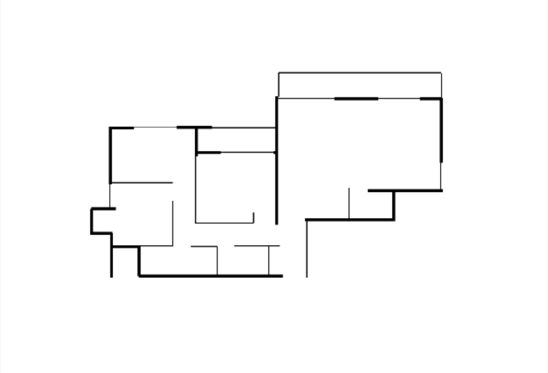
Name of Company: Dovec
Name of Building: Golden Residence
Name of Plan Type: 3+1 Type 1

Adaptability Potential for Future Upgrades

	Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
SMART BUILDING FEATURES	Fire Detection	Smoke detectors			*				Easily improving the space
	Fire Protection	Not found		*					Changing the space & services
	Occupant Detection	Not found		*					Changing the space & services
	Activity Recognition	Not found		*					Changing the space & services
	Communication Network	Central satellite/Internet system				*			Changing the function
	Smart Security	Camera system			*				Easily improving the space
	Smart Lighting control	Photocell stair lighting			*				Easily improving the space
	Smart Lift	Card lift			*				Easily improving the space
	Smart Heating	Central generator system		*					Changing the space & services
	Smart Solar Panels	Not found				*			Changing the function
	Kinetic facade	Not found					*		Changing the size of building
	Double-skin facade	PVC double glazing					*		Changing the size of building

Materials		Durability			Height
Area	Name of Materials	Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall: paint			*	2.7
	Floor: Ceramic			*	
	Ceiling: Paint		*		
Kitchen	Wall: Tile Panel			*	2.7
	Floor: Ceramic			*	
	Ceiling: Paint		*		
Bedroom 1	Wall: Paint			*	2.7
	Floor: Ceramic			*	
	Ceiling: Paint		*		
Bathroom	Wall: Tile Panel			*	2.4
	Floor: Ceramic			*	
	Ceiling: Paint		*		
Living Room	Wall: Paint			*	2.7
	Floor: Ceramic			*	
	Ceiling: Paint		*		
Balcony	Wall: Paint			*	2.74
	Floor: Ceramic			*	
	Ceiling: Paint		*		
Bedroom 2	Wall: Paint				2.7
	Floor: Ceramic			*	
	Ceiling: Paint		*		
Bedroom 3	Wall: Paint			*	2.7
	Floor: Ceramic			*	
	Ceiling: Paint		*		

Floor Plan of 3+1



Space Organization of 3+1

Photographs

Figure 44: Dovec, Golden residence 3+1 type 1

Golden Residence / 3+1 - Type 2

DÖVEC CONSTRUCTION

Name of Company: Dovec
Name of Building: Golden Residence
Name of Plan Type: 3+1 Type 2

SMART BUILDING FEATURES

Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Not found		*					Changing the space & services
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Central satellite system				*			Changing the function
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Photocell stair lighting			*				Easily improving the space
Smart Lift	Card lift			*				Easily improving the space
Smart Heating	Central generator system		*					Changing the space & services
Smart Solar Panels	Not found				*			Changing the function
Kinetic facade	Not found					*		Changing the size of building
Double-skin Facade	PVC double glazing					*		Changing the size of building

Adaptability Potential for Future Upgrades

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint			*	2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Kitchen	Wall	Tile Panel			*	2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Bedroom 1	Wall	Paint			*	2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Bathroom	Wall	Tile Panel			*	2.4
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Living Room	Wall	Paint			*	2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Balcony	Wall	Paint			*	2.74
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Bedroom 2	Wall	Paint				2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Bedroom 3	Wall	Paint		*		2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		

Floor Plan of 3+1

Space Organization of 3+1

Photographs

Figure 45: Dovec, Golden residence 3+1 type 2

Golden Residence / 2+1 - Type 1

Name of Company: Dovec
Name of Building: Golden Residence
Name of Plan Type: 2+1 Type 1

SMART BUILDING FEATURES

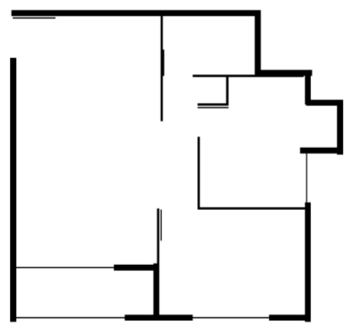
Adaptability Potential for Future Upgrades

Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Not found		*					Changing the space & services
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Central satellite system				*			Changing the function
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Photocell stair lighting			*				Easily improving the space
Smart Lift	Card lift			*				Easily improving the space
Smart Heating	Central generator system		*					Changing the space & services
Smart Solar Panels	Not found				*			Changing the function
Kinetic Facade	Not found					*		Changing the size of building
Double-skin Facade	PVC double glazing					*		Changing the size of building

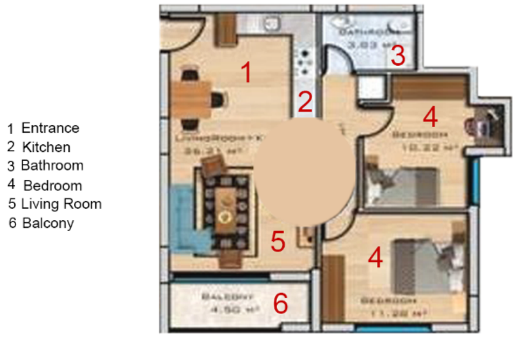
Materials — Durability — Height

Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint			*	2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Kitchen	Wall	Tile Panel			*	2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Bedroom 1	Wall	Paint			*	2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Bathroom	Wall	Tile Panel			*	2.4
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Living Room	Wall	Paint			*	2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Balcony	Wall	Paint			*	2.74
	Floor	Stone Tile			*	
	Ceiling	Paint		*		
Bedroom 2	Wall	Paint				2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Bedroom 3						

Floor Plan of 2+1



Space Organization of 2+1



Photographs

Figure 46: Dovec, Golden residence 2+1 type 1

Golden Residence / 2+1 - Type 2

DÖVEC CONSTRUCTION

Name of Company: Dovec
Name of Building: Golden Residence
Name of Plan Type: 2+1 Type 2

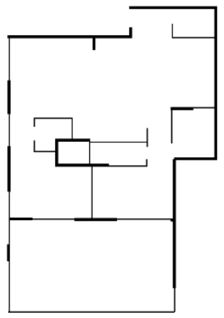
SMART BUILDING FEATURES

Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Not found		*					Changing the space & services
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Central satellite/Internet system				*			Changing the function
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Photocell stair lighting			*				Easily improving the space
Smart Lift	Card lift			*				Easily improving the space
Smart Heating	Central generator system		*					Changing the space & services
Smart Solar Panels	Not found				*			Changing the function
Kinetic Facade	Not found					*		Changing the size of building
Double-skin Facade	PVC double glazing					*		Changing the size of building

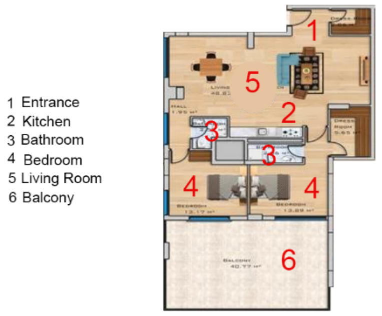
Adaptability Potential for Future Upgrades

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint			*	2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Kitchen	Wall	Tile Panel			*	2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Bedroom 1	Wall	Paint			*	2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Bathroom	Wall	Tile Panel			*	2.4
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Living Room	Wall	Paint			*	2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Balcony	Wall	Paint			*	2.74
	Floor	Stone Tile			*	
	Ceiling	Paint		*		
Bedroom 2	Wall	Paint				2.7
	Floor	Ceramic			*	
	Ceiling	Paint		*		
Bedroom 3						

Floor Plan of 2+1



Space Organization of 2+1

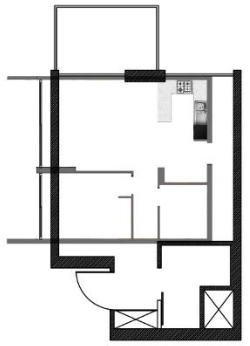
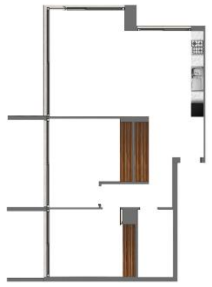
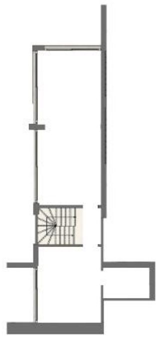
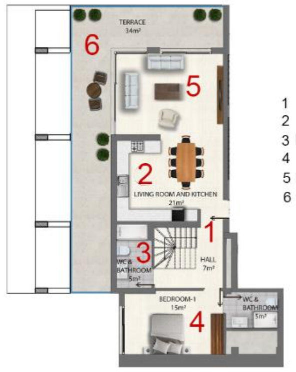


Photographs

Figure 47: Dovec, Golden residence 2+1 type 2

Terrace Park

Plan Organization

Names	1+1	2+1	3+1
Plan			
Space Schema	1 Entrance 2 Kitchen 3 Bathroom 4 Bedroom 5 Living Room 6 Balcony 	1 Entrance 2 Kitchen 3 Bathroom 4 Bedroom 5 Living Room 6 Balcony 	 1 Entrance 2 Kitchen 3 Bathroom 4 Bedroom 5 Living Room 6 Balcony

Floor Plan Organization

Photographs

Map

Figure 48: Dovec, Terrace park project

Terrace Park / 1+1

Name of Company: Dovec
Name of Building: Terrace Park
Name of Plan Type: 1+1

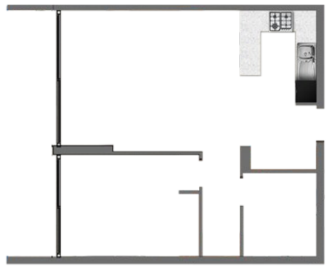
SMART BUILDING FEATURES

Adaptability Potential for Future Upgrades

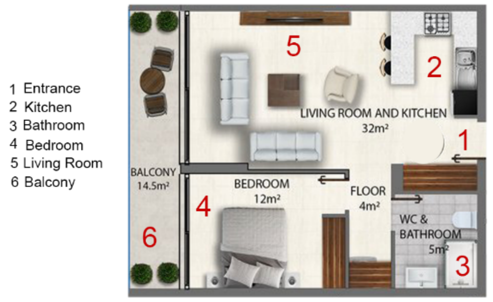
Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Not found		*					Changing the space & services
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Video intercom system				*			Changing the function
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Lighting sensors			*				Easily improving the space
Smart Lift	Card lift			*				Easily improving the space
Smart Heating	Central ventilation systems		*					Changing the space & services
Smart Solar Panels	Not found		*		*			Changing the function & services
Kinetic Facade	Not found					*		Changing the size of building
Double-skin Facade	PVC double glazing					*		Changing the size of building

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint			*	2.62
	Floor	Laminate			*	
	Ceiling	Paint		*		
Kitchen	Wall	Tile Panel			*	2.62
	Floor	Laminate			*	
	Ceiling	Paint			*	
Bedroom	Wall	Paint			*	2.62
	Floor	Laminate			*	
	Ceiling	Paint			*	
Bathroom	Wall	Tile Panel			*	2.35
	Floor	Marble			*	
	Ceiling	Paint			*	
Living Room	Wall	Paint		*		2.62
	Floor	Laminate			*	
	Ceiling	Paint			*	
Balcony	Wall	Paint		*		2.62
	Floor	Stone Tile			*	
	Ceiling	Paint		*		
Bedroom 2						
Bedroom 3						

Floor Plan of 2+1



Space Organization of 2+1



Photographs

Figure 49: Dovec, Terrace park 1+1

Terrace Park / 2+1

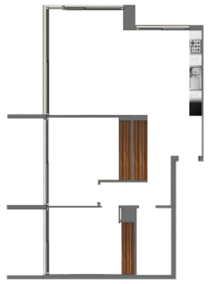
Name of Company: Dovec
Name of Building: Terrace Park
Name of Plan Type: 2+1

SMART BUILDING FEATURES

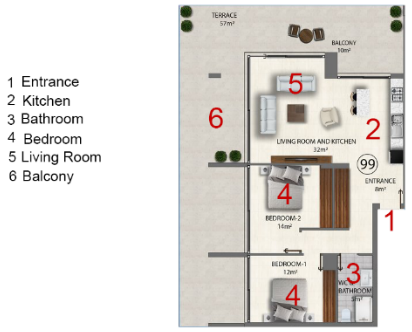
Name of Smart Features	Current Status	Adaptability Potential for Future Upgrades						
		Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
Fire Detection	Smoke detectors			*				Easily improving the space
Fire Protection	Not Found		*					Changing the space & services
Occupant Detection	Not found		*					Changing the space & services
Activity Recognition	Not found		*					Changing the space & services
Communication Network	Video intercom system				*			Changing the function
Smart Security	Camera system			*				Easily improving the space
Smart Lighting Control	Lighting sensors			*				Easily improving the space
Smart Lift	Card lift			*				Easily improving the space
Smart Heating	Central ventilation systems		*					Changing the space & services
Smart Solar Panels	Not found		*		*			Changing the function & services
Kinetic Facade	Not found					*		Changing the size of building
Double-skin Facade	PVC double glazing					*		Changing the size of building

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint			*	2.62
	Floor	Laminate			*	
	Ceiling	Paint		*		
Kitchen	Wall	Tile Panel			*	2.62
	Floor	Laminate			*	
	Ceiling	Paint			*	
Bedroom	Wall	Paint			*	2.62
	Floor	Laminate			*	
	Ceiling	Paint			*	
Bathroom	Wall	Tile Panel			*	2.35
	Floor	Marble			*	
	Ceiling	Paint			*	
Living Room	Wall	Paint		*		2.62
	Floor	Laminate			*	
	Ceiling	Paint			*	
Balcony	Wall	Paint		*		2.62
	Floor	Stone Tile			*	
	Ceiling	Paint		*		
Bedroom 2	Wall	Paint		*		2.62
	Floor	Laminate			*	
	Ceiling	Paint		*		
Bedroom 3						

Floor Plan of 2+1



Space Organization of 2+1



Photographs

Figure 50: Dovec, Terrace park 2+1

Terrace Park / 3+1

Name of Company: Dovec
Name of Building: Terrace Park
Name of Plan Type: 3+1

	Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
SMART BUILDING FEATURES	Fire Detection	Smoke detectors			*				Easily improving the space
	Fire Protection	Not Found		*					Changing the space & services
	Occupant Detection	Not found		*					Changing the space & services
	Activity Recognition	Not found		*					Changing the space & services
	Communication Network	Video intercom system				*			Changing the function
	Smart Security	Camera system			*				Easily improving the space
	Smart Lighting Control	Lighting sensors			*				Easily improving the space
	Smart Lift	Card lift			*				Easily improving the space
	Smart Heating	Central ventilation systems		*					Changing the space & services
	Smart Solar Panels	Not found		*		*			Changing the function & services
	Kinetic Facade	Not found					*		Changing the size of building
	Double-skin Facade	PVC double glazing					*		Changing the size of building

Adaptability Potential for Future Upgrades

Area	Name of Materials		Durability: Low	Medium	High	Height: Floor to Ceiling (m)
Entrance	Wall	paint			*	2.62
	Floor	Laminate			*	
	Ceiling	Paint		*		
Kitchen	Wall	Tile Panel			*	2.62
	Floor	Laminate			*	
	Ceiling	Paint			*	
Bedroom	Wall	Paint			*	2.62
	Floor	Laminate			*	
	Ceiling	Paint			*	
Bathroom	Wall	Tile Panel			*	2.35
	Floor	Marble			*	
	Ceiling	Paint			*	
Living Room	Wall	Paint		*		2.62
	Floor	Laminate			*	
	Ceiling	Paint			*	
Balcony	Wall	Paint		*		2.62
	Floor	Stone Tile			*	
	Ceiling	Paint		*		
Bedroom 2	Wall	Paint			*	2.62
	Floor	Laminate			*	
	Ceiling	Paint			*	
Bedroom 3	Wall	Paint			*	2.62
	Floor	Laminate			*	
	Ceiling	Paint			*	

Materials

Durability

Height

Floor Plan of 3+1

Space Organization of 3+1

Photographs

Figure 51: Dovec, Terrace park 3+1

4.8 Calculating the Percentages of Results

After filling the tables and finalizing the analysis for each building (also for different types of plans of one building) the results of the study are going to be converted to percentages to have more data for the analysis. Following this approach can lead to have more scientific outcomes from this research. To give an instance, the result of fire protection adaptability potential was made from the number of all recorded adaptability types, which is going to present in percentages.

Computing the percentages can lead the thesis to evaluate final results. The percentages are going to be explored in order to find out the major and minor adaptability potentials of selected buildings. The study of percentages can also show the overall lack of adaptability potential for some smart features in North Cyprus building market. With the help of summarizing and making the charts, it can be seen that the comparison of the results can lead to thesis outcomes and the research question will be answered. Also, the findings will help to propose further research potentials and suggestions and recommendation at the final part of this study. The findings and final results will be used for the conclusion chapter. In table (4) the percentages of the thesis will be presented.

Table 3: Case study overall percentage of all cases

Overall Percentage Results

Name of Company: Uzun, Northernland & Dovec

	Name of Smart Features	Current Status	Percentage of Adaptability Potential for Future Upgrades						
			Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
SMART BUILDING FEATURES	Fire Detection				100%				
	Fire Protection			83%	16%				
	Occupant Detection			100%					
	Activity Recognition			100%					
	Communication Network		16%	27%		55%			
	Smart Security				100%				
	Smart Lighting Control				100%				
	Smart Lift				100%				
	Smart Heating			100%					
	Smart Solar Panels			15%	40%	45%			
	Kinetic Facade		Not adaptable:16%				83%		
	Double-skin Facade		Not adaptable:16%				83%		

Materials			Durability		
Area	Name of Materials		Low	Medium	High
Entrance	Wall			100%	
	Floor			33%	66%
	Ceiling			100%	
Kitchen	Wall		11%	16%	72%
	Floor		11%	38%	50%
	Ceiling			83%	16%
Bedroom 1	Wall			50%	50%
	Floor			33%	66%
	Ceiling			83%	16%
Bathroom	Wall			44%	55%
	Floor			50%	50%
	Ceiling			83%	16%
Living Room	Wall		6%	53%	40%
	Floor			20%	80%
	Ceiling			80%	20%
Balcony	Wall		41%	23.5%	35%
	Floor			23%	76%
	Ceiling			100%	
Bedroom 2	Wall			46%	53%
	Floor			15%	84%
	Ceiling			100%	
Bedroom 3	Wall			25%	75%
	Floor				100%
	Ceiling			25%	75%

Table 4: Case study overall percentage of Uzun

Uzun Percentage Results

Name of Company: Uzun

			Percentage of adaptability potential for future upgrades						
	Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
SMART BUILDING FEATURES	Fire Detection	100% Smoke Detectors			100%				Easily improving the space
	Fire Protection	100% Not Found		100%					Changing the space & services
	Occupant Detection	100% Not found		100%					Changing the space & services
	Activity Recognition	100% Not found		100%					Changing the space & services
	Communication Network	100% Central satellite system		100%					Changing the function
	Smart Security	100% Camera system			100%				Easily improving the space
	Smart Lighting Control	100% Photocell stair lighting			100%				Easily improving the space
	Smart Lift	100% Card lift			100%				Easily improving the space
	Smart Heating	100% Central generator system		100%					Changing the space & services
	Smart Solar Panels	100% Not found			100%				Changing the function
	Kinetic Facade	100% Not found					100%		Changing the size of building
	Double-skin Facade	100% PVC Double Glazing					100%		Changing the size of building

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint		100%		2.67
	Floor	Ceramic/Laminate			100%	
	Ceiling	Paint		100%		
Kitchen	Wall	Tile Panel		100%		2.67
	Floor	Ceramic/Laminate			100%	
	Ceiling	Paint		100%		
Bedroom 1	Wall	Paint		100%		2.67
	Floor	Ceramic/Laminate			100%	
	Ceiling	Paint		100%		
Bathroom	Wall	Ceramic/Tile Panel		100%		2.35
	Floor	Ceramic/Marble		100%		
	Ceiling	Paint		100%		
Living Room	Wall	Paint		100%		2.67
	Floor	Ceramic/Laminate			100%	
	Ceiling	Paint		100%		
Balcony	Wall	Paint	100%			2.67
	Floor	Ceramic/Stone		100%		
	Ceiling	Paint		100%		
Bedroom 2	Wall	Paint		100%		2.67
	Floor	Ceramic/Laminate			100%	
	Ceiling	Paint		100%		
Bedroom 3	Wall	Paint				
	Floor	Ceramic/Laminate				
	Ceiling	Paint				

Table 5: Case study overall percentage of Northernland

Northernland Percentage Results

NorthernLAND

Name of Company: Northernland

	Name of Smart Features	Current Status	Percentage of Adaptability Potential for Future Upgrades: Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
SMART BUILDING FEATURES	Fire Detection	Smoke Detectors			100%				Easily improving the space
	Fire Protection	Not Found		50%	50%				Changing the space & services
	Occupant Detection	Not found		100%					Changing the space & services
	Activity Recognition	Not found		100%					Changing the space & services
	Communication Network	Central Satellite System	50%	33%		16%			Changing the function
	Smart Security	Camera System			100%				Easily improving the space
	Smart Lighting Control	Photocell Stair Lighting			100%				Easily improving the space
	Smart Lift	Card Lift			100%				Easily improving the space
	Smart Heating	Central Generator System		100%					Changing the space & services
	Smart Solar Panels	Not found			83%	16%			Changing the function
	Kinetic Facade	Not found	Not adaptable			50%	50%		Changing the size of building
	Double-skin Facade	PVC Double Glazing	Not adaptable			50%	50%		Changing the size of building

Materials: Area	Name of Materials		Durability: Low	Medium	High	Height: Floor to Ceiling (m)
Entrance	Wall	paint		100%		2.67
	Floor	Ceramic/Laminate		100%		
	Ceiling	Paint		100%		
Kitchen	Wall	Tile Panel	33.3%		66.6%	2.67
	Floor	Ceramic/Laminate	33.3%	66.6%		
	Ceiling	Paint		100%		
Bedroom 1	Wall	Paint		100%		2.67
	Floor	Ceramic/Laminate		100%		
	Ceiling	Paint		100%		
Bathroom	Wall	Ceramic/Tile Panel		83.3%	16.6%	2.35
	Floor	Ceramic/Marble		100%		
	Ceiling	Paint		100%		
Living Room	Wall	Paint	33.3%	66.6%		2.67
	Floor	Ceramic/Laminate		100%		
	Ceiling	Paint		100%		
Balcony	Wall	Paint	80%	20%		2.67
	Floor	Ceramic/Stone		20%	80%	
	Ceiling	Paint		100%		
Bedroom 2	Wall	Paint		100%		2.67
	Floor	Ceramic/Laminate		100%		
	Ceiling	Paint		100%		
Bedroom 3	Wall	Paint				
	Floor	Ceramic/Laminate				
	Ceiling	Paint				

Table 6: Case study overall percentage of Dovec

Docev Percentage Results

Name of Company: Dovec

Percentage of Adaptability Potential for Future Upgrades

	Name of Smart Features	Current Status	Adjustable	Versatile	Refit-able	Convertible	Scalable	Movable	Description
SMART BUILDING FEATURES	Fire Detection	Smoke Detectors			100%				Easily improving the space
	Fire Protection	Not Found		100%					Changing the space & services
	Occupant Detection	Not found		100%					Changing the space & services
	Activity Recognition	Not found		100%					Changing the space & services
	Communication Network	Central satellite/Internet system				100%			Changing the function
	Smart Security	Camera system			100%				Easily improving the space
	Smart Lighting Control	Photocell stair lighting			100%				Easily improving the space
	Smart Lift	Card lift			100%				Easily improving the space
	Smart Heating	Central generator system		100%					Changing the space & services
	Smart Solar Panels	Not found		27%		72%			Changing the function
	Kinetic Facade	Not found					100%		Changing the size of building
	Double-skin Facade	PVC Double Glazing					100%		Changing the size of building

Materials			Durability			Height
Area	Name of Materials		Low	Medium	High	Floor to Ceiling (m)
Entrance	Wall	paint			100%	2.67
	Floor	Ceramic/Laminate			100%	
	Ceiling	Paint		100%		
Kitchen	Wall	Tile Panel			100%	2.67
	Floor	Ceramic/Laminate			100%	
	Ceiling	Paint		66.6%	33.3%	
Bedroom 1	Wall	Paint			100%	2.67
	Floor	Ceramic/Laminate			100%	
	Ceiling	Paint		66.6%	33.3%	
Bathroom	Wall	Ceramic/Tile Panel			100%	2.35
	Floor	Ceramic/Marble			100%	
	Ceiling	Paint		66.6%	33.3%	
Living Room	Wall	Paint		33.3%	66.6%	2.67
	Floor	Ceramic/Laminate			100%	
	Ceiling	Paint		66.6%	33.3%	
Balcony	Wall	Paint		33.3%	66.6%	2.67
	Floor	Ceramic/Stone			100%	
	Ceiling	Paint		100%		
Bedroom 2	Wall	Paint		12.5%	87.5%	2.67
	Floor	Ceramic/Laminate			100%	
	Ceiling	Paint		100%		
Bedroom 3	Wall	Paint		25%	75%	
	Floor	Ceramic/Laminate			100%	
	Ceiling	Paint		75%	25%	

Bar chart of adaptability potentials of all cases:

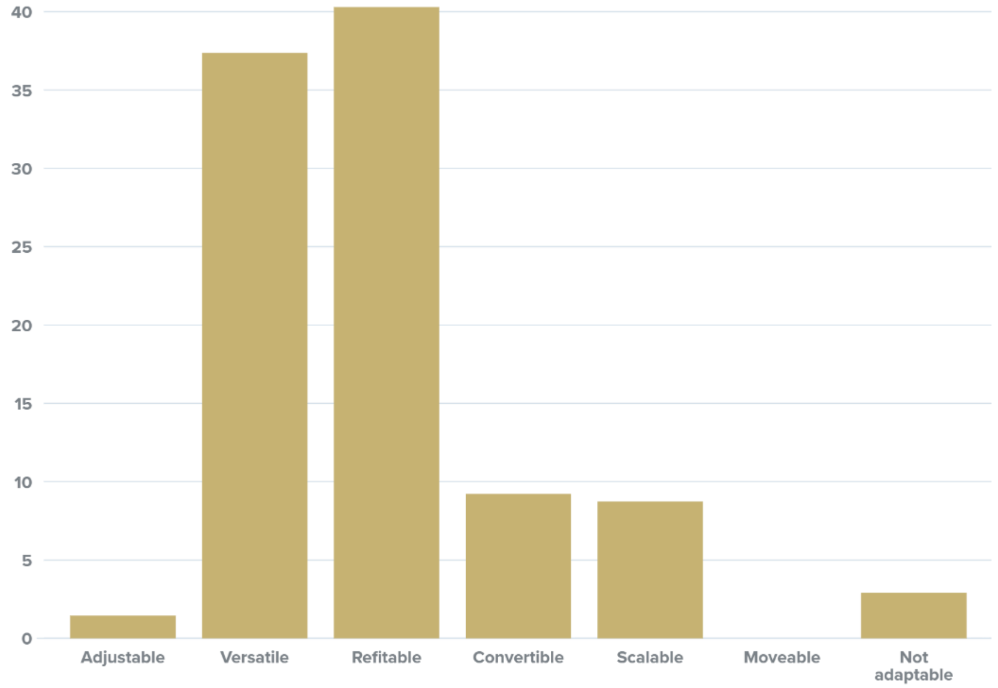


Figure 52: Bar chart of overall adaptability potentials

Bar chart of material durability of all cases:

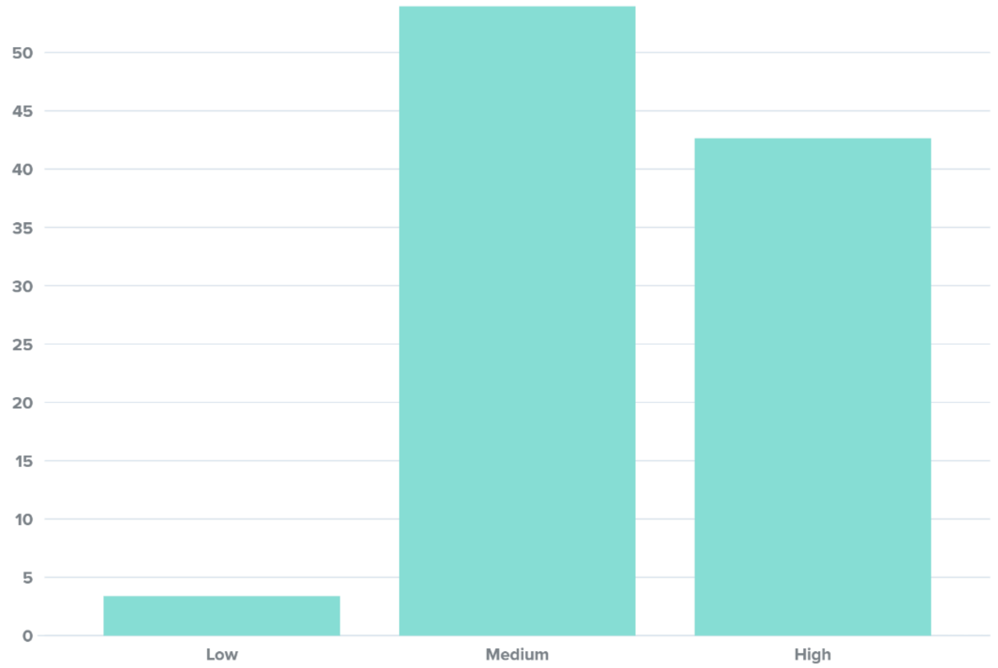


Figure 53: Bar chart of overall material durability

Line chart of Uzun overall adaptability potentials:

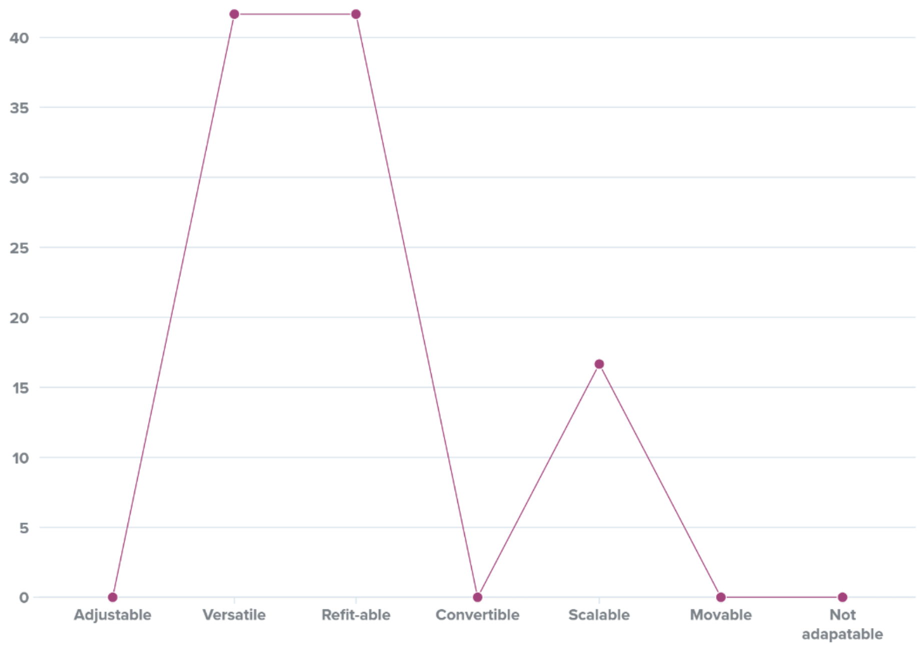


Figure 54: Line chart of Uzun adaptability potentials

Line chart of Northern Land adaptability potentials.

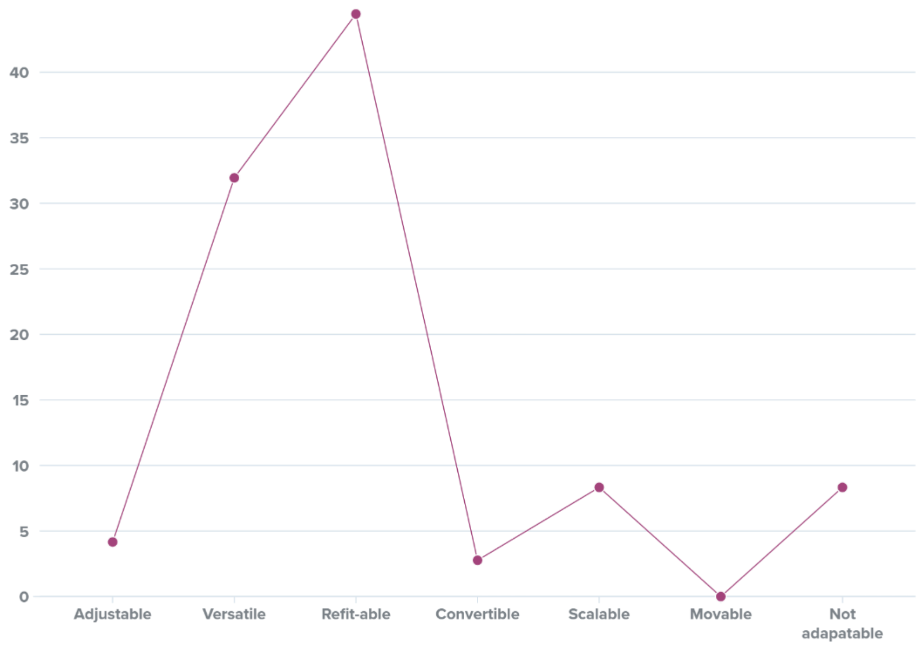


Figure 55: Line chart of Northernland adaptability potentials

Line chart of Dovec adaptability potentials:

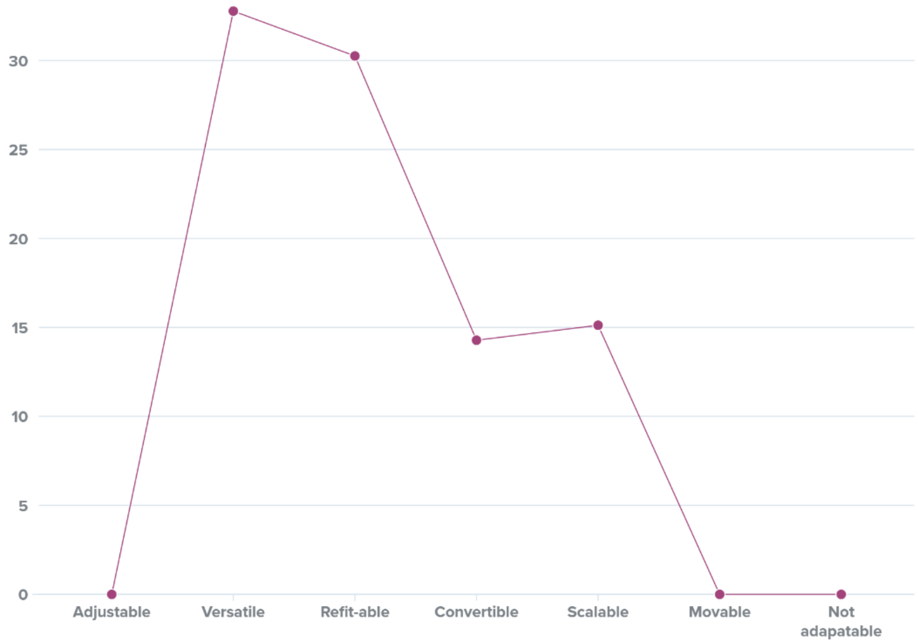


Figure 56: Line chart of Dovec adaptability potentials

4.9 Findings of the Study

In this part of the thesis, the percentage of the results will be explored and presented. As mentioned as early in this chapter three major construction companies (Uzun, NorthernLAND and Dovec) in Famagusta were selected for this study. These case studies were analyzed with frameworks that were generated from the literature review from chapter 2 and 3 of the study. The finding of the thesis would discuss the result of these frameworks for each of the case studies. the percentage were calculated in the previous part. Firstly, recaps the results for Uzun, Northernland and Dovec. These companies highest and lowest percentages will be discussed by using line charts to present the common and not common adaptability potentials in terms of smart house features. Later, overall percentage of all the companies together are going to be analyzed to sum up the results of previous part. For supporting the outcomes of overall percentages, bar charts will be shown. At the end, comparison of the results is going to be explored based on the data from literature review of the study.

Uzun Overall Percentages

it can be seen for the current status of the all Uzun buildings percentages, that smart features like occupant detection, activity recognition, smart lift, smart heating as well as kinetic façade are missing in the building, but having more conventional features in place. For the potential of adaptability for future upgrade, versatile and refit-able are the most recorded adaptability type for future upgrades, with no record of convertible, Scalable and moveable. like adjustable missing. For material durability, it can be observed that the floor materials which laminate are high durable material, with medium level of durability for the wall and ceiling material which are paint and ceramic. The most durability percentage belongs to medium and then Uzun uses high materials and the least material durability percentage is explored for low materials.

Uzun Vanora

In this case three floor plans that make up the apartment building; the first floor plans are the penthouse A and B (2+1) and duplex (2+1), it can be seen for the current status of the building that smart features like occupant detection, activity recognition, smart lift, smart heating as well as kinetic façade are missing in the building, but having more conventional features in place. For the potential of adaptability for future upgrade, versatile are much refit-able, with little of being scalable. While potentials like adjustable and movable are missing. For material durability, it can be observed that the floor materials which laminate are high durable material, with medium level of durability for the wall and ceiling material which are paint and ceramic.

Northernland Overall Percentages

it can be seen for the current status of the all Northernland buildings percentages, that smart features like Fire protection, occupant detection, activity recognition and kinetic façade are missing in the building, but having more conventional features in place. For the potential of adaptability for future upgrade, versatile and refit-able are the most recorded adaptability type for future upgrades, with no record of moveable. Northernland is the only company which has a record of not adaptable for the kinetic facades and double-skin facades, because of the facades of Uptownpark with random design of balconies which makes it hard to apply a kinetic façade without any environmental risk. For material durability, it can be observed that the floor materials which are both laminate ceramics are medium durable material, with medium level of durability for the wall and ceiling material which are mostly paint. The most durability percentage belongs to medium and then Northernland high materials and the least material durability percentage is explored for low materials.

Northernland Uptown Park

For the Uptownpark case, three floor plans which are the studio, 2+1, and 1+1 were analyzed using the framework from the literature review, the findings of the floor plans analyzed are; for the smart building feature of the building occupant's detection, activity recognition, smart heating, smart solar panel and kinetic façade are missing. They have conventional smoke detectors, responsive lighting system, Pvc double glazing and fire protection unit in each floor. For the potential to adapt for future upgrade, it can be seen that refit-ability is the high with little of adjustability, more of versatility. Potentials like scalability, convertibility and movability are missing. For the analysis of the material durability of the design, it can also be observed from the framework, that the durability level of the material is within the medium level, less high level seen from material like marble and ceramic.

Northernland Subway Park

For this case two floor plans (Studio and 2+1) of the building were analyzed using the framework generated from the literature review, the findings of this case are as follows; for the smart building features presence for case, it can be observed that occupant detection, activity recognition, smart heating, smart solar panel and kinetic façade are missing, still having PVC double glazing conventional smoke detectors and Fire protection, smart feature like card lift, camera system and but low end network for the building. For the adaptability future potential of the building, potentials like versatile and refit-able are seen on the high level, while scalable is seen at the low level, with absence of adjustable, convertible and movability in the future upgrade of the building being missing. For the case of material durability, it can be observed that there is medium level of durability, with low level at the wall and floor parts of the kitchen.

Northernland Center

The last case for analyzed for the construction company NorthernLAND, is the center building studio, it can be observed from the framework that smart building features of the building have the following missing, occupant detection, activity recognition,smart heating, smart solar panel and kinetic facade. for the part adaptability potential for future upgrade, the strategies of versatile, refit-able are of higher level, while convertible and scalable are at the low level. For the matter of the material durability of the building it can be seen that the higher level of durability is at the medium level, alongside little at the high level in relation to durability.

Dovec Overall Percentages

it can be seen for the current status of the all Dovec buildings percentages, that smart features like Fire protection, occupant detection, activity recognition, smart solar panels and kinetic façade are missing in the building, but having more conventional features in place. For the potential of adaptability for future upgrade, versatile and refit-able are the most recorded adaptability type for future upgrades, with no record of moveable. For material durability, it can be observed that the floor materials which are both laminate and ceramics are high durable material, with medium level of durability for the wall and ceiling material which are mostly paint. The most durability percentage belongs to high and then Dovec medium materials and the there is no record for low materials.

Dovec Terrace Park

For the case of the analysis of Dovec's terrace pack in which floors plans of 3+1, 2+1, and 1+1 that were evaluated using the framework, the following findings were observed; for smart building features missing are the fire protection, occupant detection, activity recognition, smart solar panel and kinetic facade. for the case of the adaptability potential for future, strategies with high potential are versatile, and refit-able, while those with low potential levels are the convertible and scalable. For the case of building durability, it can be observed that there is a very high level of material durability in the building alongside little medium level of durability.

Dovec Golden Residence

for this case a combination of 3+1 (type one and two) and 2+1 (type one and two) floor plans were analyzed using the framework from the literature, the following findings were observed; the smart building features that are missing are the fire protection, alarm system, occupant’s detection, activity recognition, alarm system, security monitoring, communication network, smart heating system, smart solar panel and kinetic facade. In relation to the adaptability potential of the building for the future upgrade, strategies with high level potential are versatile, and refit-able, while those with low potential levels are convertible and scalable. while for the case of durability of materials it can be seen that there is a very high level of material durability in the building alongside little medium level of durability.

Dovec Corner

for the case of corner building of Dovec which is the last case selected for the study, in which the 3+1 and 2+1 were analyzed with the framework mentioned above, they following findings were observed; for the smart building features of the building that are missing fire protection, occupant detection, activity recognition, smart solar panel and kinetic facade. In relation to the potential for adaptability for future upgrade, strategies with high level potential are versatile, and refit-able, whereby those with low potential levels for upgrade in the future are convertible and scalable. It can be observed that for the case of durability of materials it can be seen that there is a very high level of material durability in the building alongside little medium level of durability.

4.10 Comparison of Results

Nevertheless, it can be seen from the findings of each of the cases that are common traits that can be found within the cases as well as differences traits which can also be found in the findings. for the comparison of findings within the analysis of the various case studies and literature review are as follows:

- The future of buildings is known as to be in relation with smart and intelligent buildings, smart building is newer term and most of previous researchers recognize it as the future of built environment.
- Smart houses can now be defined as a house with a number of services and features which is an answer to users demands for higher level of comfort in their residential buildings.
- Smart houses cover variety of services, in most of them the equipment’s uses communication networks to connect the sensors, cameras and etc. to the control of users or processors.
- The absence of smart building features like occupant detection, activity recognition, smart heating system, smart solar panel and kinetic façade in most cases.
- Between all the smart services and technologies, 12 smart features are recognized by the researcher as the smart feature which can be evaluated in the scope of adaptability and also related to interior architecture.
- Each of the smart features effects the interior space with applying the needed sensors, communication networks, specific equipment. In some cases, like smart lifts just the sensors and processor is enough for the upgrade but in some cases such as solar panels, the space needs to cope with changes of equipment.
- In the case study of this thesis, an evaluation table was designed and collected data from the case studies. The features of smart houses were analyzed and adaptability potentials of each case was calculated in percentages.
- The presence of conventional systems like smoke detectors, camera system, satellite system, smart lighting, and PVC double glazing in most cases.

- The absence of adaptability potentials for future upgrades like adjustable and movable.
- The presence of high potential for adaptability in potential like refit-able, versatile, scalable and convertible. refit-able with 40% is the major potential of all the strategies for upgrading potential of the future among all the cases. Then versatile with more than 35% is the second most recorded adaptability potential, convertible and scalable recorded at below of 10% of all cases and the least recorded percentage belongs to moveable.
- For the durability of material, it can be observed that the Dovec cases have high potential levels of durability for their material used in the buildings, while that of Uzun is at the lower part in material durability. Manewa et al. (2015) argues that the usage of high durable materials leads to have more refit-able spaces. This claim fits the outcome of percentages which shows refit-able is one of the high recorded adaptability types for smart house upgrades.

4.11 Conclusion

The objectives of this chapter are to employ the aid of the framework generated from the literature review in chapter two and three for the analysis of the various cases that were selected by three construction companies in Northern Cyprus, with all the cases located in the city of Famagusta, discuss the findings from these case studies analyses and compare the results of the findings to find common and distinct discourse among the cases. it can be observed from the analysis that the various buildings still lack smart building features, which can be adapted when needed, reducing the energy consumption and improving the indoor comfort quality of the building. it was also deduced that all the cases have the potential to be refitted in the future for adaptability potential upgrade. Other potentials like versatility, convertibility and scalability, were also possessed by the building potential for adaptability of future upgrades, while potentials like movability and adjustability are very low or absent within the buildings. for the durability of the materials, their high and medium level of durability of the materials for the various cases. with the Dovec building leading in the discourse.

Chapter 5

CONCLUSION

Smart house is a result of new needs of a residential building user. These new needs are mainly related to the fast developments of IT and technological expansion. According to Buckmen et al. (2014) modern buildings will be more dynamic and complex in contrast to traditional buildings which were designed with basic materials before. According to literature review in chapter 2 future of building design is related to smart and intelligent features and devices which has been used inside building. A smart house can automate our daily life at different levels and functions. Users are demanding for more functionality in their houses and these developments are changing the spaces and functions. The users want to add value to their living spaces by upgrading them with new technologies. By recognizing the features of a smart house, it can be possible to predict the future needs of an existing building. By categorizing these features, an existing residential building can be analyzed in order to find adaptability potentials for future smart house changes. By considering these changes the environmental risks of demolition and the disadvantages of obsolescence will be minimized.

At first step, a smart house has the adaptability at its core. smart house is covering a variety of features and functions which users demand to have them in their residential houses. According to Kamel & Memari (2018). The definition of smart houses is presented with a variety of objectives and services, they all work to facilitate the users.

The smart house covers different aspects of users, according to Eugeny (2015). a smart house can ease the user's life by improving the inhabitant comfort by monitoring the user's behavior, energy saving improvements which will reduce the cost of building operation, time saving features with the automation of everyday activities, devices and features to add safety for users, and increasing the health and care level of users with the air condition systems and temperature management. Features of smart houses are very diverse and it is necessary to categorize the features, by categorizing and defining the features of smart house it can be observed that some features are not directly change the spaces and functions of an existing residential building like the smart device's software architecture and related technologies. meanwhile, there are some features which are related to the design of the building and can be used to predict the changes from their upgrade inside an existing building. These features can be observed and analyzed in order to extend the useful life-time of a residential building. Features for improving security and safety in smart houses are considered as fire protection, fire detection systems and smart security. Occupant detection and activity recognition can help both security and energy consumption management inside a residential house. Communication network is necessary for smart devices while most of these features are working together and should be connected to a central processor. Smart lighting control, smart lift, smart heating and smart solar panels are helping the users to manage their energy consumption and increase the occupant comfort inside a building. At the end, intelligent facades are helping the users by controlling the environmental and they can offer low energy and in some cases zero energy houses with their ability to change the shading and reduce the temperature transfer, the smart house also demand for more adaptability in buildings and other features like the durability of materials can have impact on the lifetime of the building.

In this research the effective features of a future smart house which can affect the spaces and functions of a residential building were emphasized. The smart features that were described above examined with different point of views to predict the future changes from them. Explanations had given in depth for smart house features in this thesis. Adaptability and flexibility are other strategies which are significant for their impact on the process of change and reducing the disadvantages and environmental risks of change in the building sector. The related data about the adaptability and flexibility, their types and definitions were also considered important subjects in this thesis. Adaptability types help to have a better understanding of the cases future potentials. In this study, 6 types of adaptability types are gathered and used in the case study. Adjustable strategy is the capacity of the building to alter its tasks like changes in modular systems and furniture, Versatility can improve the space of the building like moveable walls and flexible ducts, refit-able is covering the improvement in the performance of the building, convertible is the ability to improve the functions and scalable and movable are changing the size and location of the building.

The method of this thesis is based on considering the smart features of future building as parameters and evaluating the adaptability of an existing building through these smart feature upgrades and probable changes from them. In this study, the smart features, adaptability potentials, current status of each feature and space plans were observed and examined in different residential projects by observation of the researcher. By analyzing the results, this thesis would explore the adaptability potentials and limitation for each smart feature in residential building in terms of future upgrades and materials durability of each space of the examined new residential buildings. With the case studies of residential buildings in Famagusta, North Cyprus.

This thesis would base on smart features and adaptability types to analyses the existing houses.

By giving consideration to the results which were explored in the previous chapter, it can be noted that majority of cases were adaptable in terms of versatile and refit-able strategies, these were suitable for most of the smart features such as fire detection, fire protection, occupant detection, activity recognition, communication network, smart heating, smart lift and smart lighting control. These smart futures can easily get upgraded with improving and/or changing the space and services.

Secondly, it can be mentioned that, the intelligent façade which is divide to kinetic facades and double-skin facades, are mainly working with scalable strategy or the building is not adaptable at all. The scalable buildings are going to cope with changes of the size of the building and it can be seen that the buildings with complex facades like northern land uptown park has limited their potentials for future façade upgrades and they are not adaptable for the changes from intelligent facades at first sight. According to Ahmed et al. (2015), Kinetic façade can be used to create low energy and zero energy buildings towards the sustainable developments of built environment. It is evident that in some cases like northern land which they have a record of not adaptable for this feature will have low rate of sustainable design in their projects.

By considering the results, material durability of the cases were mostly recorded ass medium and high durable materials. Of course, different types of materials were used in all the case. Overall, the better quality of materials extends the useful lifetime of a building and helps the adaptability process by extending the useful life time of the building. Among the construction companies Dovec company has the most durable materials between the cases of this research.

Between the adaptability types there were no record of moveable adaptability potentials at all. Adjustable and Convertible strategies were observed in just a few of cases. it can be seen that these spaces cannot get smart with changing the functions and tasks of the residential building. To conclude, the percentage of the case studies shows that construction companies in North Cyprus use same taste of materials and mostly same design strategies in their different residential projects.

The results which derived from this case study can be used as a guideline for the interior architects and construction companies in North Cyprus which want to make an adaptable residential house with respect to future developments in technology and smart house markets. Different smart features in this study were gathered and the results of case study shows that the potentials and limits of the residential buildings adaptability, in general the results can support the owners of companies and design architects to design more adaptable buildings and consider the potentials and limitations of the current building design trend in North Cyprus.

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