A Framework to Evaluate Smart Home

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ABSTRACT

The traditional home concept has changed because of the new lifestyle the size of the houses has become much smaller than before, and people's needs are as they are or may have increased, people are seeking for comfortable, and practical ways to live in small spaces.

The differences and changes in the lifestyle have a connection between each other and the way of design the small homes to provide accommodation, however, these changes satisfy the demands of the users in an appropriate accommodation atmosphere.

Smart homes are optimized to reach individuals well-being, and it has grown dramatically because it develops the products, makes it easier to use, and makes the product multipurpose and uses of techniques to develop homes by raising the amount of possible uses of home purposes, by provides one room to serve different purposes.

The comfortable environment aims at making individuals' activities more efficient, safe, and comfortable. Also, allows space-saving while increasing its functionality to suit the needs of the users, and suits individual's measurements in small space to avoid accidents or injuries.

Through this research study, the main focus is on the critical issues that increase the flexibility, sustainability, smart space, and smart furniture at home and explains their impacts on the improvement the smart home. This research study focuses on a number of critical issues that escalate users comfort in small home through clever as well as

tricky solutions, and enhancing the quality of the air in small residential spaces, that by making an deep analysis of the collected data and the chosen examples.

The aim of this research study is to examine the significance of technology and the function of smart innovation in residential furniture and interior space then combining these innovations to provide a framework to evaluate a smart home and explain smart home effects on human-wellbeing.

Keywords: smart home, new lifestyle, user needs, smart residential solutions, evaluation of smart home.

ÖZ

Geleneksel ev kavramı yeni yaşam tarzı nedeniyle değişmiştir. Bu nedenle, büyük evler yerini daha küçük evlere bırakmıştır ve insanların ihtiyaçları eskiye nazaran daha da artmıştır. Bu nedenle insanlar küçük alanlarda daha kolay, rahat ve pratik yollar aramaktadır.

Yaşam sistemindeki değişiklik ile konutları tasarlama şekli arasında bir ilişki vardır. Bu sebeple küçük evlerin bu değişimlere uyum sağlaması ve rahat bir konut ortamında, konut sakinlerinin gereksinimlerini karşılaması adına tasarlama ölçütleri belirlenmiştir.

Akıllı evler insan refahına ulaşmak için optimize edilmiştir. Akıllı evler, ürünü geliştirmesi, kullanımları kolaylaştırması ve ev işlerinin olası kullanım sayısını artırarak evleri geliştirmek için kullanılan çok amaçlı teknikler sebebiyle hızla büyümüştür. Bu nedenle, ev işlevlerinin olası kullanım sayısını artırarak, çeşitli amaçlara hizmet etmek için bir oda sağlamıştır.

Konforlu ortam, insan faaliyetlerini daha verimli, güvenli ve konforlu hale getirmeyi amaçlamaktadır. Ayrıca, kullanıcıların ihtiyaçlarına uyacak şekilde işlevselliğini artırırken yer tasarrufu sağlar ve küçük alanlarda insan ölçümlerine uygun olur ve herhangi bir kaza veya yaralanmayı önler.

Bu araştırma, esnekliğin etkinliğini artırması, sürdürülebilirlik, akıllı alan ve akıllı mobilyaların evdeki etkinliğini artırarak akıllı evin gelişimi üzerindeki etkilerini açıklayan önemli noktalara odaklanmaktadır. Aynı zamanda, toplanan verilerin ve

seçilen örneklerin derinlemesine bir analizini yaparak küçük alanlarda insan konforunu artıran ve küçük konutlarda hava kalitesini geliştiren önemli noktalara odaklanmaktadır. Bu araştırmanın amacı, konut mobilyaları ve iç mekânlarda teknolojinin ve akıllı inovasyonun önemini incelemektedir. Bununla birlikte, akıllı ev kavramını sorgulamak, iyileştirmek ve akıllı evlerin insan üzerinde etkilerini açıklamak amacıyla bu yenilikleri birleştirmektir

Anahtar Kelimeler: akıllı ev, yeni yaşam tarzı, kullanıcı ihtiyaçları, akıllı konut çözümleri, akıllı ev değerlendirmesi.

To…

My mom, thank you for inspiring me to be a better person, you are my idol and you will always be the one I look up to.

My brother Rabee, my backbone, source of strength, you are my shoulder that I lean on, thank you for always being my support system, I hope that you will always be proud of me, with your support I always glow and shine to achieve more.

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Chapter 1

INTRODUCTION

1.1 Background

Nowadays, the living situation has changed, the result of the new lifestyle is that the big houses have become a thing of the past. According to (Thøgersen, 2017), urban housing growth affects users and is pushed into limited space. Space surrounds us has an impact on our space perception and how we react to it (Jacobsen, 2013). Traditional houses are large in size and designed for traditional families which were much extended than today, instead of few large rooms, the space of traditional houses is usually divided into a number of small single-purpose rooms.

In the past, the aspects of design focused on form, shape and one-function for each piece of furniture and with one purpose in the room or space. These days, this concept has totally changed, the size of the houses has become much smaller than before.

Since the life style has changed, people's needs change accordingly, life is rapid, and thus individuals are seeking the easy ways to have comfortable, efficient and useful ways to live in small spaces.

According to Scattergood (1997), the nature of small spaces has a functional problem because of its size. Many problems occur in small homes due to the size, first, the inadequate natural ventilation, second, lack of light and finally insufficient storage, all

of them are considered as a troublesome in the small spaces. The users of the small spaces face problems when they practice daily life activities and their movements through and around the space.

Recently, the world has been facing a fast and continuous improvement in terms of technology, as well as resolutions to interior design issues are increased dramatically by the combination of smart solutions with flexibility, creating appropriate and valuable environments, exploiting space, plus enhancing comfort within the small spaces.

This must be completed by smart furniture solutions which are considered adaptable based on different individual needs, for this reason they are called smart and flexible by designers and the community of practice.

More space in homes is a hope of many people who are struggling from the small sizes of their places, though it is right to say that however much living space we have, it's not long-lasting before it is cluttered and the user starts to feel unsatisfied for his/her needs (Scattergood, 1997).

Over the years, a high number of research studies explored a small space design by providing solutions in different ways to save space in small homes with intelligent, space-saving solutions which should be functional and provide wellbeing of the users and focus on the user needs to get the user's satisfaction. Multifunctional and modular areas that transform into different living spaces are intelligent solutions for the lack of space problem.

1.2 Problem definition

As mentioned before, lifestyle has changed, and the homes get smaller than before. Small space design is about the ways to solve the limited size and establish solutions that can be useful to obtain the maximum space, the good design of small spaces demands to integrate a lot of functions in a little space.

According to Smith (1986), the size of small spaces leads to an ineffective space. And because of the functional problems that are considered as a result of poor designed, small spaces fail to satisfy user's needs. A good environment of living is when users can meet their needs. The concept of design in small homes affects human needs by limiting the ability to do their activities normally at home and face movement problems through and around the space.

The process of changing the form and size of the interior space to reach the user's satisfaction in a new life system, using flexibility, smart solutions through smart furniture and smart space as well as human movement in a little space were investigated by a limited number research studies, this topic has been chosen to be investigated accordingly.

1.3Aim of the study

The research study aims at exploring the function of smart innovation in small spaces and to create a framework to evaluate the concept of a smart home through improving the smart home's criteria to satisfy human needs in order to reach an appropriate design of small spaces that achieve the optimal use of space, flexibility, sustainability as well as human comfort in their home spaces. The research study focuses on individual households and no children couples.

This might have possible implication to enhance the effectiveness, easiness of utilizing, and space-saving via the flexibility and enhanced arrangements of spaces, which gives various opportunities to change the form and size of the inner space according to the individuals' needs and comfort.

1.4 Research questions

This section of the thesis includes the research questions that it is aimed to be answered in the finding and results section of the thesis, these questions are divided into two parts, main questions the former two and sub-questions the later three, the questions are as follows:

-What the framework to evaluate a smart home includes?

-How to satisfy individual needs in a small space through the concept of a smart home?

-What does the concept of "smart home" include?

-How flexibility, sustainability, and human comfort play a role in the concept of a smart home?

-What are the criteria to evaluate smart home?

1.5 Methodology

This research study implements a qualitative research method by means of literature description and data analysis of the smart home impacts on users, the data was collected from different sources like books, articles, as well as websites which include the smart residential solutions, information about human needs and wellbeing. Then the information and data were analyzed critically in order to find out possible implications that help the community of practice to develop a framework of a smart home in connection with human well-being.

Three-part investigations of literature survey are selected to be analyzed, first correlation research, a correlation study has been done in order to find out the relationship between the factors of each keyword (new lifestyle, smart home, users' needs, smart residential solutions, flexibility, sustainability, and human comfort) by previous studies. Second, action research has been done based on evaluation as a second stage after applying the correlation method that to introduce improvements to create a framework that guides smart home designs to meet the user’s needs, and to reach their satisfaction. That has been supported by analyzing selected examples, this tool has been chosen to analyze examples according to the smart home's criteria based on related literature review.

1.6 Limitation

The limitations of this research study lay out in the following:

This study focuses on the small homes and their effect on the users, users’ of such places limited level of knowledge of interior design and smart houses, and options might be available to them, because of that users cannot express the ideal design criteria for smart homes. This lack of knowledge users have contributes to promote this issue more. Another limitation is due to COVID19 since this research has been done during coronavirus pandemic. Meanwhile, the current situation did not allow us to collect the needed data, and enough participants who live in the small homes face to face.

In consequence, the author of the study collected the data from books, articles, and websites, also, in some cases via online meetings of some designers who designed the examples mentioned in this research study. One more point, the researcher is not satisfied with the number of the countries the data collected from.

1.7 Structure of thesis

Figure 1: Thesis structure

Chapter 2

LITERATURE REVIEW

2.1 The meaning of home

From ancient times to the present days, housing is still the sanctuary of the human being, taking into consideration the differences in needs, way of life, methods, and building materials.

As the human race evolved over time and the refuge evolved with it, which was the main engine for the formation and development of human communities and the emergence of cities in their primitive form, which developed with different civilizations, which appeared in a synonymous way in different parts of the world (Sixsmith, 1986).

And this was the unit that people resort to when there are danger and injustice, hence the need for a person to use various tools, such as places to sleep, cook and keep food, and this was what was followed when living in separate units in the form of small groups that include a number of people living together.

Then, with the discovery of fire, work in agriculture, and animal husbandry, the first groupings of people emerged as a small, interdependent society. The definition of housing is the establishment where a person and his/her family live in, to take shelter from nature's factors, and to spend his/her daily needs outside the scope of his/her

work, and uses it for rest and sleep, preparing and eating food, family and social gatherings, and practicing some activities, artistic, sports, recreational or productive activities and hobbies.

Home as a place that gives more strength also secures the relationship with the people that individuals care for, it emerges as a powerful category of meaning. However, Home perceived as the locus of intense emotional experience, which provides an atmosphere of social understanding where people's actions, opinions, and moods are accepted. Ideas can be considered as a place that can be shared with other people to have fun and entertain with family members and friends (Despres, 1991).

A home is a dynamic product. It comprises many different elements, ranging from structural structures to interior fittings and accessories. In reality, home is not only a physical space in which people live, but also a space in which social activities take place (Saunders, 1990 &Williams, 1987).

On the other hand, according to Mary Douglas, the idea of home: A kind of space she explains her own interpretation. She suggests that Home is located in space, but it is not necessarily a fixed place. It does not need bricks and mortar, it can be a wagon, a caravan, a boat, or a tent. It need not be a large space, but space there must be, for home starts by bringing some space under control (Douglas, 1993).

2.1.1 Home and lifestyle relationship

Nowadays, families have less and less time to spend with each other. The living situation has changed as well. Both husbands and wives still work full-time in a typical family. Individuals work more separately, mostly on their own. There's a rise in the number of individual households (Bachman, 2015). With the raise in the natural

increase of the population, it became necessary to increase the home units, and thus resorting to apartments with a small area. In the past, the extended family was popular, but nowadays the idea is no longer acceptable, and this social change has led to the need for more homes.

According to research done by SINTEF, One person's households are 18 to 30 years old. I often point out that these tenants see their apartments as a modern home (Støa et al, 2006). Therefore, the least spaces must be used to provide homes, by designing small spaces in a flexible and smart way that enables the users to fulfill their needs and feel the required comfort, enabling them to live in a home that is suitable for their needs.

As a result of the new lifestyle of people, many people face a hard time due to long working hours, people's free time is mostly spent while doing various activities that are influenced by small areas. There are several factors of the smart home which create a comfortable space for users.

2.1.2 The change of home depends on lifestyle

Today's society is influenced by a growing population and urbanization (United Nations, 2014). This leads to rising housing demand in the cities, which has led to higher selling costs and smaller homes (Lem, 2009). From this point forward, a growing number of individuals and families will possibly live in small homes due to cost, resource limitations and personal preferences (Tremblay, 2014).

The traditional homes are large in size, but the space is usually divided into a number of small single-purpose rooms instead of a few large rooms, and designed for traditional families which were much larger than today, the interior design in the past

concentrated on the shape and one function for each piece of furniture and one activity in the room or space.

According to Ghasemi, the traditional layout of the homes is one or more floors, with an open courtyard in the centre and tetragonal rooms surround them. There are a little street-to-street open from the towers, but all the spaces that are close, openings on the focal courtyard. Clearly, human have tried to separate their homes from general roads as far as can (Akbar, 1980). Nowadays, this concept has changed the size of the homes has become much smaller before. Small homes are a result of the new lifestyle, many of individuals and families live in small homes.

> "These smaller living units may be any type of structure or tenure status, for young families buying their first home or mature adults wanting to downsize, smaller homes make sense, Single adults or couples without children are also prime candidates for small homes" (Tremblay, 2014, P.299).

2.2 Small homes and smart homes issue

Small areas tend to be overcrowded and it affects the users of the space as a stress feeling because of the floor space and the physical items like a furniture. The living situation is changing but the human needs still same. The organizing of small homes faces difficulties and problems in terms of poor designing the spaces that lead to allocate the equipment in the wrong places. The home is an important interior space that the users do many activities, the interior design of the home must suit the needs and requirements of the user to do their activities.

Home spaces are no longer as in the past, and due to lack of room, homes need to be well constructed to allow inhabitants to feel comfortable in their living spaces to meet their needs. The small space living in urban areas has become a theme of modern life. It is strong, esthetic, and gives you a sense of belonging (Susanka, 1998.)

By Norman Smith's book " Small Space Living Design " the size of small spaces is the physical limitation, this limitation can be small building footprint, low highest of ceiling or the need to integrate various functions in little space (Smith, 1986)

The result of small spaces size causes problems due to the poorly designed that led to an unsuccessful and ineffective space that fails to satisfy the user's needs. According to Thøgersen, a case study by SINTEF discuss the missing qualities in small homes:

- An entrance is so small.
- Lack of storage space.
- Lack of kitchen space.
- Bedroom not a devoted.
- Not accessible for handicapped people (Støa et al, 2006).

According to Emma Scattergood's book 'small space style', provides an overview of the ways to solve the limited sizes and create better solutions to feel comfortable in a limited space. And it shows how to organize user's needs and establish priorities with attractive, practiced and healthy spaces. On the other hand, the author focuses on the power of color and the factor of lighting and furniture which shows how to get the most out of small spaces and make it appear larger than reality (Scattergood, 1997).

The concept of design in small homes focuses on form and one function for each piece of furniture which affect human needs by limit the ability to do all human activities at home, through the lack of spaces and the inability to do more than one activity in the same area, most small homes only have one or two rooms. Which means that one room for several activities.

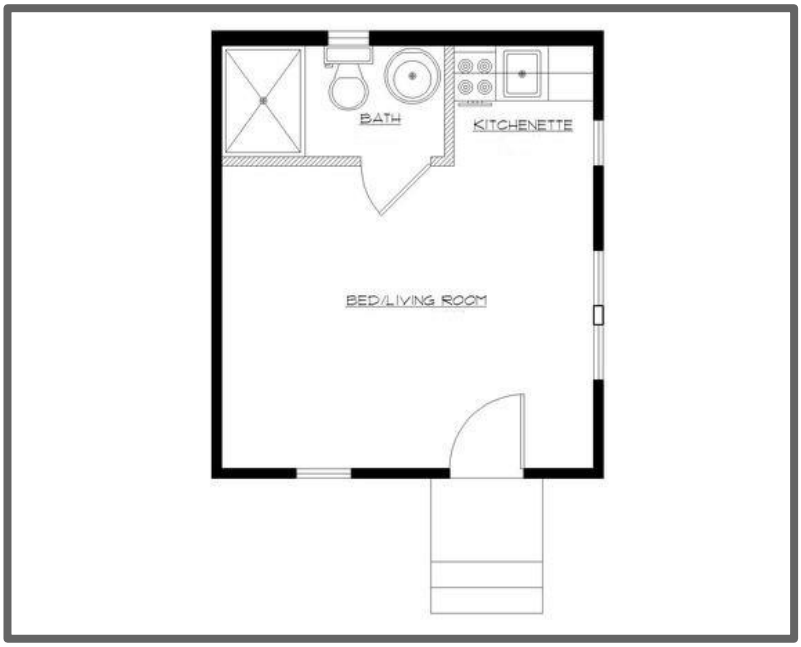


Figure 2: examples of small home's plans
(Houseplans, 2020)

The last years have a fast development in the solutions to interior design issues that creates a better environment to satisfy human well-being. Smart home floor plans are optimized to make the most of the space, with multi-purpose rooms and help the users to do their various activities through the smart residential solutions which have more than one function and more effective and with unlimited creativity in connection with human well-being.

The intelligent organization of the elements within a space can make the best change of the interior atmosphere, to get the most use of space to satisfy your needs.

Smart homes can be defined as the use of smart solutions to create a comfortable and useful environment via integration of the furniture with most of the components, easily use and the optimal use of space through flexibility and better organization of space, that provides a number options to change the form and size of the interior area, to achieving the requirements of society and adapt to the environment.

Also, smart homes are sustainable and thus safe and healthy environment, smart homes have the capacity to adjust and change to meet the needs of individuals in inner space and the smart furniture is used mostly in smart homes to meet the needs of people and to solve a lot of problems, as well as provide more spaces in small homes that are affected by the current lifestyle.

The products of smart home are organized to be exceptional, environmental, stylish, comfortable as well as flexible. The Smart furniture employs development and enhance the furniture effectiveness through making them multipurpose which create more spaces of small homes, through specific pieces of furniture that fold to seem bigger, smart as well as more comfortable area.

The table in the next page shows the differences and similarities of small and smart homes, according to Susanka, 1998 & Tremblay, 2014 & Smith, 1995.

Table 1: Differences and similarities of small and smart homes (Developed by author)

	Small homes	Smart homes
Space/Function	The design in the small homes concentrated on the shape and one function for each room/space to do one activity in the room or a space. Small space can have functional problems that are a direct result of their size.	Smart home floor plans are optimized to make the most of the area, with multi-function rooms and helps the users to do their various activities.
Furniture	Traditional furniture is calm, with one function for each piece of furniture with limited creativity. Furniture pieces are often cloning.	Furniture has more than one function and more effective and with unlimited creativity. Smart furniture is functional with a new lifestyle because it is comfortable, sustainable as well as flexible.
Lighting	The traditional homes usually have big windows to provide an abundance of natural light. In traditional design, one central pendant light may seem adequate it's poorly lit.	Smart homes usually have smaller windows. As a result, they require more artificial lighting, and more kind of light in same space because it's give the ability to do more than one activity in one place.
Flexibility	Small homes not include flexibility to reach human needs, it's depend in traditional design which may not change the form as well as the size of the interior area.	Flexibility in smart homes solves a lot of problems through multi-function as well as propose various possibilities for changing the interior area.

2.2.1 User’s need in small homes.

The process of interior design accord with various types of approaches and materials to solve issues related to design. Therefore, the whole design planes and choices have to be in connection with the needs and demands of the individuals.

It is significant to be aware by the designer, of the user's needs, the behaviors, as well as the significance and the effect of human requirements on the design process. Therefore, the aims of concentrate on user's needs in the internal design of housing are to examine, investigate, and to formulate the criteria and data in a manner that suits the activity spaces and to be abiding by the designing, as well as the needs.

Actually, homes are important architectural spaces in which people spend their time, so the designs have to provide a comfortable environment suits user's needs and demands of individuals to aid them practicing different in activities comfortable spaces since small spaces have a negative impact on people. Designers have to consider more about the matter of the small home's interior design to achieve the requirements of individuals.

The decrease in the interior space restrict the freedom of human, for instance, in the United Kingdom, making friends, sitting in peace, cooking and eating with the family is limited due to the lack of space, according to (Robert-Hughes, 2011). Through promoting these practices, more space will be expected to contribute to well-being (Foye, 2016).

The internal design is known as a direct connection with the users, which makes it significant to have established research with a plan and outline of the interior space with its content and design. With the development acceleration, users are being more convinced with furniture offered within interior design, for that makes them feel comfortable, secure, and well in a healthy and suitable environment. The different human needs are variable for different people, and they push people to make specific activities as behavior.

Human needs inside the home are a major requirement, which is achieved through a sense of control of the place and a sense of comfort and awareness of beauty, and the ability to fulfill all his/her needs in the place where he is. Human jobs and needs need an area to perform this purpose.

Usually, the home consists of several rooms, and each room serves the user to perform a specific function (receiving guests, sleeping and resting, food, etc.). These days, with the shrinking size of homes, it is no longer possible to perform various functions in several areas. Most of the needs of the user in the small homes are performed in one place, meaning that the same space is prepared as a living room and also a bedroom or other because there are not enough spaces to make it separate from each other.

The ability of small homes to provide space to fulfill the needs of the user is limited, and adversely affects the user, in addition to the shape of the internal space that impedes movement and leads to a sense of human tension and thus leads to health problems.

Small homes have no space to collect all the user's stuff in a limited space, in addition to storage issues. Due to poorly designed small spaces, the space is an ineffective and unsuccessful area.

Consequently, according to Azby Brown, crowding small spaces result in a lot of negative effects, physically such as the movement of people through and around the space and functional problems that are a direct result of their size (Brown, 1996)

2.2.2 User's need in smart homes

The traditional organizing of homes layout does not work with today's homes layout due to its size. to provide user's need in the new lifestyle, the organize of rooms have to be intelligent, each room should provide more than one function in a flexible way and create a healthy atmosphere by using smart home criteria in small spaces. According to Salazar, it is important to take into account the requirements and capabilities of the intended users to produce a successful design (Clarkson et al., 2013).

In a smart home, all of the design decisions and selections link with human needs and a comfortable environment, so that the users can do their various activities in smaller spaces without affecting their requirements and needs.

All the smart home criteria support people carrying out their everyday activities and give users the ability to control their space environment which led to provide user satisfaction. And it will affect the way of living at home and will influence the spatial needs and preferences of those living there.

Also, the smart furniture in the smart home not allowing the space to become crowding or another hurdle related to its function and use, through transformed to accommodate

user activity in that time or enough number of people. The limitations imposed by lack of space which led to limit user activities can get over by intelligent design.

2.3 Interior space components

The interior design components include space, form, line, color, light, texture, and pattern; and make a balance between them is the key to make aesthetically into the interior space.

In addition, to improve the look of the room, combine these elements, and make harmony between them will increase the functionality of the space.

2.3.1 Smart space in smart home

Our homes become part of us, shape us, and reflect our desires and habits to a far greater degree than most of us realize. And despite the comfort that our homes can offer, few people are happy with their living spaces. Many of us are able to live without trendy furniture, new appliances, or multiple bathrooms. None of us, however, wants to live without comfort, and comfort depends on space (Brown, 1996).

The planning and organizing of a room in the tradition space design does not work with a new lifestyle which led to small spaces, planning, and organizing of a room not enough to provide user needs, each room should have more than one function, create the right atmosphere by making the best use of design elements, and makes the most of space by identifying the activities that take place within it. The reorganize the space to make the most of the space.

Today's, the direction toward the open space is beginning, the purpose of it is to leave the inside space open so that it can be more visible without visual obstacles. The

interior design is, in this case, prepare toward the idea of concealing all functions and activities using innovative methods of storage and coordination of the basic needs of small space users. Moving cutters are used to divide space for several activities to suit changing needs.

The interior design of the living rooms has changed over time, each period has a distinctive shape and has its own character in the decor. The lifestyle is changing, as homes and spaces are smaller, so the need to transform the living room in our time for a more multi-functional space is greater. The living room has been devoted to the activities that are a day to day part of family life often need to accommodate in the same space.

Thus, modern living rooms face an unenviable task. The living room is the main space in the home where there are everyday events and the family is gathered there. It has to have a physical space where there is contact of self and others (Amaturo, 1987). Its space needs to be intelligently designed to use more than enough for different ways to fit the needs of individuals and to feel comfortable. According to Rubenstion, comfort is one of the vital reasons for users to physical and psychological experience in their living room (Rubenstion, 1989)

Figure 3: Example of living room in smart home
(Clei Company, 2020)

If you're relaxing or working, with good seats and storage facilities, is crucial to the success of the living rooms (Parlkh, 1994). People spend more time in the living room. Due to the new lifestyle, the living room is smaller, and it’s time to create smart solutions to satisfy users’ needs and to be welcoming, flexible, and easy to use.

The traditional living room is designed as a large area and thus need to change the traditional layout to satisfy user needs. The smart space of the living room changes the formal layout of the living room. The smart living room is comfortable, flexible, multifunctional, easy to use, and it can be for various activities. While the area of the living room was for one function and traditional layout, the smart living room has become a multi-functional, provide various activities and allows the users to change the function of the room according to their needs in an easy way, through multi-use furniture, smart and flexible space.

A comfortable and spacious lounge can provide a solution to the long-term problem of storage or display space for items such as books and dishes while allowing you to keep

the occasional fouls of work or leisure firmly under control. Ideally, the layout of the rooms would provide to various members of the household the ability to do various activities within the room such as; watch television or another activity at the same time (Parikh, 1997).

Figure 4: Example of smart furniture in living room
(Huy Long, 2020)

However, one of the most important areas at the home is a kitchen. People who spend more time in the kitchen realize the importance of it. The consumer will not be satisfied with space unless the kitchen is comfortable (Mansouri, 2011). Kitchen environment must be functional and comfortable as it is used daily and significantly.

Not only as a beautiful and elegant design but also in keeping with the needs of its users in organizing and arranging furniture. Today's kitchens, due to the new lifestyle, are small in size or even within an open space, and large areas of movement are difficult to find easily. But creating a smart space helps to make the use of space and arrange the equipment, no matter how large or as large, while space is elegant and practical. The kitchen is an area to multi-uses, the traditional design of the kitchen is a

waste of space, and nowadays the space of the kitchen gets smaller than the traditional space.

The smart kitchen has the same functions as the traditional kitchen design, but it offers more space through intelligent solutions that can reduce the waste of space in traditional design. For example, corner storage design is often a loss of space, On the other hand, smart space may enhance it by turning baskets and shelves that swing when the door opens.

When space is at a premium, every extra work surface is useful, so the look at ways of incorporating temporary pull-out or fold-down surface, which can do double-duty as a breakfast bar area, especially if they are combined with folding stools or chairs that can be kept out of the way when they are not in use (Scattergood, 1997).

Figure 5: Example of kitchen in smart home
(Virtuves, 2014)

Furthermore, the space of bedrooms should be rest, relaxation, a healthy environment, and successful storage more than other rooms. Traditional bedrooms focused on where to stored people's stuff so they need more space to reach users' needs (Taylor, 1998).

In contrast with smart bedrooms, it looks at what needs to be stored and provides space for it by smart solutions, where to store equipment than not in use as long as the space organizes well.

Traditional wardrobes are generally inadequate, the smart space of wardrobes can provide space by managing the stuff inside it by filling the space in for most of the available space as stash the stuff by baskets that swing out of the cabinets with extra shelves. The smart space of wardrobes makes a room seem bigger due to space-saving.

Figure 6: Example of bedroom in smart home
(Chris Young, 2019)

2.3.2 Smart furniture in smart home

The furniture was made of stone, timber, and minerals in ancient times to meet the basic needs of human beings, including the sit and sleep and eat. The development of furniture developed significantly as a result of the rapid industrial development after the Second World War, where the new ideas of living which led to some new creations

in interior design and furnishing because of its impact on human needs and comfort, more than being linked to the optical configuration of the interior space.

Traditional buildings are usually designed in spite of the size and weight of the furniture. At present, humans need to use furniture for more than one function and to be varied and renewable without any change in the basic functional value of it. As the lifestyle changed, new forms of multifunctional furniture were created to suit the size of homes at this time, which may be transformed into different functions.

Figure 7: From traditional furniture to smart furniture
(Zinus, 2019 & Vurni, 2019)

The complexity of furniture leads to lower beauty of the design as it will decrease the amount of attention that could be attained from the user and it can hide the details, but the concept of the smart furniture may save the functional values and the artistic form. The purpose of smart furniture is to satisfy the desires and needs of users in small spaces to not face crowded stuff which negatively affects the comfort and movement of the users within the space.

With the presence of technology, a new spread of different furniture started, which include the process of folding furniture that started with the chairs that were demanded

the need for a large amount of it, that may transfer within the space without big effort, however, with time, the ‘bed folding furniture’ used especially within the library block or cabinet, which lead to saving the space for various activities in that space, also, this helps to reduce time, with no losing any of its functional features or the shape.

One of the main and biggest pieces of furniture that can prevent the track of the movement around is the bed, however, the wardrobe needs less mostly quarter than that space. On the other hand, the library block previously was considered as the key element of hiding the bed. Then, it changed to be the sofa. However, with the acceleration of improvement of furniture, the need for continuous improvement and innovation has increased, to not specify elements that we used on a daily, it was shifted to be consistent to adapt to changes to the dynamic environment and modifications of lifestyle of individuals.

According to Nasser, the pull-out bed was yet another development in the furniture design world. The product was conceived by the American William Lawrence Murphy in 1900. The slightly bulky Murphy bed was pivoting on a closet door scale and then dropping into a dormant position. He turned around and hid in the closet until his next encounter. Murphy got a patented his "in-a-door" bed in 1908 (Bellis, 2012).

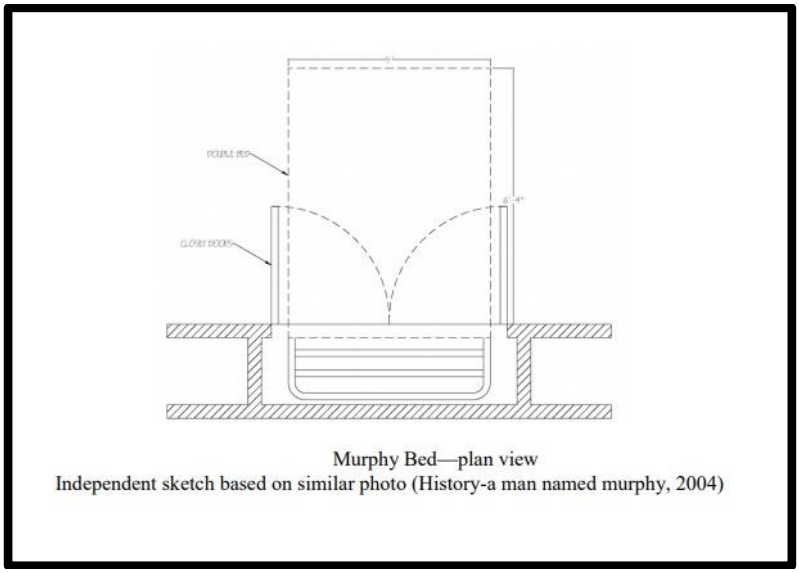


Figure 8: Murphy bed
(Nasser, 2004)

However, an example of smart furniture from 1960 is a Tube chair designed by Joe Colombo. Tube chair defies time with its new shape which can be a mutable appearance.

The designer took into account the flexibility of the user and can be suitable for different purposes. According to Panchal (2014) in his study of multifunctional space, the designer believed that the requirements is changing and the interior space should change based on needs.

Figure 9: Tube Chair – Joe Colombo
(Panchal, 2015)

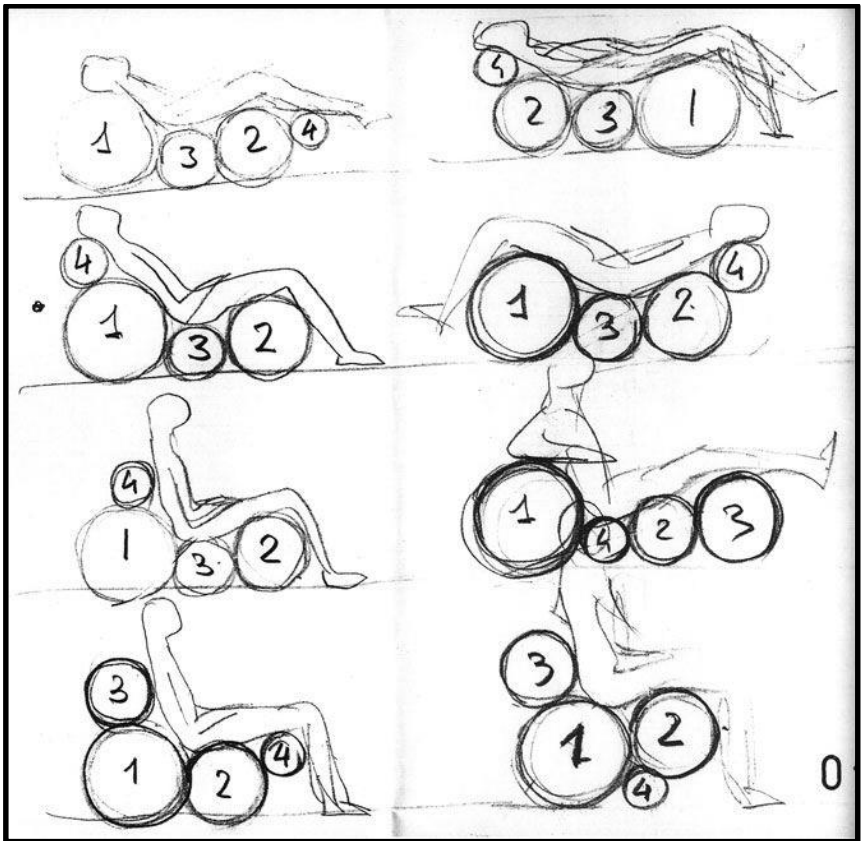


Figure 10: Sketches of the chair by Joe Colombo
(I Design, 2018)

Recently years and present day, the designers have reached the smart furniture which saves the space in a creative and most versatile way without ignoring esthetics. It is

not difficult for the users to convert it in one simple step, and if not in use can be folded to make the place more organized. Smart furniture has many different shapes and designs that decrease clutter by saving storage space, and by reducing clutter, space looks bigger and more welcoming.

Figure 11: Multi-purpose sofa: A sofa bed or sofa with storage
(Decomagz, 2017)

According to previous studies that mentioned smart furniture, some defects were found. After evaluating these defects, which include the difficulty of maintaining and caring for smart furniture, as well as a particular skill in use to avoid breaking any small part that can lose one or more of the furniture function. In the design of the smart home, flexible, sustainable, as well as the ability to use smart furniture is simple through flexibility and can be maintained through the materials used.

2.3.3 Lighting

Lighting is one of the most significant interior design basics, providing atmosphere and influencing mood. The lighting is the more element that affects the atmosphere in which we feel in the place, traditional homes ignore the importance of lighting and

spending effort in other design elements at home, consequently, it's poorly lit, and affects the human needs at homes.

With the change in the lifestyle, home space has become smaller, due to the small size, the entry of the natural light be less than before. The artificial lighting does not have the advantages of natural lighting itself and thus needs smart solutions to provide enough lighting to give users the feeling of comfort and help to solve the problems of small spaces.

In traditional design, one central pendant light may seem adequate for a small bedroom. But it will tend to produce a flat, dull and harsh effect. Well-planned lighting as in a smart home is essential in the bedroom, not only can carefully positioned lighting help to create the right atmosphere, but it can provide the right level of illumination for practical tasks.

However, the living room offers the greatest scope choice of lighting than any room in the home for more than one purpose, the smart living room has several postures of lighting in the same room. In addition, the kitchen has to be considered as a working area and lit so that you can carry out your tasks without straining your eyes. With-out over bright, smart home kitchen lightings are flexible as possible and ensuring safe and effective task lights close to all the main work areas in the room with sources of natural daylight.

2.4 Chapter conclusion

This chapter mentions the new situation of life and the changing from the traditional home which has a large space to the small homes which has a lack of space that can’t satisfy users’ needs then the problems faced by the users of small spaces.

Small homes are a result of the new life system by more population which led to decrease spaces, more people mean less space. Smart space style is full of efficient ways with smart solutions to use the maximum space. The previous studies in this chapter illustrates solutions to obtain a limited spaces, that well designed and efficient for users, as well as taking into consideration the user's needs and preferences to create a design that provide a suitable and comfortable space.

Furthermore, the chapter provides the smart homes which have the capability to achieve an individual's needs for internal designs, with smart furniture to be extra effective to satisfy the requirement of the users and obtain solutions. Smart furniture aims at maximizing the effectiveness of the use of the furniture through provide multifunctional as well as foldable pieces that providing more space in the small areas as well as comfortable space.

Chapter 3

THE FLEXIBILITY CONCEPT IN SMART HOME

3.1 Types of flexibility

The dealing with the growth of technology has led to the development of the needs of individuals, and is highly affected by people's way of life, it is fair to use the technology of mobile structures in building architecture that is in line with the changing needs of the users (Abbasian, 2017).

> "The concept of "flexibility" comes to the fore in particular in today's designs, Flexibility goes hand in hand with the concepts of changeability, adaptability, and growth" (Tuncel& Kayan, 2008, P. 4) According to UK essays, the English colloquial usage of the word "flexibility" is:
> 1. Abilities of being bent, pliancy.
> 2. Vulnerability of adjustment or alteration; measurements for readily adaptation to multiple purposes or conditions; with no stiffness or inflexibility. (Oxford English Dictionary Online, 2009).

According to Al-dakheel, flexibility types are consists into three types, the first one is a functional flexibility which is the ability to interchange the function of the space and to separate the unit. The second type that provided is structural flexibility, it included the ability to expand the unit vertically and horizontally.

The last type is cultural flexibility, index combining the ability to personalize the dwelling as well as the ability to improve privacy components (Aldakheel, 2007).

Generally, the add-in method is carried out by means of the unit's arrangement and furnishing. It takes the form of modifications and changes of space, which follow the

techniques of dividing the unit into two units by exchanging spatial components or by transforming or exchanging spaces to achieve functional versatility through a strategy of versatility (Brand, 1994). Structural flexibility usually carried out through extend or add by adding space horizontally or vertically through extra space.

"Structural/spatial flexibility' covers the notions of adaptability of size to accommodate changes in family demographics or lifestyles as defined by Schmidt-III & Austin" (Al_dakheel, 2007, P. 175).

> According to UK essays, from "Hertzberger's perspective, flexibility refers to the caple of proposing different solutions for diverse users with no certain single solution but most appropriate one, He discussed flexibility in a different perspective by introducing the term 'polyvalence' which means a characteristic of a static form, a form that can be put into different users without having undergo changes itself, so that a minimal flexibility can still produce an optimal solution" (Hertzberger , 1991, p.147).

3.2 The meaning of flexibility in design

Flexibility in general means being able to change things to fit new conditions. Flexibility in the architectural field means the ability to reshape the building to continue its work despite changing functional needs. According to Tantous, the flexibility term of housing means the ability to adjust to evolving demands and requirements from time to time, so that the transition is recognized and defined as the possibility of a gradual redesign to choose the best option that helps to find versatile and new solutions that meet the changing needs of users and the requirement (Friedman, 1993).

> According to UK essays, "Rabeneck, Sheppard and Town involve the scope of flexibility in housing project, They see flexibility as a tool to make the minimal housing environments capable of offering for 'choice' and 'personalization', They criticize flexibility can lead to too technical or complicated housing projects" (Rabeneck et al., 1974, p.86).

> "Flexibility is one of the physical properties of materials and geometrical forms used in interior design, that property depends on the physical shape in

> additional to its compositional and other structural properties, so that repetition, balance, similarity can be used for making flexible space, which means that we can use that geometrical property in order to gain a flexible space that can be transformable and multi-uses in the same plot area" (Abdulpader et al, 2014 P. 196).

The concept of living unit flexibility dates back to the early twentieth century: starting in fact from the twenties the great European masters of architecture questioned on methodologies and technical-type solutions to solve the problem of the housing construction applying project criteria careful to realize, in small spaces, high-quality performances based on both the rational organization of space and the building-furnishings integration (Canepa, 2017).

One of the most significant internal spaces is the home, which the users spend a lot of time, so it should be a comfortable environment suitable to human requirements, to help them practice their different activities in a good way.

At the moment, as in the past, we are constructing or changing home to fulfill our needs beyond being a basic refuge. Furthermore, housing is a physical space, they place restrictions on their inhabitants and at the same time create a chance for users (Ward, 1999). Due to the lack of space in home, flexible space used to respond to human needs and enhance life quality by creating functional efficiency.

As the lifestyle changes, housing needs becomes different, leading to the need for housing adaptable to changes in user's needs, flexibility in design provides the users with the ability to create interior spaces creating temporary spaces, for example, use of bedroom as living room.

3.3 Flexibility in smart home

By the designer, the flexibility and multi-use in the smart home need attention and awareness to improve the concept of a smart home, that necessary for the users in the new form of the lifestyle. Flexibility is a potential way of bringing users back into active housing engagement and providing them with management tools to meet their continuous needs in the space (Friedman, 2011).

Room proportions with the intended use are provided with function-related fixtures and fittings; lighting and socket outlets are located according to the functionality of the room (e.g. light fittings that suits the bed space), and windows are designed to suit the function of each space. The flexible space may be obtained by flexible furniture and its structure, flexible partitions, color shift by lighting, etc., providing a flexible space in the internal spaces, light as a beneficial element that may affect the users (news interior design, 2014).

3.3.1 Space flexibility in smart home

The flexibility of space seeks to fulfill the changing needs of the users by organizing space according to the requirements of the users, integrating various activities without any change in the form of architectural spaces and usability into the dwellings.

Figure 12: Example of flexibility in smart home
(Murphy, 2015)

Homes have to achieve user's requirements in the internal space through the flexibility as well as rearrangement of the space to improve the functionality of the space in addition to the aesthetic effectiveness.

3.3.2 Furniture flexibility in smart home

Through the years, designers have evaluated integration solutions among furniture and space to optimize the use of the area with a flexible functionality (Canepa, 2017). Once furniture is capable of carrying out many functions, it should be flexible and has the functionality to be achieved, however, The furniture may be pile up on the top of each other, or overlapped, with the size of lots of each item that should not exceed the size of one piece.

The procedure of stacking is a section of the design, which is necessary with multiple parts; for example, it can be used with tables, chairs, as well as beds. For example, ten chairs need a suitable method should be used to conceal the items in space, for instance, a method can be used to hide them inside the table, and the recent advanced technology uses this style of furniture stacking furniture that starts with chairs to make more user friendly and efficient to reduce effort and time.

However, the improvement and progress, introduced the bed folding furniture, which disappeared with the appearance of the block library that saves space for other activities, without the loss any of its functional characteristics.

Figure 13:Example of flexibility in furniture
(Ibrahim & Yan, 2018)

Multifunctional furniture provides the capacity to use the internal space for more than one function. Through the term flexibility, which enables the user to use the space with various activities by making one piece of the furniture have different functions. This happens with the simple effort of the user.

3.4 Chapter conclusion

This chapter provides the importance of flexibility in the interior design and especially in small spaces and the approach of using the flexibility to formulate the concept of the smart home.

Flexibility in internal design solves a lot of problems through multi-use as well as different possibilities to reorganize the space based on the need of the users which includes the change of the size and the form of the interior space.

The chapter provides the use of flexibility in the furniture as well, for example, changing the chair to a table or to another piece of the furniture, which keeps the aesthetic and functional efficiency of the furniture as well as space. In addition the ease of use by users in one step without big effort.

Chapter 4

THE SUSTAINABILITY CONCEPT IN SMART HOME

4.1 Types of sustainability

Sustainable design is a way of thinking putting in consideration the impact of various issues on the environment and human wellbeing. Interior design is an integral part of any building construction or renovation with choices made in designing the inner space, which environmental and human wellbeing implications (Mustafa, 2017).

Our homes are filled with different spaces that must be organized, and made functional by the interior designers while focusing elements of beautification in those spaces. These days, sustainability plays an important role which affect the residential spaces in terms of interior functionality, which influence a good design of the interior atmosphere with a major impact on both the human and the environment. Sustainability is part of creative solutions to reduce costs, as high material costs is still an obstacle to users.

"Sustainability includes a wide range of meanings and definitions in the interior design field. By definition, the word "sustainable" refers to the capability of being maintained, borne, defended, upheld, or supported" (Oxford University Press, 2007, p. 327).

Sustainability includes multiple dimensions that overlap with each other, this include economic dimensions that require less material cost with improved efficiency,

environmental dimensions that focuses on the structure and internal function of spaces. Social dimensions focuses on humans (the users); and how to achieve comfort and safety for human with the addition to aesthetic and emotional expression.

The different dimensions should take into consideration as requirement to improve the quality of space. As a result of the increasing population coupled with need for more residential spaces; and the high cost of traditional materials used in these spaces. And influence poor users experience; this have harmful health effects due to the poor quality of the indoor air. Sustainability is an approach directed towards solving the problem. Through the re-use of materials that help to organized these spaces in an effective manner.

4.2 The meaning of sustainability in design

Sustainability as a concept in interior design means continuity, existence, and renewal in order to create a systematic interaction between humans and the environment through reinforcement of the life that allows others to meet their needs and achieve them in the best possible way with minimum costs of view. This is achieved by making use of the existing materials without the need to exploit other materials (Rashdan, 2016).

Sustainability includes several interrelated aspects that complement each other, benefiting both the design and the user. The first one, economic aspects focus on material cost and how to re-use them in an appropriate way. Secondly, the environmental aspects, focuses on internal functions and smart spaces in an innovative way.

Thirdly, the social part focuses on human's needs and comfort. All these aspects improve the quality of the internal space.

"Interior designers in particular can help, as they often work on the renovation and residential projects, carefully select materials and finishes, and frequently choose lighting and appliances" (Moxon, 2012, P. 14).

4.3 Sustainability in smart home

According to Attaianese, by a more comprehensive viewpoint, it has been assumed that a sustainable building has to contribute to sustainable development, through its characteristics and attributes, addressing some goals: safeguarding and maximizing functionality, serviceability as well as aesthetic quality (Attaianese, 2014) The new development has an impact on the interior design and the used materials, which aims at using the development to adjust to the environment and satisfy the design needs.

The concepts of design earlier in time aimed to focus on form and function, recently, this idea has changed towards natural ambience that aim to make smart designs to be environment friendly as to sustain and protect environment resources to satisfy the desires of the society and adapt to the environment and use resources more effectively and efficiently.

The continuous changes of lifestyles and human behaviors requires a continuous reconsideration to fulfill the needs of the user to develop the furniture industry, previous methods can be considered as outdated, nowadays, the world is moving towards methods of reuse and durability.

The acceleration of technology must fulfill the needs of the present, however, Sustainability is not forever, it can be considered as adapting to changes and using methods of reusing to improve performance and increase the durability of furniture by using more efficient materials.

The homes are filled with spaces that must be designed in an attractive and smart way in line with the new technology used in homes, where sustainability forms an important role in influencing both the internal space and the user's full filing satisfaction and comfort.

A clear understanding of the function and physical setting of sustainability is basic to achieve its success, the purpose and desired effect. When the design is satisfied the aesthetically, and the needs of the people who use it, the space achieve functionality. So we focus and achieve other design objectives: sustainability, accessibility, safety, aesthetics, and cost. To improving quality of is essential in designing the sustainability residential spaces that are sustainable.

A smart home achieves maximize aesthetically, efficiency, and functionality while minimizing the cost which leads to fill filing the required, attractive, and comfortable residential spaces.

4.3.1 Space sustainability in smart home

The parallel pattern was environmental awareness, in which almost all items are either "natural" or "biological." The building industry was moving towards green construction practices even before the recession, as the advantages of sustainable design were too fair to be ignored. Many may not discuss the merits of homes, most do not dispute the merits of energy-efficient buildings or low-maintenance materials,

and as more and more studies prove the health benefits of better indoor air quality and daylight, the decision to switch to green is a good investment. (Panchal, 2015)

From here, we can have a smart, healthy and low-cost home that offers all the amenities and safety that meet the user's needs. In addition, to keeping pace with technology and taking advantage of all developments in design in our lives and homes. In addition to using the right material in the smart home, the use of energy in the design from lighting, pumps, and hot water. In the smart home, the use of natural resources helps work for a longer time in less space.

“The choice of construction methods will affect a project’s environmental impact, and interior designers are in a strong position to influence this” (Maxon, 2012, P. 106). The first step in improving healthy interior spaces is to find products with low or zero toxic or any other pollutant and to use "environmentally friendly" alternative products (Mustafa, 2017)

Sustainable interior design provides a healthier, more productive space to maximize the functional use of space where the interior spaces used efficiently are organized to maintain the size of the room. In addition, sustainability is an additional and new option for interior designers as it can be rearranged and organized in another vital way that gives new life to a specific space.

4.3.2 Furniture sustainability in smart home

Sustainability is one of the most important innovative and effective solutions in reducing material costs through recycling materials and benefiting from them and making long-term materials to be used smartly.

When referring to sustainability, we mean materials and furniture, whereas green furniture is the main part in the internal space and the most important element in sustainability. Changes in the human behaviors and attitudes towards a different lifestyle that consider the environment and how to use more efficient materials with less pollution has led the designers to adapt to these requirements and use methods such as reuse and recycle with the usage of efficient materials to satisfy the needs of their users.

One of nature- friendly and useful solutions, it's the use of green furniture in organizing residential space which has a major impact on showing the functional and aesthetic aspect of that space.

> According to Elnaz, “Green Furniture is a term that is used for furnishings that have a significant impact on the ecology of the planet, “Green" Furniture, often symbolized by a tree, are products that use materials from sustainable forests, have low toxic material levels, locally manufactured, and are durable enough to last” (Farjami, 2014, P. 39).

Green furniture (material) is an expression that is used for furnishings that have a significant impact on the environment in it (space) also the material sustainable have low toxic levels and it is made to last long.

The Green materials may be managed below two subtitles as eco-friendly materials and recycled materials. Sustainable furniture design is the treatment of products that exist after a review of the design and manufacturing aspects. In the industrial process, materials that may be dismantled, recycled to be re-used which helps to employ those materials in a way that would serve the user and reduce the cost of material. So the use of sustainable materials and green materials such as stones, straw, wood, bamboo,

steel, glass fiber, cork, polystyrene, natural clay, non-volatile organic compounds, and fiber cement inside the work help to create good atmosphere.

However, when employing sustainability in designing residential spaces, we can have important benefits that will help both the designer and the user, such as: give utilizable items other functions, keep the money, support the reuse and recycling the material, decrease the use of the environmental resources. For that, big attention has been provided to utilize the smart materials to raise the environmental sustainability, reduce the cost, safety, as well as aesthetic perspective.

Sustainability employed in a large way in furniture affects homes in general and space, air quality, and humans (users) in particular. This is because the materials used are of low toxic degrees and almost non-existent as environmentally friendly materials are recycled.

In terms of sustainability, companies must enhance the efficiency of the internal environment by eliminating pollution, reducing the pressure on raw materials and energy use, and minimizing waste (Mustafa, 2017). By using non artificial materials in the design of the furniture, the quality of interior space will be increased.

The use of those materials considered to be efficient and renewable. Such as wood, which is the main natural material that is often used in construction of housing units in which designers mainly rely on this material during their construction activities.

These materials are less harmful to the environment. Sustainable furniture uses several materials such as recycled materials which is used in manufacturing process,

sustainable furniture materials use products that can be reused and recycle these materials that can be permanently to protect the environment.

“Materials such as clean timber, metals, gypsum wallboard, and cardboard/paper that are produced during construction can be recyclable materials” (Farjami, 2014, P.43).

Recycling is the reusing the materials in order to reduce pollution and preserve the environment by reducing the consumption, prolonging product life in recycling. In the process of manufacturing sustainable and smart furniture, materials that can be recycled, dismantled, reused, and incorporated in the interior space includes flexibility to achieve functionality aesthetic value in space.

One of the existing companies that use sustainability in their products is Green design, the company approach consists of two sections. Reduction of the residual footprint of the manufacturing cycle of new products, which could be accomplished by using low-impact, non-toxic, sustainably produced or recycled products that require less energy to move from raw to finish (Green Designs, 2011). Design products, buildings, and services to function in an environmentally friendly manner are equally important for determining whether it is truly 'green'.

The "green design" uses less energy, built to last longer with less maintenance, reused or recycled, and does not cause any physical harm (Green Designs, 2011).

3.3 Chapter conclusion

As a result of population and environmental developments, remarkable progress in the field of interior design, and the effective role of designers in finding solutions with a positive impact, they must consider the prosperous trend such as sustainability

and its positive impact considering functions that lead to successful and organized residential spaces. The concept of sustainability is a wide topic, this chapter focus on the use of material through the use of long-term, recycled green materials to reduce the material cost to users and give them a feeling of comfort in a healthy spaces. Moreover, achieving balance in the interior spaces is between function, balance, and beauty.

Chapter 5

HUMAN FACTORS IN SMART HOMES

5.1 Human comfort in interior architecture

Previously, the emphasis was placed on functional need in small space design. In this chapter, an important part of the design process, human factors, has been emphasized, because the space designed must satisfy the user to enable them to perform their activities in comfort and without risk.

Afford an atmosphere and location that satisfy the user's needs in a contented way which is considered essential to have an effective response when designing the home. The comfort atmosphere is influenced by several factors which led to a poor space for the users.

Many essential factors can be measured to accomplish a successful design to obtain security, suitability, and to offer a healthy interior atmosphere. In addition, many main focal factors are considered significant in terms of designing a home that accomplishes the proper, relaxed and active environment through evaluating the user's desires that includes individuals' dimensions, choices, and their favorite tastes. Furthermore, comfortable furniture achieves the utmost benefit.

5.2 Human comfort in smart home

Smart home spaces can serve for multiple purposes. Such as the living room serving as an office/study room in day time or it can transform in to bedroom to serve for night

time activities. This conceptual design support all kind of activities that occurs during the day time or night time in the most comfortable and healthy way.

Physical impacts affect both health and well-being and by more indirect cognitive impacts like the impact on mood, and stimulus. So the building's interior space has been the main contributor to the type of user's life (Livesey, 2012).

5.2.1 Human comfort and space in smart home

According to Hamdy there is a several options for designers to make interior space healthier and safer by attentive choice of materials for their interior designs such as; glasses, paints as well as fabric. In addition to that intensity friction as slip-resistant as well as the impact of the toxic in the quality of the indoor air as the fabric, painting etc. (Hamdy, 2017).

> Hamdy emphasizes that "Avoid sudden changes of level which could trip people, if they are present, it must be made clearly visible with contrasting colors, make the floor slip-resistant, non-reflective light, glare-free, and easy to clean, solid core construction for interior spaces partition (Sliding walls), enhance the levels of lighting where it's needed, it should also be easy to control and adjust, choose comfortable and safe furniture with healthy design" (Hamdy, 2017, P. 6, P.7).

The Indoor air quality is a method of researching indoor air elements that has an impact on the comfort as well as the health of individuals living in the home. Indoor air is unprotected to pollution by the microbe, mold as well as many toxins, chemicals, or any pollutants that affect the health state of people generally. Observing that the indoor air in contrast with the outdoor one is more polluted.

The health is effected by indoor air quality, which received little attention by the community of practice. The issues of indoor air quality have been evaluated frequently, however this issue needs more investigation and more research studies. Many sources

of pollution in the domestic sphere, and they are separated into two main kinds the first, pollution produced by non-biological sources, second, pollution produced by biological sources.

Furthermore, the movement of the air reduces the evaporation that results loss of heat by convection, and play a role in decreasing the level of comfort in an under heated space, and raises the level of comfort in an overheated environment. The movement of air in excessively hot rooms would help maintaining our level of comfort by increasing the thermal convection rate of our skin and facilitate evaporation. For this reason the breeze decreases the effective temperature and helps individual to feel more relax within high temperature sphere (Northern Architecture, 2020).

However, Visual Comfort is considered as a personal feedback to lighting of the amount and in terms of quality in terms of space. Visual comfort can depend on the capability to have the ability of control light levels. When there is a poor light and excessive light can lead to a person's visual discomfort. However, in terms of light levels or the sharp difference of anxiety and exhaustion, as the human eye constantly adapts to light levels.

The correct use of daylight is necessary for visual comfort for people, and visual comfort depends on the maximum independence of daylight, moreover, the design of the windows is critical for providing the appropriate visual comfort for people.

There are two aspects to visual comfort:

1- The social aspect of visual comfort

History and culture also shape the way we value light and visual environments. There are severe variances in the preferred range of lighting depending on age and culture. For example, in Asia's culture, they prefer lighting colors while on the other hand, it is different in other cultures and therefore countries such as the European countries.

2- Physiological aspect of visual comfort

Scientists and researchers have started to understand the way the light influences the human body and impacts the state of mind and mood, light has a direct and deep effect on regulating several biological functions, such as sleep, mood, and alertness.

5.2.2 Human comfort and furniture in smart home

"Everyone pays attention to comfort, comfort is an important issue in the design of many consumer products, in particular those with physical contact with the consumer, eg headsets or chairs" (Kristense, 2012, P. 1).

"The man uses the furniture and depends on it in his life, so it should be different in its specifications to matching the various activities of the man and achieving comfortable sitting to maintain his physical and psychological aspects" (Harairy, 2013, P.3).

Basically, the smart furniture aims at satisfying the users comfort at the residential space by using a sustainable materials. In order to develop the relations between individuals and furniture by the comfortable use. Smart furniture suit the human body in more than one function through uses the human dimension.

Anthropological data is significant for making smart furniture and designing smart spaces in an intelligent home because sizes and shapes vary from individual to another,

hence, smart furniture may not be able to be produced without a reference to anthropological data.

However, good ergonomics aims to contribute to the learning of human strengths and weaknesses in order to enhance interactions with spaces and objects and to reduce accidents. The traditional design of small homes result in accidents or injuries, especially if the design is indigent, which causes stress and effect negatively individuals' health (Meeks, 2016).

5.3 The anthropometric and ergonomics issue in smart home

"The science which dealing specifically with the measurement of the human body to determine differences in individuals, groups, etc is termed anthropometric" (Panero& Zelnik,1979, P.23).

"Anthropometry is the study of the measurement of human bodily features in terms of length, width, thickness, and circumference, among others, These body measurements are commonly referred to as anthropometric data" (Novabos, 2012, P.2).

There connection between the new lifestyle and the technique to design homes are being designed, in order to accommodate these changes and to achieve user's needs in a comfortable domestic sphere, and measurements of the human bodies have to be taken into consideration. Thus, the sizes of the design spaces and their functions are major factors when the designer organizes the residential spaces.

Interior architectural design has to be done be based on individuals' measurements and some dimensions because it's a science constructed to serve human beings and satisfy the various needs of them (Haider, 1988).

The design of the smart home needs measurements based on who live in that home, for instance the design of couples without children home differs from single-person households and that measurements vary due to different factors, including gender, climate, sex, etc. this idea is supported by Panero, Zelnik (1979) as he stated in his study.

> "If anthropometry is viewed mainly as exercises in simple measurement and nothing more, one might conclude that the dimensional data could be gathered simply and effortlessly, Nothing, however, could be further from the truth, There are many complicating factors and difficulties involved, One such factor is age, sex, race, and even occupational group" (Panero, Zelnik, P. 23, 1979).

Not only that, disabled people and their needs are investigated by many researchers as well, Panero& Zelnik (1979) discussed this issue, and they stated that this issue of physically disabled people that deals with the manufactured by human surrounding are a big one.

To convenience the user, human anthropometric is used widely. All dimensions have to be appropriate for individuals' requirement and comfort. At smart homes, the smart space dimensions have to suit measurements of human, as they are expected to provide adequate area to fit a lot of activities in a small spaces. By utilize anthropometric aspects of the ergonomics that are:

"Matching the physical form and dimensions of the product or workspace to those of its user; and likewise, with matching the physical demands of the working task to the capacities of the workforce" (Pheasant, 1996, P. 7).

According to Meeks, to ensure that physical discrepancies between the size of devices, products, and the size of the corresponding user are avoided, anthropometric data on

human body measurements are used in ergonomics to assess the physical dimensions of work space, equipment and furniture (Chakrabarti, 1997).

Because of the lack of space, the individuals' comfort has to be done through providing smart interior spaces as well as designing smart furniture so they adapt individuals' dimensions in limited areas. What mentioned previously based on providing individuals' dimensions, which used in multipurpose furniture, which is smart furniture. Here an example, the design of a bed-sofa based on human measurements in both positions, sleeping positions, and sitting positions.

The next table provides the human dimensions connected to the majority utilize of small spaces furniture according to (Thogresen, 2019) & (Panero& Zelnik, 1979).

Table 2: Human dimensions connected to the majority utilize of small spaces furniture

Furniture	Body Dimensions
Bed	Stature, weight and popliteal
Sofa	Seat Height, Seat Depth, Armrest Height, Back Height
Chair	Sitting height normal, sitting height erect, knee height, popliteal height, elbow rest height, thigh clearance height, buttock knee-length, elbow to elbow breadth, seat breadth, and weight.
Table	Sitting height (popliteal height, elbow rest height, sitting, shoe allowance). The eye height (sitting, popliteal height, shoe allowance). Standing height (elbow rest height, standing, shoe allowance). The eye height (standing, shoe allowance). Viewing depth.
Wardrobe	Height, Chest, Waist, Hip, Arm length.
Commode	Sitting height normal, sitting height erect, knee height, popliteal height, elbow rest height, thigh clearance height, buttock knee-length, elbow to elbow breadth, seat breadth.

For instance, a bed that transforms into a studying desk is considered as a multiple-use product since it can be used as a reading desk and as a single bed. The ergonomics are taken into consideration when designing the bed and the desk, for example, its length, height, and popliteal height (Meeks, 2016).

Stature and the weight of the user have to be taken into account when designing this kind of furniture, for many reasons as designing the fit height, width of the bed, as well as the popliteal height in order to control the higher of the bed from the floor. As for the sitting height erect has to be measured for determining the desk height overhead the bed to avoid accidents or harms in different positions (ex; when the user sits on the bed). Also, the user's stature is significant to define the maximum height of the desk in order to reach the desk by the user. And when the user uses the product in the second position which is a studying desk the sitting height erect should be taken when the user set on the chair to reach the desk.

The visual figure down explains in details the human dimensions that mentioned to clarify the movements of the individuals in order to avoid accidents while utilizing both options.

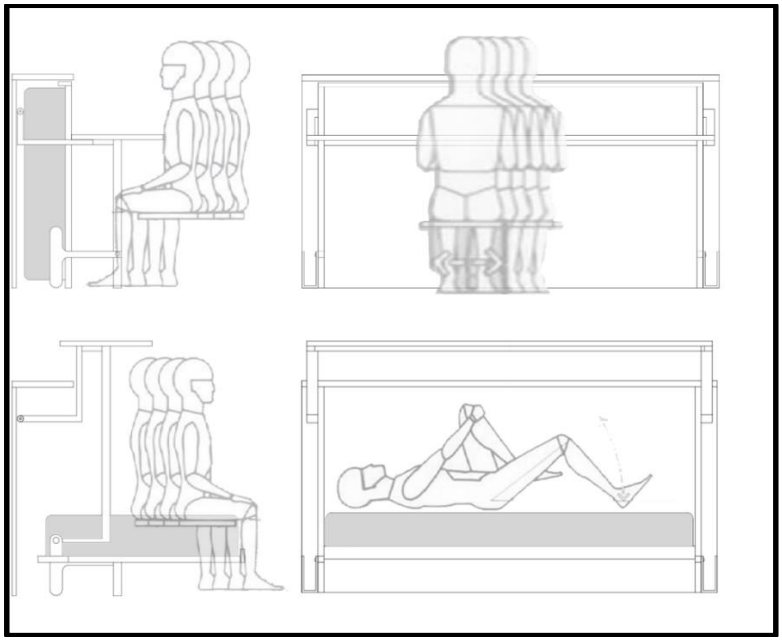


Figure 14: Visual explanation of using body dimension in smart furniture design (by the author, 2020)

The next table illustrates the anthropometric data which have to take into account when designing the bed which transforms to reading desk, and the purpose of using ergonomics. (Panero& Zelnik,1979) & (Meeks, 2016).

Table 3: User's anthropometric data of smart furniture and its ergonomic purpose

Anthropometric data	Ergonomics purpose
Stature	Bed height, maximum height the desk can reached
Weight	Bed width
Popliteal height	The bed height from the ground
Sitting height erect	Desk height above the bed, reach the desk while using the second function as studying desk.

5.4 Chapter conclusion

The small homes interior design needs practical manners and intelligent solutions to exploit the small living space exists, the mentioned research studies of small homes designs provide many solutions in order to make a small spaces functional, however,

the significant issue is that every element in the home has to serve users and to seem aesthetical and comfortable.

In this chapter, the good design of small homes provides and clarified safety and healthy in the space, and that by making an appropriate design to avoid accidents or indoor air quality that play a role in the individuals' health and to promote the sense of privacy. Furthermore, it creates an appropriate design that provides air movements to enhance user comfort. Also this chapter illustrates how to measure the space for better individual's movements, and finally, it discusses the furniture that suits body dimensions.

Chapter 6

EVALUATING OF SMART HOME

6.1 Proposed framework to evaluate of smart home

This chapter illustrates the research methodology, firstly the qualitative part of the study will be introduced. A qualitative method approach adopted to identify the criteria of the smart home, through previous studies as it reviewed it and analyzed the authors' opinion on smart solutions of small spaces. The flexibility, sustainability, and human comfort in smart home and their impact on the users; besides that, the coordination of these fields provides a comprehensive solution for solving the living issue of small spaces. In order to develop a space that people will use and live in it. As well as the tool used to collect information based on previous studies.

This research was structured around human needs concerning the small spaces and smart solutions to reach the concept of the smart home.

Secondly, general information and analyze the interior space of each chosen home that includes the smart home criteria will be given, followed by an analysis sheet summary of the findings. In the last part of the chapter, the results of the study will be presented.

Therefore, two tables for each example were developed to analyze the selected samples according to the use of smart solutions includes flexibility, human comfort, storage

units, optimal use of space, smart spaces, smart furniture, lighting, and sustainability based on literature review.

In the first table, the demographic data was provided of the examples includes the number of the users consists of couples without children and single-person household, location, the name of the designer, the size of the home as well as photos of the homes. Meanwhile, the required photos have been selected to perceive the building.

Moreover, the second table consists of six of the main criteria, and ten of sub-criteria of a smart home. While the examples of the selected homes according to these criteria to find the answer of (What the framework to evaluate a smart home includes, as well as how to satisfy individual needs in a small space through the concept of a smart home).

Figure 15: Structure of thesis methodology

6.2 Selected examples of smart homes

The study focuses on a qualitative analysis of the interior space that related type in which the study is the conduct of the selected ten examples that take attention by the websites, articles...etc.

The “case study research" was chosen as the method between the five approaches mentioned by (Creswell, 2007, P. 73).

The researcher chooses this method based on providing the improved interior design in the small spaces, and frames the concept of smart home through the selected examples.

- The selected examples are:

1. **Small SOHO home**

   The small SOHO home called a "Life Edited" is located in New York, the size of the home is 420 square feet (39 square meters). The home takes a smart design solution consists of re-arrange the interior space to suit the user's everyday needs. The home designer “Graham Hill" provides sustainable living solutions to the small spaces, in addition, provide a space for one person and two guests (Vinnitskaya, 2013).

2. **Five to one home**

   The home located in Gramercy Park, a private park in Manhattan, New York City, USA. The home size is 390 square feet (36.2 square meters). The home designer is MKCA. During the night it becomes a full bedroom with low lighting and TV on the wall. During the day, the bed is turned over to the wall and a wardrobe appears in place, and the bedroom area is returned to the living and working areas

of the apartment. There is also a dining area adjacent to the living room (MKCA, 2016).

3. **Graham Hill’s home for one person**

   The is home called Life Edited Two, it's a two-rooms that can suit various activities through a moveable, extended, and folding furniture to make 349.9 square feet (32.5 square meters) use as double its size. The designer of this home is Graham Hill the originator, of the sustainability website "Tree Hugger" (Life Edited, 2018).

4. **Fabio Cherman’s home**

   The home located in Asa Sul, Brasilia, Brazil, it’s the home of the designer Fabio Cherman, the home size is 290 square feet (27 square meters). During the night, the bed folds out on the sofa to be a bedroom, also the wall panel can be a guest bed in addition to the table. The chairs can be stored in the cabinet when it's not in use (studio Fabio cherman, 2016).

5. **Petite Apartment Packs Pivot Power**

   The home designed by Robert Garneau, located in New York City, for one single-person. The home hosts of custom storage solutions and transforming elements. The home size 499 square feet, 37 square meters (Life Edited, 2016).

6. **Yolanda's House**

   The home located in Spain-Madrid, the family members are two-person, and the home size is 500 square feet (46.4 square meters). The home consists of a flexible and sustainable three units include all the user's requirements in the home such as bedroom, kitchen, and also a studio. In addition, the three units provide storage space for the home's equipment. (arch daily, 2014).

7. **YO home**

The home located in London, the family members are two-person. the home designer is Robert Garneau, he designed a 430 square feet (40 square meters)in smart design, used the floor as storage units and the space transfer from a living room in the day time to a bedroom in the night (dezeen, 2012).

8. **Anton-Medvedev's home**

The home located in Kyiv, Ukraine, this home designed for two-person. The home designer is Anton Medvedev, the size of the home is 269 square feet (25 square meters), each piece of furniture can serve more than one function in an easy way and the users can hide the furniture away when it isn't in use (Medvedev, 2016).

9. **Attic transformer home**

The home located in New York, this home designed for one person. the home designer is Michael K Chen, he designed a 225 square feet (20.9 square meters)in smart design, The space of the home was well designed with transforming elements includes storage units, pull out table and foldout bed in limited space (MKCA, 2016).

10. **Petite Penthouse**

The home located in Barcelona, Spain, this home can serve a single person. The home designer is Anton Medvedev, the size of the home is 258 square feet (24 meters), the design aims to provide continuous and clean interior through hiding all the furniture away into two long walls (Luke, 2014, P 42, 43).

- The study provide ten examples selected based on smart home criteria.
- The selected examples are between 200 to 500 square feet.

- The selected examples includes a smart home's criteria (flexibility, human comfort, storage units, and optimal use of space, smart spaces, smart furniture, lighting and sustainability based on literature review.
- The selected examples are used by couples without children and single person household.

6.3 Evaluation of selected examples by using proposed framework

Table 4: Small SOHO home demographic data

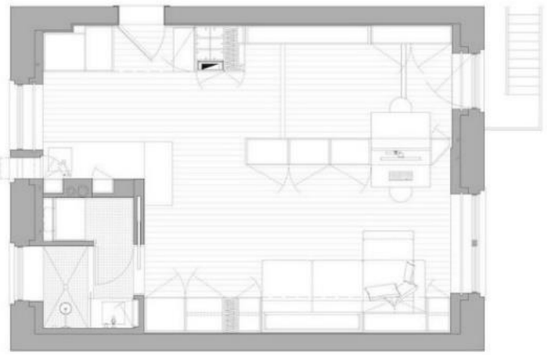
Name of the home	Small SOHO home
Location	New York
Family members	One person with two guests
Home size	420 square foot 39 square metres
Home designer	Graham Hill
Plans of the home	 
Photos of the home	   Photo credit: (Life Edited ,2013)

Table 5: Analyze small SOHO home according to the smart home criteria

Smart home criteria	Small SOHO home
Smart furniture	- Each piece of the furniture is efficient as possible for multiple uses. - The designer used a sofa that transforms into a bed and a guest room that folds into the wall. In addition, the table that can extend to use it with ten people.
Smart space - Storage unit - Optimal use of space	- The living room is a major place for multiple uses through: - Bed folded outside the wall to transform the living room into a bedroom. - The hidden wardrobe also accommodates two beds for guests. - Overhead cupboards conceal a projector that transforms the living room into a presentation room. - The design moves in the bathroom also creates a soundproof environment that can double as a private room. - A hidden table under the pull-out kitchen table to accommodate a large group that fits into the living room.
Flexibility - Flexibility in a space - Flexibility in a furniture	- Moving the wall to opposite the folded cupboard divides the living room into two parts, one for sitting and use it as a presentation room in morning and sleeping at night and the other for guests. - The flexibility in the furniture used as folded furniture that the user can open in one step and ease of return when they need without losing any of its functional characteristics or formality. - Transfer furniture which can use it as two functions without any effort.
Sustainability - Sustainability in a space - Sustainability in a furniture	- According to the life edited company, the design allows the user to live within an environmental design and focuses on green design through the material.
Human comfort - Human movement - Privacy space	- Furniture that used is sourced from Resource Furniture –a company that specializes in space-saving designs and sustainable that keep the home airy and provide more space for the residents. - The flexible wall gives privacy to the user through moving and create various spaces.
Lighting - Artificial light - Natural light	- Dimmable LEDs are used throughout the home. - Natural light used in the living room that transfers to the bedroom, and in the guest room when the wall move. In addition to the use of the natural light in the kitchen.

Table 6: Five to one home demographic data

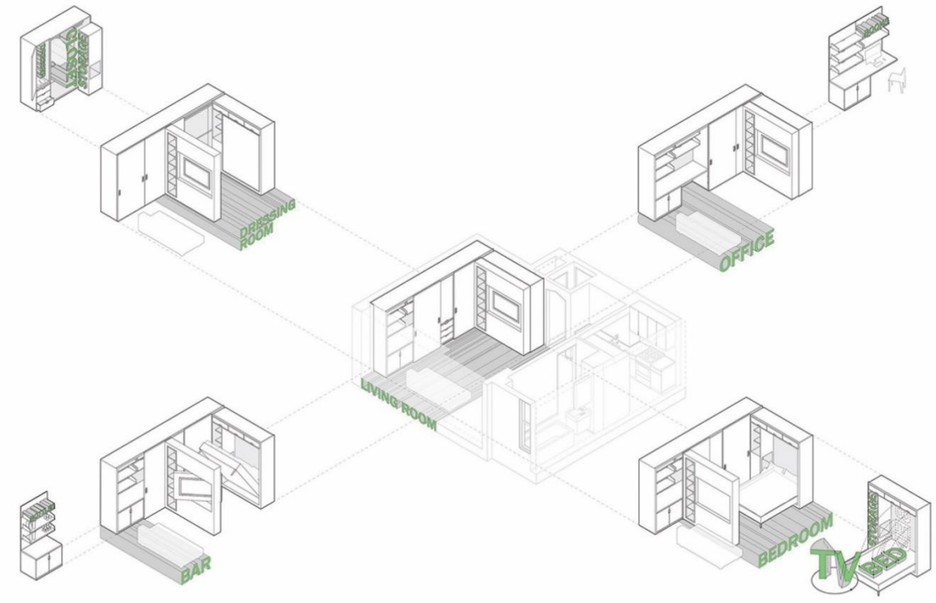
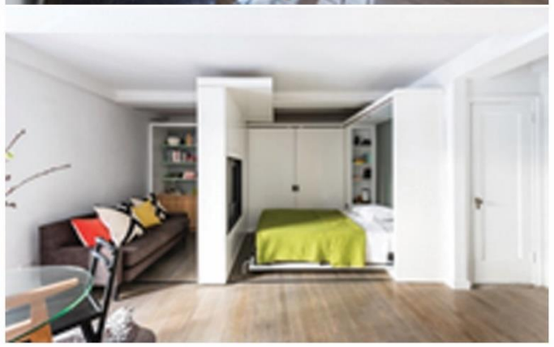
Name of the home	Five to one home
Location	Gramercy Park, a private park in Manhattan, New York City, USA.
Family members	Two person
Home size	390 sf
Home designer	MKCA, Michael K Chen Architecture
Plans of the home	
Photos of the home	   

Photo credit: (MKCA,2016)

Table 7: Analyze 5:1 home according to the smart home criteria

Smart home criteria	Five to one home
Smart furniture	- The design uses storage units for clothes and dresser drawers built-in, and the design uses a fold-down bed.
Smart space - Storage unit - Optimal use of space	- By moving the flexible wall, it reveals built-in storage for clothing in addition to space for a dressing room and space for a fold-down bed. The flexible wall includes a storage and a television that can rotate 180 degrees to view it from the living room and the bedroom. - The smart space includes a home office and library at the opposite end of the room.
Flexibility - Flexibility in a space - Flexibility in a furniture	- The storage element simply moves from the end of the room to the middle to provide another function in the space which is a bedroom and dresser room.
Sustainability - Sustainability in a space - Sustainability in a furniture	- The design uses powder-coated steel to create the shelving and the open library's rows. Powder coatings, not include any toxic, which means that you can recycle them. (Powder Vision Inc., 2018).
Human comfort - Human movement - Privacy space	- The space design focuses on the ergonomics of the body. Also when the space exchange from the night time to the day time, the design gives privacy to the user. - Provide more space to get the best for human movement. The space provides a functional option for the user, in addition, affordable.
Lighting - Artificial light - Natural light	- Hidden light uses in the design, and a light for reading, but the design has a lack of artificial light in the storage units. LED lighting was added throughout the apartment - Lack of natural light.

Table 8: Graham Hill's home demographic data

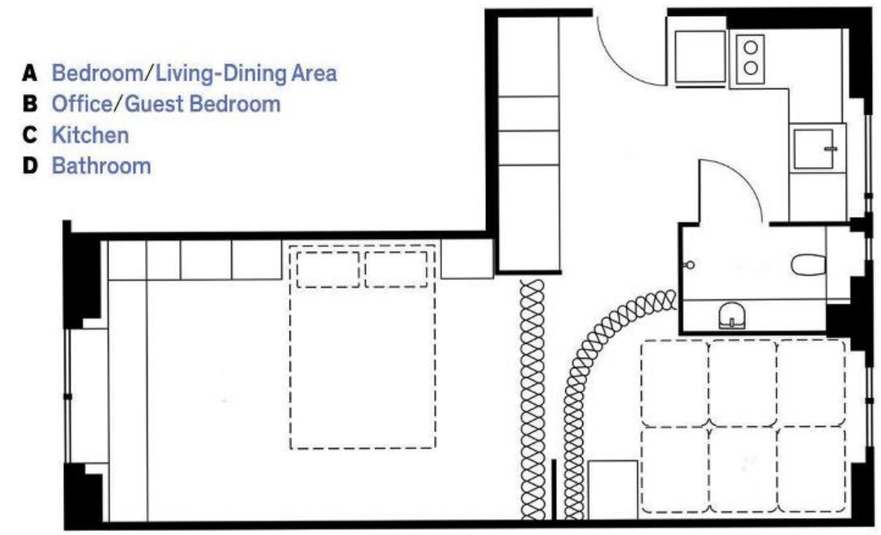
Name of the home	Graham Hill's home/ Life Edited 2
Location	New York
Family members	One person
Home size	Size: 350 square foot. (32.5-square meter)
Home designer	Graham Hill
Plans of the home	
photos of the home	 Photo credit: (Alan Tansey,2018)

Table 9: Analyze Graham Hill's home according to the smart home criteria

Smart home criteria	Graham Hill's home
Smart furniture	- The design uses smart furniture can transfer to different functions, such as: - The small wooden table can extend to be a big table that can use by 10 people as a dining table. - The folded bed transfer the living room to the bed room.
Smart space - Storage unit - Optimal use of space	- The room may also transforms to be a bedroom. - The bed in the design folds down from the wall that has several white storages cabinets, and the cabinet doors open from the two sides to be small tables from the bedside covered with dark wood.
Flexibility - Flexibility in a space - Flexibility in a furniture	- In the living room space, the sofas can be simply moved to be as an L shape to watch the TV or can move to be around the table. - In the second space, space can be a guest room and a home's office, through swing the office down from the wall in addition to storage space in the above of the office.
Sustainability - Sustainability in a space - Sustainability in a furniture	- The design uses walnut cabinets also herringbone oak floor. - In the kitchen, recycled grey stone forms a splashback to complement the white cabinetry. - Lithoverde that looks like a marble material uses in the sink stand may provide energy-saving to the users (Life Edited, 2018).
Human comfort - Human movement - Privacy space	- To take in sound, the material Grey felt panels cover the room wall (LifeEdited, 2018). - The design uses a flexible partition to the guest area which transfers to the office room that aims at making more privacy in the home. - Through the transactions, the design provides more area for better human movement.
Lighting - Artificial light - Natural light	- Brass lighting are used in the design. - As well as the design uses Energy-saving Plumen light bulbs (Graham Hill, 2020). - The design uses a natural via the windows.

Table 10: Fabio Cherman's home demographic data

Name of the home	Fabio Cherman's home
Location	Brasilia, Brazil, Studio Brasilia
Family members	One person and one guest
Home size	290 Square feet (27 square meters)
Home designer	Fabio Cherman
Plans of the home	
Photos of the home	 Photo credit: (Fabio Cherman, 2016)

Table 11: Analyze Fabio Cherman’s home according to the smart home criteria

Smart home criteria	Fabio Cherman’s home
Smart furniture	- The design uses a sofa and folding bed into one compact piece, Italian-fabricated. - In the night times, the folding bed interferes with the sofa.
Smart space - Storage unit - Optimal use of space	- The dining table and the chairs can be stored in the cabinets when it is not in use. - The wall panel can folds down to be a table.in addition, it can be a guest bed. - The rectangular shelf work as a support to the folding bed in the night times.
Flexibility - Flexibility in a space - Flexibility in a furniture	- Instead of the move from room to another, the design provides the user's needs in one space can be simple without high effort transfer to different functions. - The flexible furniture can simply use from the user as two functions or more.
Sustainability - Sustainability in a space - Sustainability in a furniture	- The design covered the walls with timber. - The chair is designed from wood.
Human comfort - Human movement - Privacy space	- The design has a lack of privacy, the user’s room and the guest room are in the same space without any partition. - The storage units provide more space for human movement.
Lighting - Artificial light - Natural light	- The light that used make the space more comfortable for the eyes. In addition, the light creates various scenes depend on the style that it's used.

Table 12: Petite home Packs Pivot Power demographic data

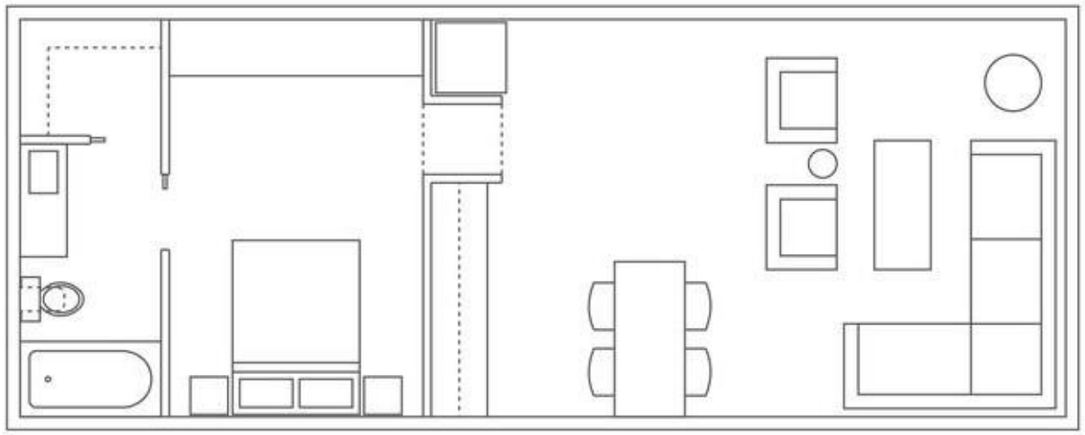
Name of the home	Petite home Packs Pivot Power
Location	New York City
Family members	One person
Home size	400 square feet (37.1 square meter)
Home designer	Robert Garneau
Photos of the home	    Photo credit: (Robert Garneau, 2016)

Table 13: Analyze Petite home Packs Pivot Power according to the smart home criteria

Smart home criteria	Petite home Packs Pivot Power
Smart furniture	- The design uses a folding bed, it folds from the wall. - Storage as cabinets next to the bed and in the flexible wall. - The table can use as a dining table for ten people, it comes down when it not in use.
Smart space - Storage unit - Optimal use of space	- the smart space is in the day times provides an open space enough for a dining table with seating for ten-person and living room, in the night times the flexible wall open and provides a bedroom with folding bed and storage cabinets.
Flexibility - Flexibility in a space - Flexibility in a furniture	- The flexibility in the furniture consists of a folding bed and the dining table that can come down, which can open in a simple way.
Sustainability - Sustainability in a space - Sustainability in a furniture	- To keep the air less toxic the design uses the sustainability as a blond wood throughout the home.
Human comfort - Human movement - Privacy in space	- The space appears comfortable and airy because the whole walls colored with a whit color as well as the blonde wood that uses in the home. - The design provide open space and privacy for the bedroom through the flexible wall.
Lighting - Artificial light - Natural light	- The artificial light in the design uses in spotlight, artificial light are not use well in the corners as well as near to the cabinets. - Natural light uses well while the wall is close when the wall is open the bedroom has no natural light.

Table 14: Yolanda's House demographic data

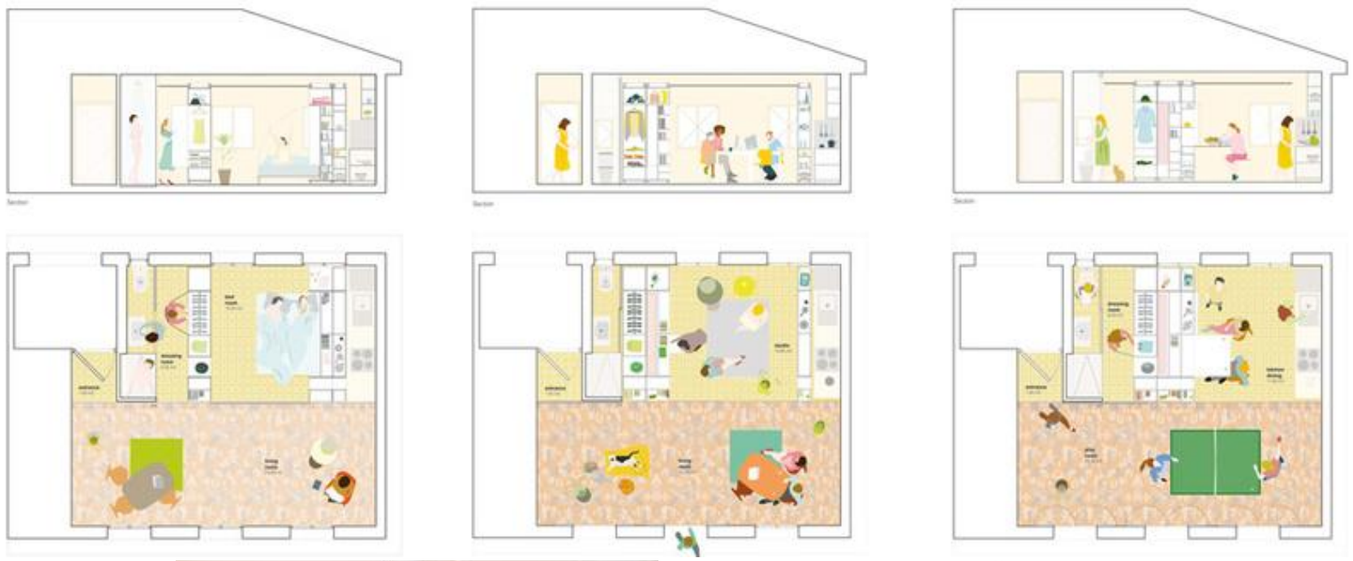
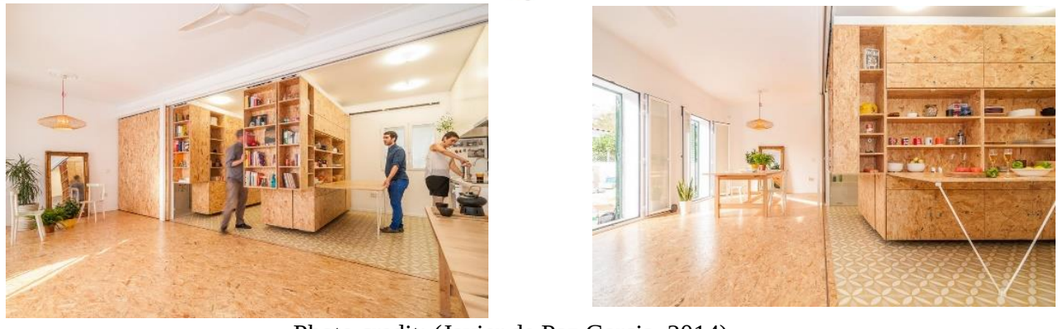
Name of the home	Yolanda's Home
Location	Spain – Madrid
Family members	Two person
Home size	500 square feet (46.4 square meter)
Home designer	Robert Garneau
Plans of the home	
Photos of the home	 Photo credit: (Javier de Paz Garcia, 2014)

Table 15: Analyze Yolanda's home according to the smart home criteria

Smart home criteria	Yolanda's Home
Smart furniture	- The design of the units includes a folding bed, Bookshelves and storage. In addition to the cabinets.
Smart space - Storage unit - Optimal use of space	- The space suit all the user's needs in a limited size, through three wooden units that can flexibility move to make space a multifunctional space. The users can arrange the space depending on their requirements. The first unit includes the kitchen and the studio. The second unit includes smart furniture as a folding bed in the bedroom and on the other side include the library. The third unit includes a dresser room and a bathroom.
Flexibility - Flexibility in a space - Flexibility in a furniture	- Each unit weighs between 500 and 800 kg when completely filled, but the use of industrial and flexible rails can easily be moved with one hand. - One of the units has a folding bed, the flexible wall makes privacy for the bedroom.
Sustainability - Sustainability in a space - Sustainability in a furniture	- The main material of the unit is the wood.
Human comfort - Human movement - Privacy in space	- The units are modified to all the human's at home. As well as the units may move to provide more space for different functions that aims to feel more comfortable. People have special relationships with their personal things, so, the home design based on the privacy of residents.
Lighting - Artificial light - Natural light	- The artificial light uses in white color throughout the home. - Natural light uses in the design through windows.

Table 16: YO! Home demographic data

Name of the home	YO! Home
Location	England
Family members	Two Person
Home size	430 square feet (40 square meters)
Home designer	Glenn Howells Architects
Photos of the home	  Photo credit: (Jessica Mairs, 2016)

Table 17: Analyze YO! Home according to the smart home criteria

Smart home criteria	YO! Home
Smart furniture	- A bed lowered over the seating area from the ceiling. - A dining table that folds up from the floor and Storage units inside the floor and the wall.
Smart space - Storage unit - Optimal use of space	- The smart use of the floor as storage units to use the most of the space. - The use as a living room in the morning and as a bedroom in the evening through the bed that can be tucked in the ceiling when it is not in use. - Space transferred morning to living room, also to kitchen and dining area, the dining table comes from down when the user wants to use it.
Flexibility - Flexibility in a space - Flexibility in a furniture	- Simply, transfer the room's function through being drawn down the bed over the seating space. - The storage needs not so effort to open it from the floor. - Flexible use to open the kitchen space through cabinet doors.
Sustainability - Sustainability in a space - Sustainability in a furniture	- As the main important material the design uses the cross-laminated timber.
Human comfort - Human movement - Privacy in space	- Smart furniture provides more area by come down to the floor as well as hung up in the ceiling, which affect the human movement possibly. - The design has a lack of privacy, not use a partition to separate the spaces.
Lighting - Artificial light - Natural light	- The design uses a spots in the celling as well as wall's storage units. - The design uses the natural light through the bog glazed windows.

Table 18: Anton-Medvedev's home demographic data

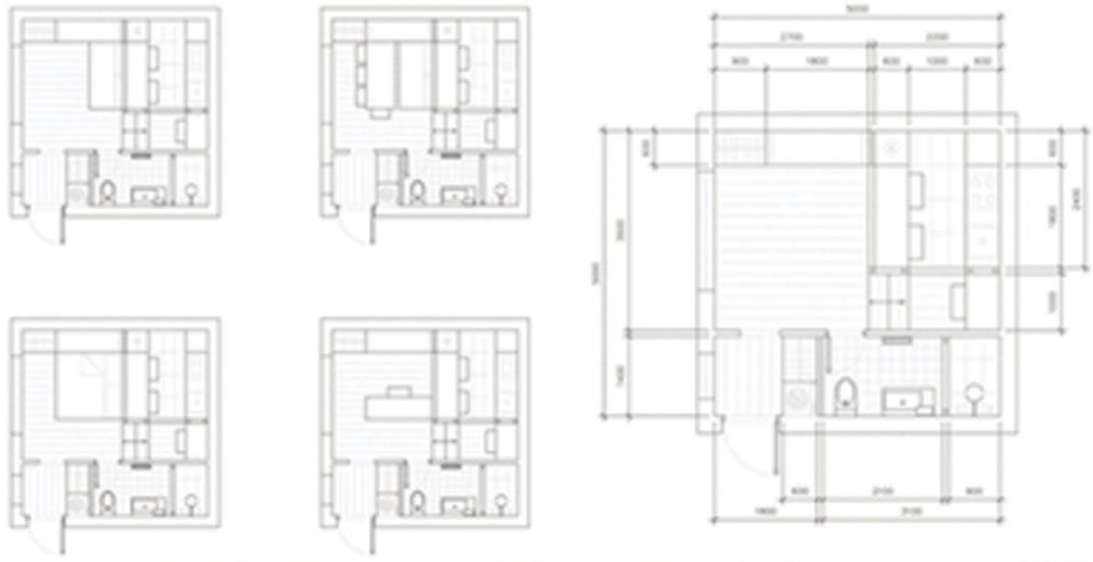
Name of the home	Anton-Medvedev's home
Location	Kyiv, Ukraine
Family members	two Person
Home size	269 square feet (25 square meter)
Home designer	Anton Medvedev
Plans of the home **Photos of the home**	  Photo credit: (livinginashoebox,2016)

Table 19: Analyze Anton-Medvedev's home according to the smart home criteria

Smart home criteria	Anton-Medvedev's home
Smart furniture	- The design uses a dining table that can transform into a desk. - The sofa transforms into a bed when it’s pulled out.
Smart space - Storage unit - Optimal use of space	- The cabinet of the kitchen is so tall that can save more space as storage units. - The entrance of the wardrobe has a laundry, dryer, and washing machine, as space-saving storage.
Flexibility - Flexibility in a space - Flexibility in a furniture	- The bed can be stored easily in a drawer under the kitchen because the smart design of the home raised the kitchen on a platform. - The dining table that transforms into a desk, simply stored into shelving storage.
Sustainability - Sustainability in a space - Sustainability in a furniture	- On the floor the designer used low-toxic wood.
Human comfort - Human movement - Privacy in space	- To get a sense of privacy the kitchen can be separated from the living and bedroom by a roll-down curtain.
Lighting - Artificial light - Natural light	- The artificial light used in the whole space even in the storage spaces. - The home has big windows to enter light to the whole space.

Table 20: Attic transformer home demographic data

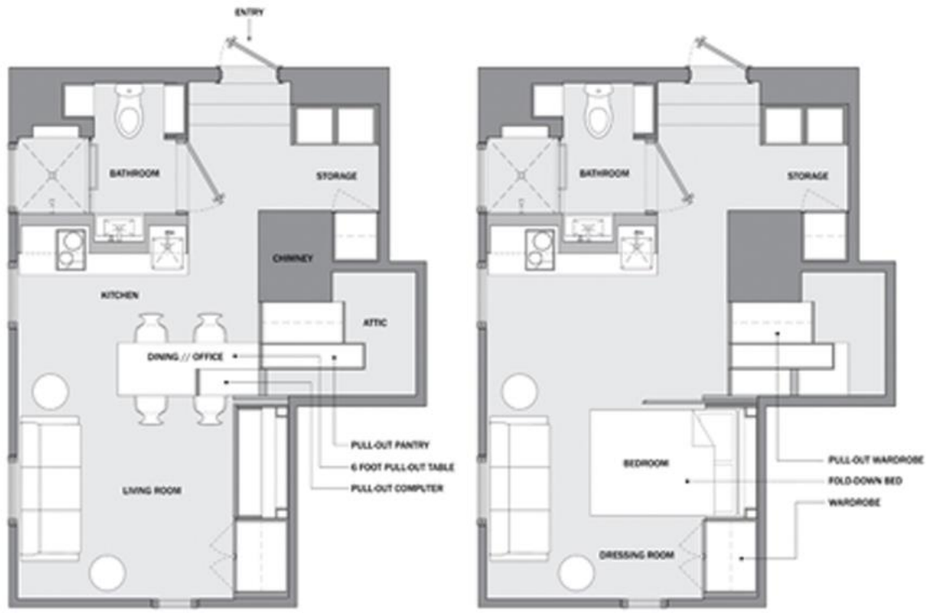
Name of the home	Attic transformer home
Location	New York, NY, United States
Family members	Two person
Home size	225 square feet (20.9 meters).
Home designer	MKCA, Michael K Chen Architecture
Photos of the home	    Photo credit: (MCKA,2014)

Table 21: Analyze Attic transformer home according to the smart home criteria

Smart home criteria	Anton-Medvedev's home
Smart furniture	- The design uses a pull-out dining table that can be a home office. - The design uses a fold-down bed.
Smart space - Storage unit - Optimal use of space	- Space was subdivided with a custom fabricated transforming elements that include several issues as; hanging clothing storage, and pantry storage, with a pull-out dining table that can be paired with a pull-out workstation which works as converting the table into a home office that includes the desktop computer and storage below.
Flexibility - Flexibility in a space - Flexibility in a furniture	- The centerpiece that is in the main living space is a six-foot-long, it includes the dining table that can be transformed into a home office in a flexible and easy way.
Sustainability - Sustainability in a space - Sustainability in a furniture	- Several non-toxic materials are used such as white oak flooring, and charcoal Corian these materials are being offset by the rose high gloss lacquer and mohair in the bedroom area, which creates a subdued with a dynamic environment that conducive to a dynamic space, such as in dining, kitchen, working areas.
Human comfort - Human movement - Privacy in space	- The design uses a thermal with a waterproof system in the roof and also the exterior facades.
Lighting - Artificial light - Natural light	- The artificial light used as a spots in the whole home. - The home has a natural light that enter from the three windows.

Table 22: Petite Penthouse demographic data

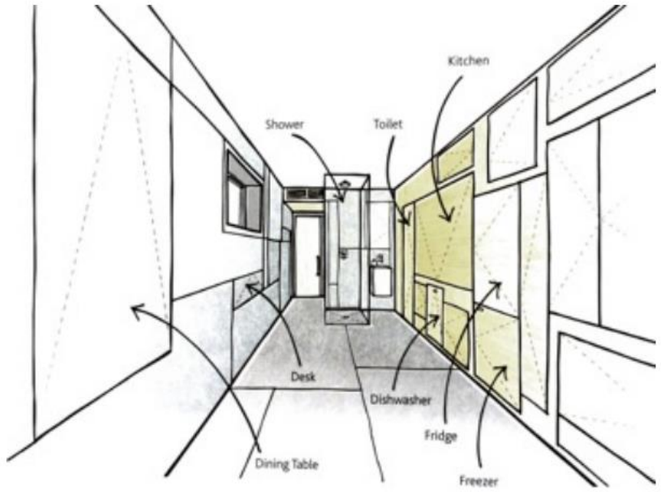
Name of the home	Petite Penthouse
Location	Barcelona, Spain
Family members	Two person
Home size	258 square feet (24 meters).
Home designer	Sources: Luke Riggall, 2014, P 42, 43
Plans of the home	
Photos of the home	
	Photo credit: Luke Riggall, 2014, P 42, 43

Table 23: analyze Petite Penthouse home according to the smart home criteria

Smart home criteria	Petite Penthouse
Smart furniture	- Two long walls of fold-out furniture - Fold-out desk. - The double bed which pulls out under the terrace.
Smart space - Storage unit - Optimal use of space	- In a hidden and foldable furniture, storage, and functions that can maximize the space. - It is a highly multitasking area with combining several uses in a single room includes different uses such as; sleeping, living, kitchen, and cooking, with a working, and entertainment area with a bath area.
Flexibility - Flexibility in a space - Flexibility in a furniture	- The flexibility uses in the foldable furniture inside the two walls, ease of use.
Sustainability - Sustainability in a space - Sustainability in a furniture	- A wide range of a soft and natural materials that can increase the feeling of relaxing.
Human comfort - Human movement - Privacy in space	- Space has defined as a foldable element that can serve the users at the same time with the capacity to move in the space. - Space has a lack of privacy but it gives the user a sense of control with the folding elements.
Lighting - Artificial light - Natural light	- The artificial light uses as spots, on the other hand, the natural light enters the space from the glass door.

According to the analysis of the examples, the researcher gives the findings. Besides, the purposes and objectives of the research were to satisfy human needs, and developed performance, easily use, and space-saving elements through flexibility, sustainability, and a better organization of the small spaces, in addition, focus on human comfort. That offers a possibilities to change the form as well as size of the space.

To begin with, the first example provide the smart solution for 39 square feet as smart furniture for instance, it contains furniture with multiple function, foldable furniture, and extended furniture. With using sustainable materials from the Resource furniture company. In addition to using a Dimmable LED lighting.

Secondly, the home shows the use of smart space by giving the ability to use the limited space for various activities and changing the room function according to the user's need in that moment in a flexible way without a big effort, therefore it provides a sense of privacy through the flexible wall and comfort in human movement

On the other hand, the second selected example in five to one home, the designer shows the use of smart home criteria through the foldable furniture that leads to an increase in the use of the space by a flexible wall which creates a bedroom and built-in storage, however, when it is moved to the middle of the space, with the flexible wall that provide more pace to a better human movement. In addition to that, the design uses LED lighting

The third example provides the use of smart furniture as foldable furniture, extend furniture and make a smart space through the best use of the area with transformed rooms, with a simple changing from function to another one.

The designer focuses on sustainability through using the non-toxic material and recycled material on the floor and in the kitchen. However, as according to the designer of the home through Email, the designer said that he use energy-saving Plumen light bulbs in the design.

On the other hand, the design of Fabio Cherman's home illustrates the best use of the space through another aspect of hiding the elements that is not in use to provide more space, and therefore to change the atmosphere of the area based on the user's activities and needs, however, because of the use of flexibility in the home design the transfer into a different function without any big effort. The wood material has been used in the design with changes of the light style that provides various senses to the user.

The fifth example provides various activities in 37.1 square meters through using a folding, extend furniture and storage units as well as using the area as a smart space by using a flexible wall which can create a bedroom with a storage cabinet. But, the user of this new function faces a problem in the natural light because the flexible wall hide it.

The design of Yolanda's House uses three wooden units that includes smart furniture and storage units which is to achieve human needs in a limited space, which can make the area a smart space with a flexible move and give the users the capacity to re-arrange the space based on their needs. It also provide a flexible wall that can give the users a sense of privacy. The space uses artificial light throughout the home and natural light through a big glass window.

In the seventh example, the design illustrates a bed that lowers from the ceiling over a sitting area which provides more space and lead to comfort in human movement.it also

provides the smart space that includes storage units into the floor, the space provide a specific function that has the ability to change in day and night without any effort from the user, the design has a flexible function which explains the reason behind the main material that is used in the design which is the cross-laminated timber.

The ten example shows the use of smart home's criteria through smart furniture such as the transformer dining table that changes to a desk and can be stored easily as it is flexible in the design, moreover, the transformer sofa changes to be a bed, the design uses the space through space-saving storage it also provides good use of the lighting through the natural light and using artificial lighting in the storage units.

The ninth example provides a space for two-person in 20.9 meters through the smart furniture such as a pull-out dining table and fold-down bed through a smart space by subdivided and transforming elements and the centrepiece, it also includes a storage units and a transformer table. The design uses a various sustainable material that gives a comfortable environment to the user. It also has a thermal and waterproof system that is used in the design of the Attic transformer home, as well as the design utilize the artificial and natural light in the whole area.

Lastly, the final example provides a space for two-person in 24 meters in a highly effective design. It’s a smart space collecting several functions into a limited space including a living space, sleeping space, kitchen, and working space.it also uses an artificial and a natural light throughout the home. However, the smart space hide the elements into two long walls that is made in a flexible way with natural materials. The home provides all these functions without affecting human movement through the use of foldable elements.

While, in the research questions, it focusses on satisfying user’s needs in a small area through the concept of a smart home, the efficiently of flexibility, sustainability, as well as human comfort. The researcher has thus employed a table that shows the best use of the smart home's criteria in the selected ten examples, to choose the best use as an improvement of the criteria.

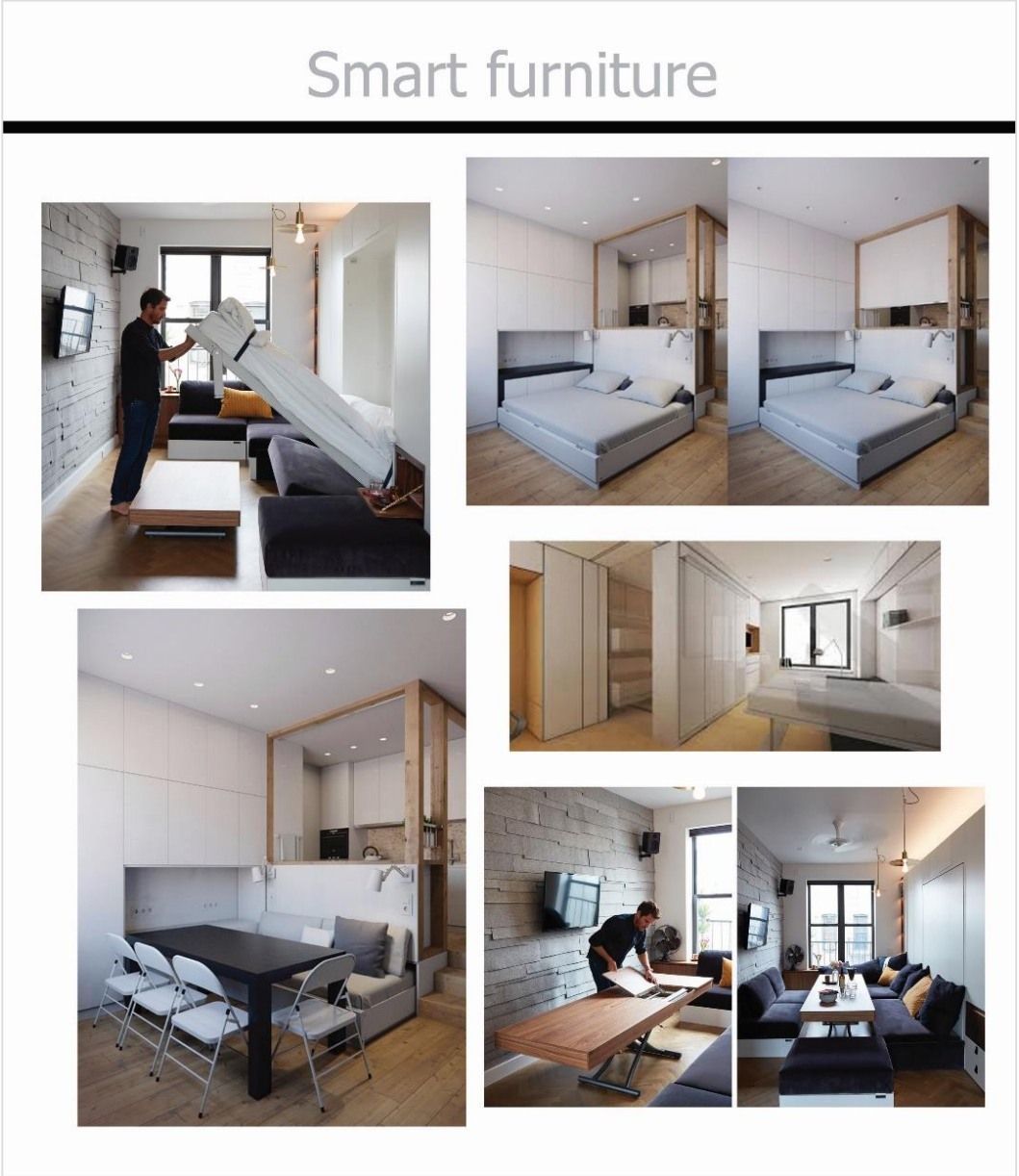
The table on the next page provides the best use of smart home criteria is colour with red, the middle use of smart home criteria is colour with black, and finally, the lowest use of smart home criteria, is colour with grey.

And, the following sections will propose one by one the improvement of smart home criteria inspired by the selected ten examples of homes includes the smart home criteria, to reach user’s needs in a small space through the concept of a smart home.

Table 23: Comparative analysis between the selected ten examples (created by the author).

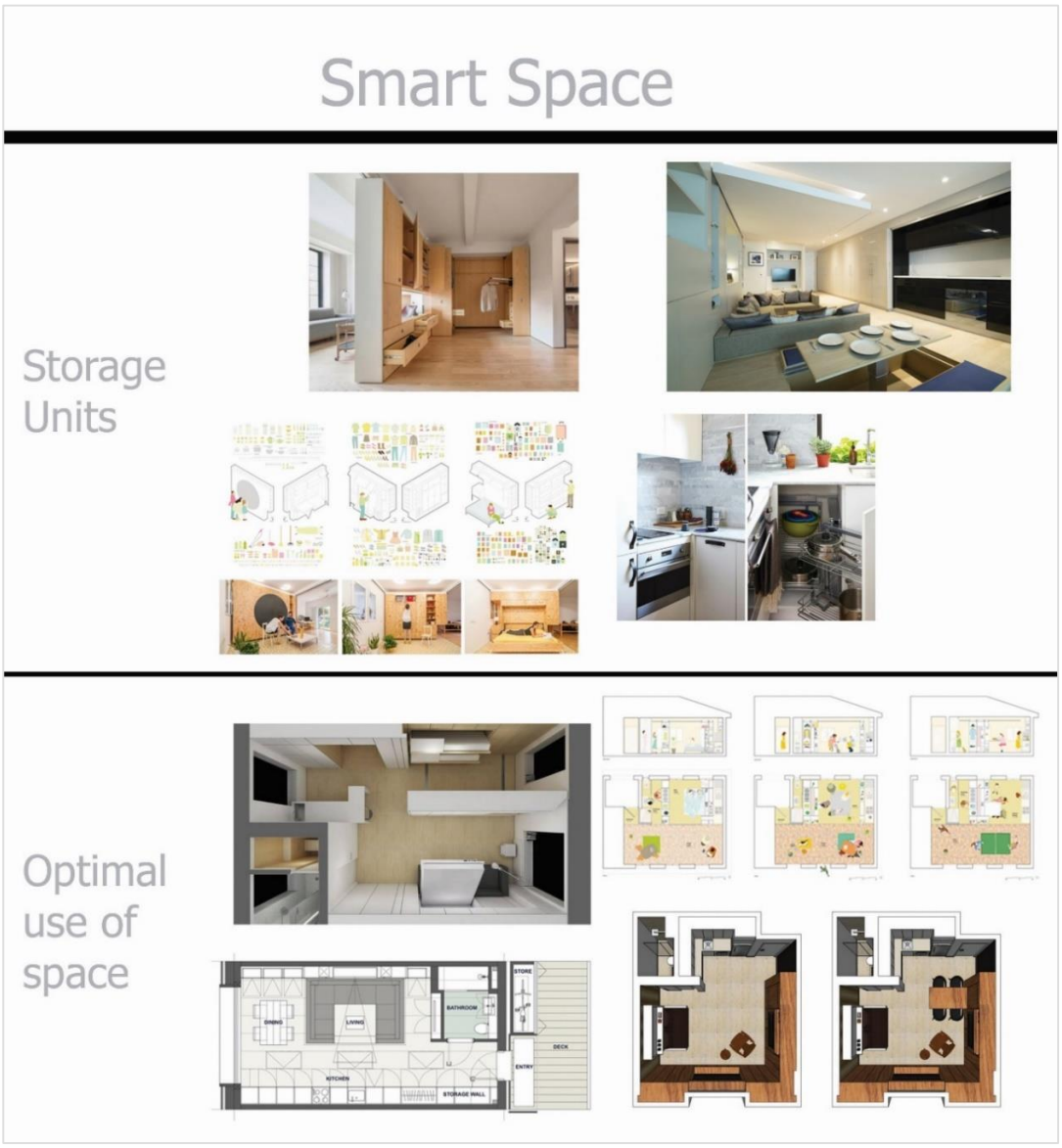
Criteria	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Example 9	Example 10
Smart furniture	●	●	●	●	●	●	●	●	●	●
Smart space										
Storage unit	●	●	●	●	●	●	●	●	●	●
Optimal use of space	●	●	●	●	●	●	●	●		
Flexibility										
Flexibility in a space	●	●	●	●	●	●	●	●	●	●
Flexibility in a furniture	●	●	●	●	●	●	●	●	●	●
Sustainability										
Sustainability in a space	●	●	●	●	●	●	●	●	●	●
Sustainability in a furniture	●	●	●	●	●	●	●	●	●	●
Human comfort										
Human movement	●	●	●	●	●	●	●	●	●	●
Privacy in space	●	●	●	●	●	●	●	●	●	●
Lighting										
Artificial light	●	●	●	●	●	●	●	●	●	●
Natural light	●	●	●	●	●	●	●	●	●	●

1. Smart Furniture



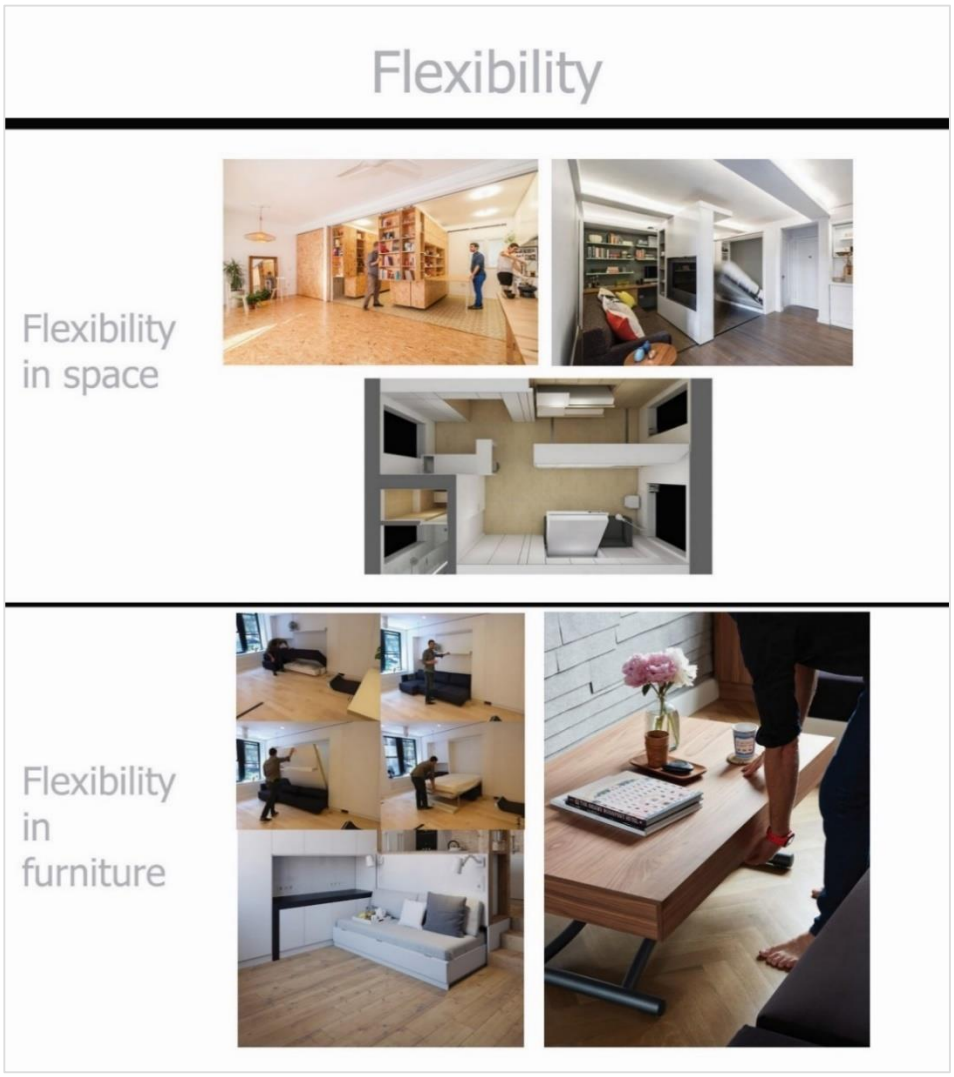
The best use of smart furniture in the selected examples led to satisfying user's needs through multifunction use, as shown in the photos the sofa can be used as a bed when lowered the bed over the sofa in one step. Also, through expanding, as a small table can be a dining table for ten people, as well as through disappear in the wall or a cabinet.

2. Smart Space



The best use of smart space in the selected examples led to satisfying user's needs through the optimal use of space as changing the function of the space as shown in the photos the same space can be a living room, bedroom, dining room. Also, providing space for the user's equipment as the best use of storage units.

3. Flexibility

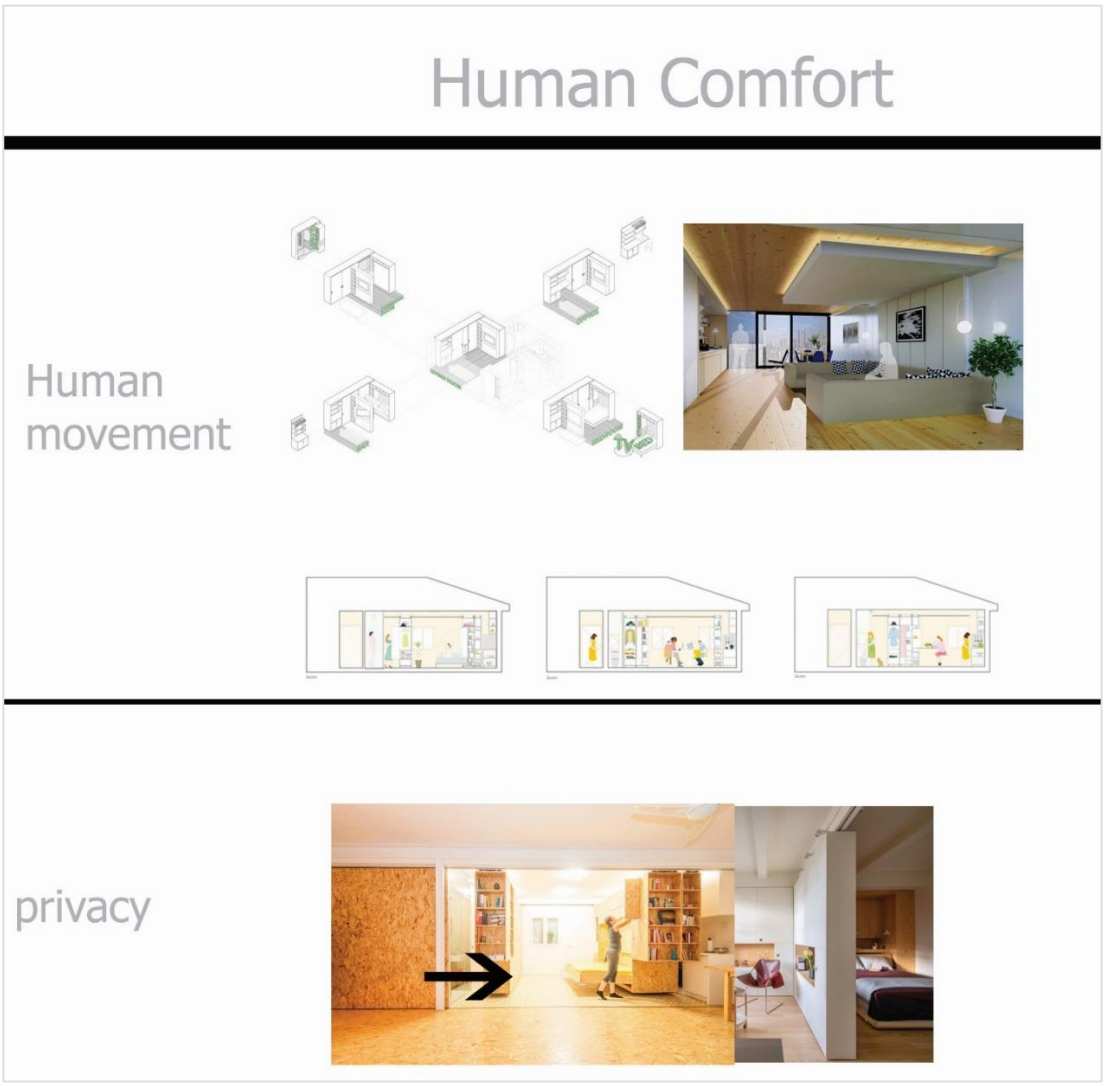


The best use of flexibility in the smart home as shown in the selected examples, it changing the space through a flexible wall that can move by the user without hard effort, it makes the space as an open space or separates the space, to serve a different activity. The flexibility in the furniture makes a small table serve ten people in one easy move from the user without damage the table, also in the sofa-bed furniture and the dining table inside the cabinet.

4. Sustainability

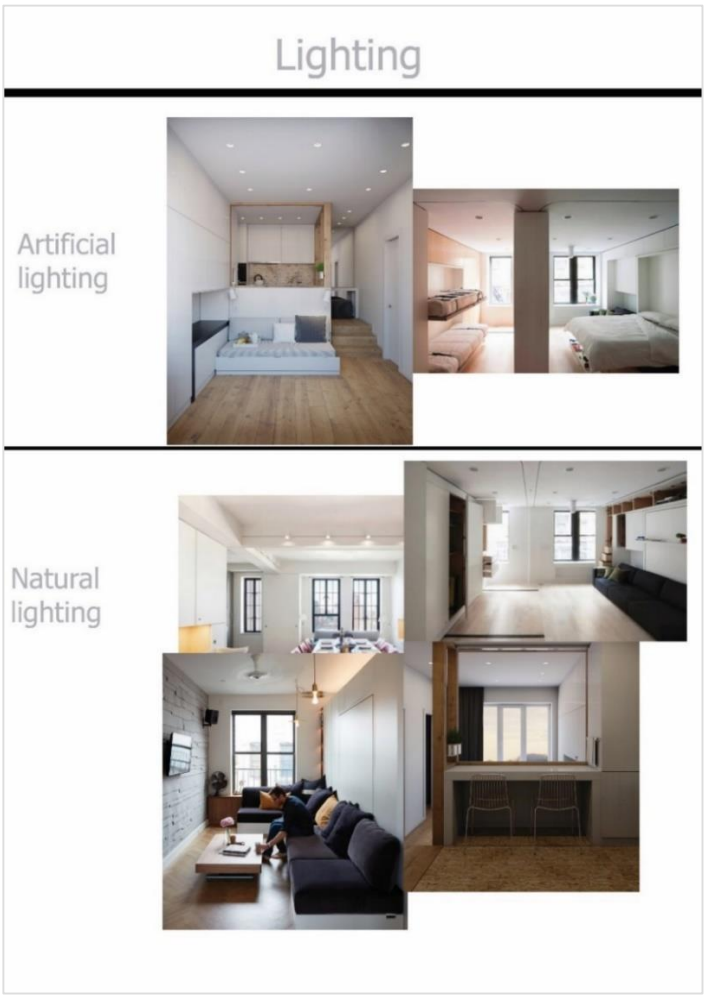
The optimal use of sustainability shown by these selected examples. the use of walnut cabinetry and herringbone oak flooring, the recycled grey stone, energy-saving fans, marble-like material called Lithoverde (recycled stone), and the use of the wood in the floor and the furniture.

5. Human Comfort



The best use of human comfort as a criterion of a smart home is shown in these selected examples. The design permit the user to move within the interior space with no risk, also it provides the air movement via the change in the interior space that gives a sense of privacy. As well as the best choice of the material produces good quality indoor air.

6. Lighting



The artificial light used in the selected examples to reach a comfortable and safe environment for the users, as spots in the whole space, and the space that user's used to doing risking tasks as the kitchen. In addition to using energy-saving Plumen light bulbs. The natural light used as possible as can in the selected examples, in some cases the natural light cannot use due to the place of the building, instead, the smart design finds a smart solution as the best use of the artificial light.

As a result, the smart home organization improves the life quality, and provides a comfortable space for users as well as look good, practical living space. A smart residential home is organized of space with smart furniture that has properly shape and dimension for human comfort.

Also, Provide area in small r spaces that affected by the new lifestyle. As well as, it is sustainable interior environment.

Smart home floor plans are optimized to make the most of the space, with multi-purpose rooms and smart home is eco-friendly to preserve environmental resources.

The criteria of the smart home based on literature review and the selected examples are:
Smart furniture: smart furniture is one of the smart home criteria, it aimed to satisfy user's needs in small spaces through use the piece of the furniture as one or two functions in order to provide comfortable space. In addition, smart furniture provides space for different activities when it disappears completely in a wall, floor, cabinet...etc.

Smart space: smart space is one of the smart home's criteria, it provides a wide range of activities and services into a small space by making the efficient use of the space. the user's needs in the day times different than the night time, smart space provide the user's needs in both situations in the same space, through change the space function as an optimal use of the space. In addition, it suits the user's equipment through the storage units that can be on the floor, wall...etc.

Flexibility in smart home: flexibility is one of the smart home’s criteria, it seeks to reach the changing needs of the users through change the space organization based on the user's

needs without any change in the home structure. In addition, the usability of smart furniture through flexibility, by changing the function without hard effort, and the ease of return at the time of need and does not lose any of its functional characteristics or formality.

Sustainability in smart home: sustainability is one of the smart home's criteria, it influences both the internal environment and the human (user), to achieve user satisfaction and comfort, through maximizes the potential of nature in the space and the furniture, as well as reduce the cost of materials by reuse it.

Human Comfort in smart home: one of the smart home's criteria, it makes the space safe and healthy by making the best design to avoid the accident or bad air quality that affects the user's health, and provide the sense of privacy. Also, it creates the best design that provides air movement to increase human comfort. In addition, enough space for human movement, and the furniture suits the body dimension.

Lighting: lighting is one of the smart home's criteria, it aimed to provide a safety as well as comfortable environment to the user specially in the places that need to do tasks as in the kitchen, the best lighting is not so high and not so dark that gives the user the capacity to do the various activities, by ensuring safe and effective light. The designs in a smart home used natural light as possible as can.

The created framework below is to evaluate a smart home, which is a benefit for future researchers and designers who want to study or design the smart home.

1. Smart Furniture

2. Smart Space
    - Storage Units
    - Optimal use of space
3. Flexibility
    - Flexibility in a space
    - Flexibility in a furniture
4. Sustainability
    - Sustainability in a space
    - Sustainability in a furniture
5. Human comfort
    - Human movement
    - Privacy in space
6. Lighting
    - Artificial light
    - Natural light

6.4 Chapter conclusion

In this chapter several issues has been discussed, it discussed the approach of collecting data to develop the criteria of a smart home as in ways to improve the concept of the smart home with different aspects and ideas that the designers has used with different materials with different ways to provide comfort and special features to the users and their homes.

However, this chapter provided ten different selected examples that include various aspects of the smart home's criteria then an evaluation of these selected examples were made and illustrated in two different tables, the first one has a demographic data while

the second table has an evaluation of the examples according to the smart home's criteria that were discussed earlier in the chapter.

After the evaluation of these selected examples, the chapter provided the results of the examples one by one, then a table was made to provide the best used criteria in smart home. Finally, the chapter illustrated the improvement of the smart home's criteria that can create a better and more comfortable environment to the users, to make it more attractive to satisfy their desires, these improvements are made based on the evaluation of the ten selected examples as well as the literature review.

Chapter 7

CONCLUSION

7.1 Summary of the study

This chapter will provide a conclusion of the study. In addition, a summary of the literature review also provide a result of the study includes the research questions, that were illustrated through the previously studied and analysing the selected examples. Finally, the chapter will provide the importance of the study in future small housing models.

The traditional home's design has been changed with the change in lifestyle, an increase of the number of single households, also couples without children is increasing. However, the minimum space must be used to provide home. The traditional design of the small homes faces a difficulties in terms of user's comfort and needs, also user's equipment, because of the lack of space.

The aim of the study is to frame the concept of the smart home by improving the smart home's criteria to satisfy the user's needs and provide safety, healthy, and comfortable environment. The criteria of smart home based on the literature review include the smart furniture that can provide two functions or more in the same piece of the furniture, smart furniture more effective than the traditional design of the furniture.

The traditional design of the furniture affect human comfort in the small spaces because of its limited creativity and often cloning with one function. On the other hand, the use of smart furniture criteria of the smart home increases user satisfying at his own place through changing the function in a creative way based on the user's needs at that moment.

The multifunction of furniture loses the aesthetically because it distracts attention and stores away detail, but with the term of smart furniture, the pieces of furniture save their functional values as well as artistic form.

Also, the smart space that makes the optimal use of space gives the user the capacity to change the shape and function of the space-based on his needs. The formal layout of the space is gone in the smart home, the traditional design of the interior design of the small homes is not enough to provide the user's need.

However, create the right atmosphere through the optimal use of the space, and fitting a wide arrange of activities in one small space to satisfy user's comfort and need, is the thing the smart space aimed.

In addition, many problems in the small housing can solved by flexibility in the space and also in the furniture through provides various possibilities to change the interior space without any change in the home's structure. The flexibility of space seeks to fulfil the changing needs of the users by organizing space according to the requirements of the users.

As well as the lighting which is the more element that affects the atmosphere in which we feel in the place, traditional design in the small spaces ignore the importance of

lighting, and spend effort in other design elements at home, consequently, it's poorly lit, and affects the human needs at home.

7.2 Summary of the study finding

The function of the Smart home is developing the life quality and provide a comfortable environment for users that an important role in future homes models. Provide area in small homes that affected by new lifestyle.

The result provide the improved smart home's criteria and frames the concept of the smart home through improved the previously studied and the author's opinions of the solutions of small housing to reach the user's needs and provide a safe, healthy and comfortable environment.

In addition, the study analysed ten examples based on " case study research" then the researcher choose the best use of smart home's criteria in each selected examples in order to improve the smart home that satisfies human needs in small spaces.

The section below answers the key research question based on the study results.

The approach of satisfying user’s needs in a small space through the concept of a smart home?

The organization of smart home provides the user’s everyday activities in small spaces by the optimal use of space by change the shape and the function of the space through flexibility. And creative storage units. Also, the smart home uses a sustainability material in the space and the furniture that has less toxic to preserve the user’s health and the quality of the indoor air.

In addition, the smart home provides human comfort through design the space to suit the human body and avoid the accidents. Finally, the smart home focuses on the lighting in its design to provide a comfortable environment to the users.

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