REPUBLIC OF TÜRKİYE

ALTINBAŞ UNIVERSITY

Institute of Graduate Studies

Architecture

FUNCTIONAL SPACES IN SMALL HOUSESCHARACTERISTICS OF INTERCAVE MULTIFUNCTIONAL SPACES IN RESIDENTIAL BUILDINGS

Razan ALHUSAINI

Master's Thesis

Supervisor

Asst. Prof. Dr. Can UZUN

İstanbul, 2024

FUNCTIONAL SPACES IN SMALL HOUSES: CHARACTERISTICS OF INTERCAVE MULTIFUNCTIONAL SPACES IN RESIDENTIAL BUILDINGS

Razan ALHUSAINI

Architecture

Master’s Thesis

ALTINBAŞ UNIVERSITY

2024

The thesis titled FUNCTIONAL SPACES IN SMALL HOUSES: CHARACTERISTICS OF INTERCAVE MULTIFUNCTIONAL SPACES IN RESIDENTIAL BUILDINGS prepared RAZAN ALHUSAINI and submitted on 04/04/2024 has been **accepted unanimously** for the degree of Master of Science in Architecture.

Asst. Prof. Dr. Can UZUN
Supervisor

Thesis Defense Committee Members:

Asst. Prof. Dr. Can UZUN	Department of Architecture, Altınbaş University	_____
Asst. Prof. Dr. Ayşe Esra İDEMEN	Department of Architecture, Altınbaş University	_____
Asst. Prof. Dr. Erhan KARAKOÇ	Department of Interior Architecture and Environmental Design, Ankara Medipol University	_____

I hereby declare that this thesis meets all format and submission requirements for a Master's Thesis.

I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Razan ALHUSAINI

Signature

DEDICATION

I would like to dedicate my thesis to the souls of my mother and father whose spirits never left me.

To my dear husband “Mohammad Qadrieh” who helped and supported me through every step of the thesis.

To my beloved son Ward, whom I got to know I was pregnant with him, the same day I got the confirmation to do my thesis.

To my family who were there for me through good and bad Rula, Anas, Khaled, Rawan, Malak, Diana, Baraa, and All my brothers’ and sisters’ children and my sisters’ husbands (Hussain and Dr. Tamim.)

To my second mom “Basima Qadrieh” and my uncle” Waleed Qadrieh” who always stood beside me.

To all my brothers and sisters Muhanad, Majd and Mais, Fardos.

And finally, to the friend who never left my side since the day we met, Fatma.

To everyone who was by my side at all times and everyone who helped me and wished me well.

Thank you all.

PREFACE

It is with great pleasure and honor to extend my gratitude and thanks to my Dr. CAN UZUN, for guiding me throughout the thesis process. Thank you for your continuous support and your knowledge you shared with me.

I am proud to be a student at Altinbaş University which was the perfect place for me to positively evolve as an architecture student. It was a great experience where I met amazing professors and colleagues and got to learn from every person I met.

ABSTRACT

FUNCTIONAL SPACES IN SMALL HOUSES: CHARACTERISTICS OF INTERCAVE MULTIFUNCTIONAL SPACES IN RESIDENTIAL BUILDINGS

ALHUSAINI, Razan

M.Sc., Architecture Department, Altınbaş University,

Supervisor: Asst. Prof. Dr. Can UZUN

Date: April / 2024

Pages: 103

Responding to changes is the biggest challenge at the present time. The world has changed over time due to factors like environmental shifts, technological advancements, financially shifts, etc., which have caused changes in human needs and requirements as well. As a result, social and physical spaces have had to alter in order to create an environment that is both acceptable and comfortable for users. Residential spaces are comprehensive for all human needs, which began to respond to the change in the increasing population growth and urban development of cities through what are called small homes. The term small house has become the basic type of spaces adopted in housing, and the functional spaces in the small house have been modified to face these continuous changes to be an "interactive" space, as the research defined the interactive space as the space that is associated with the user and interacts with him by achieving a response to the continuous change in his needs, which is accomplished in three ways: altering the interior space environment and social requirements; altering the space physically or functionally; altering the space technically and technologically; and even adding multipurpose furniture. These responses illustrate the traits of interactive spaces found in compact homes. Three major projects are explored in this study including Project (A): Ciel et Terre Residential Tower / Molestina Architekten, project (B): Via Verde—The Green Way, and Project (C): MVRDV focusing on sustainability, flexibility, economy and environmental benefits as main theme. Findings suggests that MVRDV is more sustainable and flexible than rest of two and will offer a comfortable life

to its dwellers. The primary objective of the research was to determine which attributes are most crucial to have. Small-sized homes can benefit from interactive space to maximize use and provide a cozy atmosphere for their occupants: These spaces need to be able to adapt continuously to changes in the internal environment (sustainable), to changes in the space's functionality and design (flexible), and to changes in the space's advancement of technology (smart).

Keywords: Small House, Interactive Functional Spaces, Sustainable Space, Flexible Space, Smart Space, Multifunctional Furniture.

TABLE OF CONTENTS

Pages

LIST OF TABLES

Pages

LIST OF FIGURES

Pages

LIST OF CHARTS

Pages

1. INTRODUCTION

The functional social spaces that support the entire society are dwelling units, which are described as functional arrangements that accommodate all human activities. Small houses or compact living spaces of various types have become a fundamental style for many residential buildings which have been adopted in big cities. This restriction and reduction in spaces' size resulted from: increasing in population growth, changes in economic conditions, spatial and urban developments in cities, and technological development, which accompanied by social changes for whole society. Urban land is becoming increasingly expensive for both established and emerging countries' economies because of its constant rise, particularly in places with high population densities and commercial districts. Individuals might possess a smaller plot of land. Their tiny homes enable them to survive in the fast-paced world of major cities. Even those who own larger properties can prefer a smaller home with more unoccupied areas for other pursuits. It's probable that people in rural areas prefer modest homes [1]. In addition to using fewer resources, tiny houses are frequently well-built and reasonably priced. For older parents, students, or empty nesters, they can be the ideal size [2].

Ideas and challenges have persisted in producing practical design solutions to meet human needs inside these dwelling units. These small spaces have become the biggest challenge faced by architects in achieving the appropriate balance to meet the requirements of the change in the population growth, economy, social change and technological development of urban areas [3].

1.1 IMPORTANCE OF THE EFFECTIVE USE OF SMALL SPACES

Living patterns, cultural norms, and environmental factors all have an impact on housing. A house's design prioritizes both safety and comfort as well as a feeling of community within the home [4]. The challenge appears in these small-sized configurations is how to achieve balance that takes social factors like secrecy and personal comfort into mind while creating a cozy, healthful, and happy atmosphere. This balance is achieved in the relationship between the user and the space and changing requirements that user needed and the response of the space to these changes. It's called interaction architecture, and interactive space is

known as the space that responds to changes occurring in the circumstances surrounding the functional space, and is responsive in meeting the needs of the user.

Interactive architecture is not only architecture with smart, interactive technologies, but it also carries innovative fixes that respond to frequent change in the interior environment inhabited by humans. According to the research, an "interactive functional area" is defined as a space that is responsive to the needs of the user by creating a space that is suitable in terms of size and comfortable surroundings (sustainable), and is adaptable in terms of function and dimension through the use of contemporary technologies. Compact apartments and homes have become increasingly common in metropolitan areas and urban centers due to limited available real estate. Designing these small spaces requires a delicate balance between style and functionality, making every square meter count. Interactive functional spaces are one of these solutions, and the research has set its goals by "determining the design characteristics of interactive multifunctional spaces as a sustainable and socially comfortable environment." In addition to using fewer resources, tiny houses are frequently well-built and reasonably priced. For older parents, students, or empty nesters, they can be the ideal size.

1.2 PROBLEM STATEMENT

The issue statement describes the need to develop a thorough "cognitive framework for the methods and qualities needed to create interactive multifunctional places".

1.3 AIM AND OBJECTIVES

The research study looks into small-space design and offers advice on how to maximize available space without compromising functionality or style. So, the research defines its limits and objectives by answering these questions:

a. What are small houses and what is their importance in the current time with the changes accompanying it?
b. What are the functional spaces in small residential units and what are their dimensions and Gradations?
c. Is the interaction of the internal space with the user an "important" matter? And what are the characteristics of the interactive space?

d. Could debt payoff or early retirement savings be accelerated by moving into a smaller, less expensive home?
e. Could traveling or living off the grid be made possible by the mobility of a tiny house?

Wherever the research establishes the boundaries in terms of terminology to ascertain the user's relationship with the interactive space and its attributes, as well as the spatial limits by selecting residential buildings particularly smaller ones to assess and scrutinize their spaces and identify the most crucial features that must be present in small-sized residential buildings.

2. METHODOLOGY

To achieve the research objectives here, the research adopts a clear and specific methodology, which is divided into three main steps showed in figure 2.1. A specific approach is adopted in each step, which are:

a. Literature of Review: The research adopted an analytical approach in reviewing previous literature to build a cognitive base where the research can begin, that is included in (Chapter Three), where the knowledge base is sequenced, starting with the definition of the concept of small houses, which has become the contemporary trend for designing residential units, its types, patterns, idea of its development over time. There is nothing new about the tiny house movement or the principles behind opting for a simpler way of living. Living in a tiny home gives you freedom from excessive materialism, but some people choose to live this way because it allows them to save money on bills and other expenditures that come with bigger homes. The goal of this literature review is to attempt to learn more about a particular topic.
b. Theoretical frame work: The research adopts an analytical deductive method to achieve the results of research as theoretical frame work. From literature review in the disciplines of, interactive spaces in house design, sustainable, flexible spaces, multi- functional furniture's, smart furniture which showed as followed (chapter four) latterly. There may be conflict when housing decisions deviate from more conventional expectations of living space since the theoretical framework made it possible to tie individual expectations to a larger social environment in which housing expectations and ambitions are also collectively maintained. By integrating compensating cultures and cruel optimism into a concentrated examination of housing expectations, research aims to reveal the ways in which small-home living practices will be shaped by adaptation to "crisis" circumstances.
c. Case Study: In the 1990s, the growing expense of housing sparked the tiny house movement. In the current environment, for some people, purchasing a home can be an almost unattainable life ambition that will get harder to achieve as housing costs climb. Tiny homes are becoming more and more popular worldwide, especially in the US where there is an abundance of land available for them. Thus this research adopts a comparative method to evaluate and examine an analysis that results from the collecting data by

choosing three projects designing as small houses in any type as selective samples, these projects are: project (A) Ciel et Terre Residential Tower / Molestina Architekten, project (B): Via Verde—The Green Way, and

Project (C). MVRDV

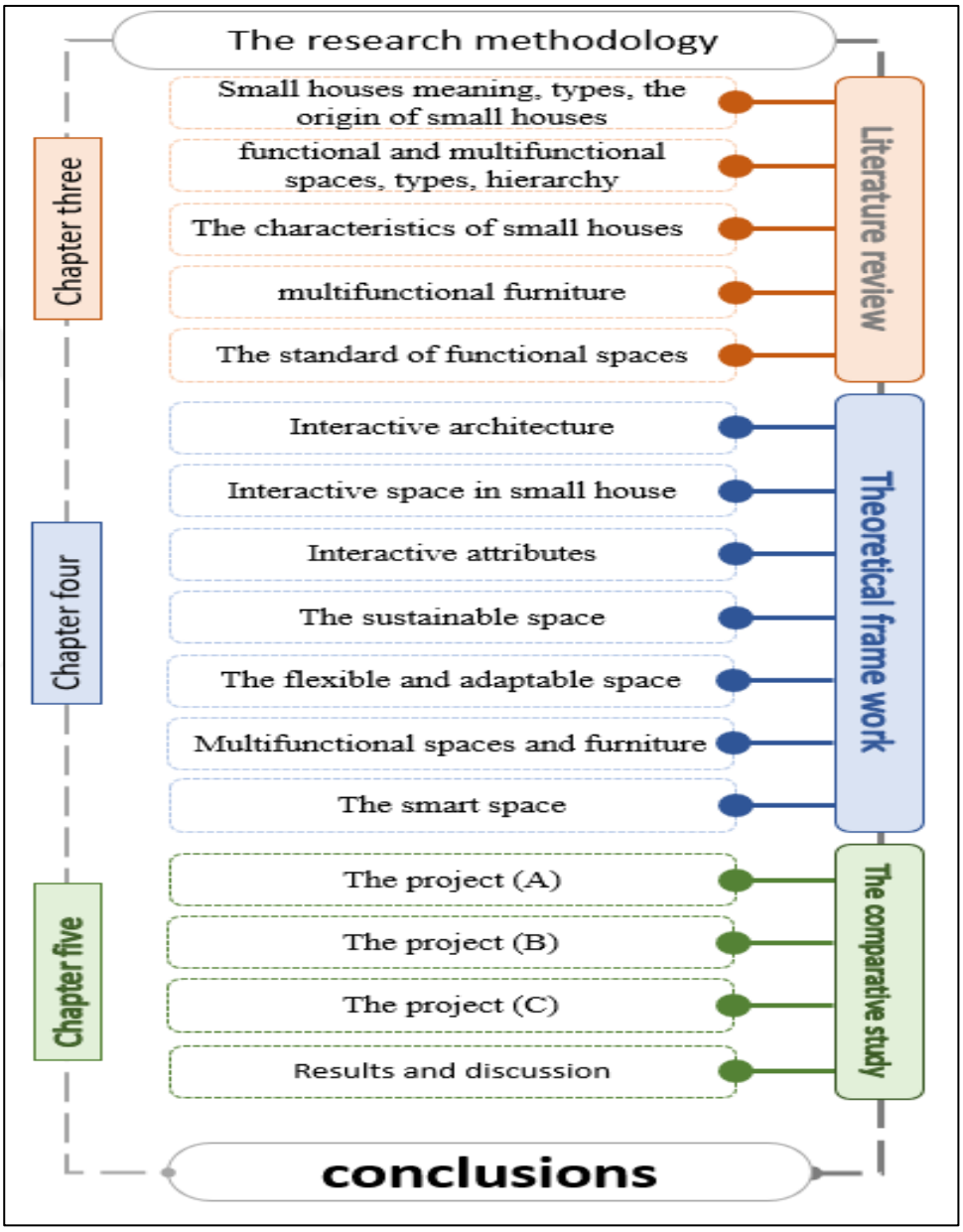


Figure 2.1: The Research Methodology by Author.

3. SMALL HOUSES DESIGN

Most cities faced the continuing of population growth problem, Urbanization growth and marketing prices force citizens to live in small space. That related with constantly changing, cities' development and their expanding horizontally or vertically way, more than 50% of the citizens lives in the cities and this ratio is continuous increasingly. It's also, the urban sprawl defined as a hurtful process [1] as shown in Figure 3.1, Figure 3.2. These are basic necessities that are required to ensure human wellbeing, even though human needs and requirements may not have changed or may perhaps be growing [2]. Due to these issues, tiny homes and apartments are becoming more commonplaces worldwide, that is shown in Figure 3.3 while Figure 3.4 and Figure 3.5 showed the significant decrease in average apartment's size in the world. The average size of new apartments in the U.S. in 2018 is 87.4 m², 5 percent smaller than ten years ago, with studio apartments shrinking the most, by more than 10 % [3]. According to research from the Royal Institute of British Architects, which refer to the lack of space is the most common cause of dissatisfaction people cite in relation to their homes [4]. With these problems a lot of small spaces fail to provide a comfortable living space with good quality[5]. This chapter will dictate about the small houses, their history, and characteristics, functional spaces and their standards.

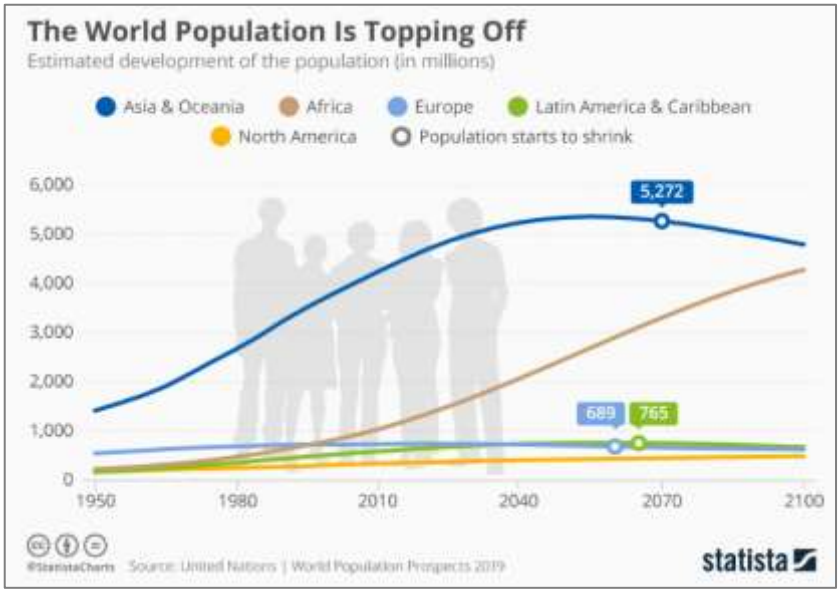


Figure 3.1: The World Population Increasing In The World (2019) [53].

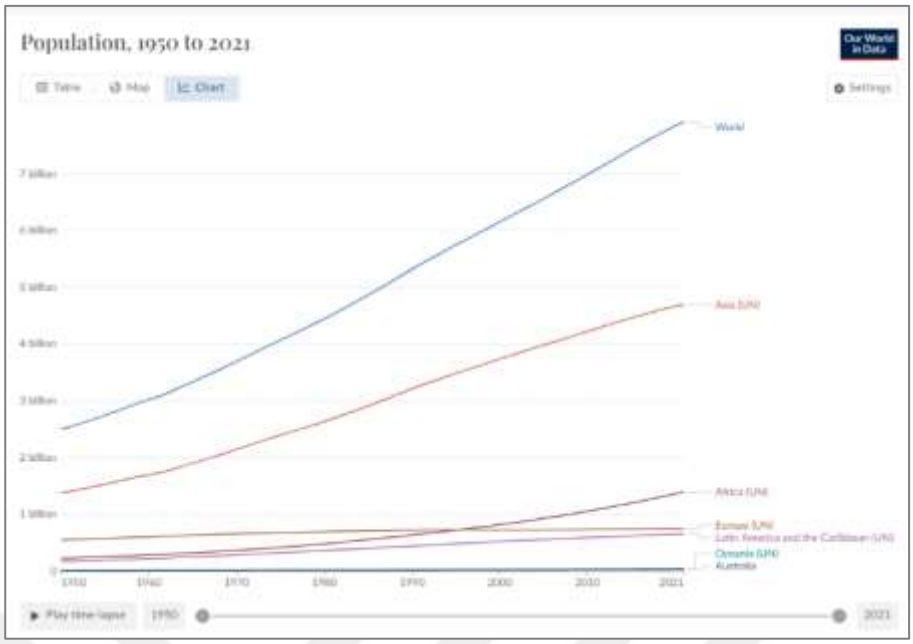


Figure 3.2: The Population Growth In The World (2021) [53].

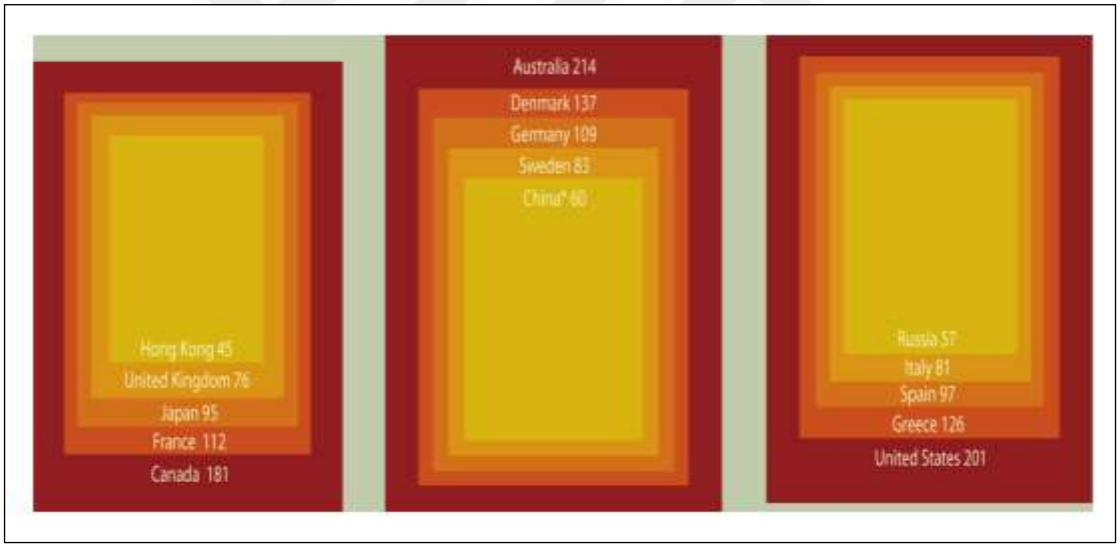


Figure 3.3: Average Home Size Around The Globe In M^2 According To Researches Of Commsec, RBA, UN And US Census From 2009 [6].

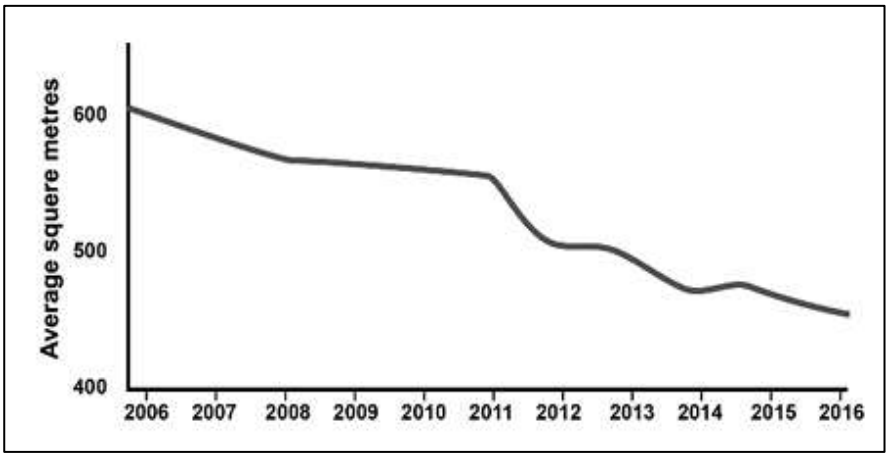


Figure 3.4: Development Of Average Apartment's Size In The Big Cities [2].

AVERAGE SIZE OF NEW APARTMENTS IN THE U.S.

Year Built	All	Studio	1 Bed	2 Bed
2008	993	573	790	1,132
2009	992	600	796	1,133
2010	984	614	787	1,147
2011	979	511	762	1,109
2012	956	493	753	1,092
2013	957	525	757	1,108
2014	944	536	751	1,113
2015	947	515	752	1,122
2016	936	503	752	1,121
2017	941	497	752	1,136
2018	941	514	757	1,138
2018 vs. 2008	-5.2%	-10.3%	-4.2%	0.5%

Figure 3.5: Average Size Of Apartment In U.S.A. [3].

CHANGE IN NEW APARTMENT SIZE BY REGION

Region	Average Size (sqft) New Apartments 2008	Average Size (sqft) New Apartments 2018	10-Year Change
California	974	858	-12%
Northeast	1,048	945	-10%
Pacific Northwest	890	805	-10%
South	1,022	931	-9%
Western	1,011	938	-7%
Mid-Atlantic	951	886	-7%
Southwest	975	930	-5%
Southeast	1,049	1,007	-4%
Midwest	934	947	1%

Figure 3.6: Average Size of Apartment In U.S.A By Region With Comparative Percentage Through 10 Years [3].

3.1 SMALL HOUSES (DEFINITION, SYNONYMS TERMS, TYPES)

There are several definitions about a house or home, which differs according to the various literatures that could be considered from the historical, architectural or social views, whereas house can be defined as an integration and distinct segregation between different domestic activities in rooms [7] that describes a house as a dynamic construction that is always expanding or contracting to meet the demands of its occupants [8], [9]. While another definition refers to the pattern of spaces, dominated by combined relations of space types, the connection, and sequence. People require a place that is suitable for their needs. a multifaceted environment that takes into account requirements for stability, enclosure, comfort, security, and privacy [5].

The term "small houses" or "compact living" is crucial to note because not all small house types fall into the same description or typology within the scope of this research. Instead, it should be considered that there are several different types of small compact houses which all differ more or less from each other, either in size, shape, function or practical use etc. [10]. There is a general misconception about small spaces and quality, for some people, small means cheap or undesirable. Despite this, small houses can be perfect places to live in. Studio apartments are small houses [11]. Which type people choose might depend on many things, and the reasons may also change depending on the user group in question. When one chooses to live in such a small space it is important that the space fits to the wants and needs of the user[6] which has numerous definitions and synonyms terms like: tiny house, micro house, compact living, bungalow, cottage, cabin, casita, studio, granny flat, shack, carriage house, RV, trailer, houseboat, shipping container house, tree house and yurt [12]

A small home is a tiny house or mobile home that usually has a fewer than 46.41 m² floor plan and is made with ergonomics and space efficiency in mind [13] while according to [7] is the minimum size for a one-bedroom apartment is between 0.65-0.92 m². According to ICC report, any building that is smaller than 400 square feet—not including lofts—is considered a small living space [17]. While according to Olick (2018), the average size of a small house for sale in the US is 20 m², or about one-eighth the size of a typical home. A tiny home village, created as homeless shelters by a number of American communities, can have living quarters as small as 2.4 m, 6 inches by 2.1 m, 6 inches, or 5.9 m². The smallest

flat available in Oslo, Norway right now is just 0.92 m² in size. Micro homes and tiny houses are similar in concept, but they differ in design. Tiny houses and micro homes are different from one another. The concept of tiny houses includes various elements, such as size, mobility, DIY (do it yourself) design, affordability, environmental sustainability, and social characteristics [16]. The different between them is size, in micro homes typically have an area of 24.3 to 91 m² but tiny house is bigger than that. Also "Compact living" refers to the current state of operational remedies or strategies for leading a wise life in a reasonably priced and little place. It can take many different forms. This phrase can also be used interchangeably with tiny houses and micro homes to refer to small houses. A little house is smaller than a compact house. The normal area of a compact residence is 37– 92 m². This finally correlates to smart living, which is low built-space living with high-quality amenities and design [14].

In contrast, a bungalow is a small house that has only one level. It typically has low ceilings and a front porch. Most bungalows also have a front or back yard or both. Bungalows have an area of 22.57 to 139 m², although some may be slightly bigger. Bungalows, on the other hand, are smaller versions of conventional dwellings. It is usually don't have space-saving features or multi-functional furniture, although you can add these features if you'd like. It is not a mobile and is designed for a permanent dwelling [8]. A cottage is a type of modest housing that is typically found in rural settings. They were frequently spotted near the water or in rural areas. Cottages range in size from 37 to 92 m², and they are frequently characterized by their vintage styles [18]. They typically have double-hung windows with shutters and low-pitched gabled roofs, giving them an uneven appearance. The majority only tell one tale. It is intended to be a permanent home [8].

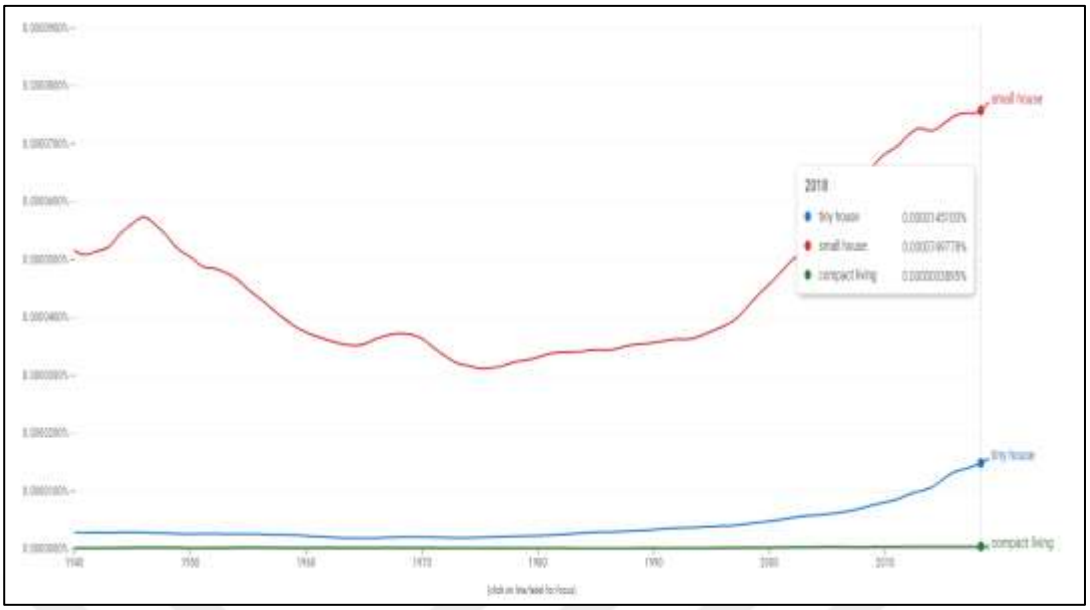


Figure 3.7: The Small House Term and Synonym Terms In Literatures By Google N Gram [55].

Following up on the previous discussion, small house units can be found in any kind of building and be occupied by a variety of people. These people include young families purchasing their first home, adults who need a small home, workers, artists, retirees, bachelors, and childless couples [19]. Small house owners also tend to maintain their homes more sustainably and energy-efficiently than those in larger buildings. Furthermore, living in a tiny house gives its residents more time for personal or recreational pursuits. These factors make tiny homes a popular alternative for single people and small families looking to meet their needs and live a better lifestyle [9]. Small house types were categorized by rentants, size, and moveability, as shown in Table 3.1 below: [20]

Table 3.1: Small Houses Classification by Author.

Types of small house	Type of structure stabile		Types of users	Permanent or temporary life style	Levels		size		
					One story	Multi story	Small size 25 - 100 m^2	Medium size 100-300 m^2	Large size 300-800 m^2
Tiny house	Stabile		Not specific	P		■	❖		
Micro home	Stabile		Not specific	T			❖		
Small houses Compact living	apartment	Stabile	Not specific	P	■	■		❖	
	loft	Stabile	Not specific	P		■		❖	
	studio	Stabile	One or couple without children	T or p		■	❖		
	condos	Stabile	Not specific	P		■		❖	
	Duplex	Stabile	Not specific	P		■		❖	
	Single or multi- family unit	Stabile	Families with children	P		■		❖	
	Multi story	Stabile	Families with children	P		■		❖	
	penthouse	Stabile	Families with children	P		■		❖	
Bungalow	Stabile		Guest	T					❖
Cottage	Stabile		Guest	T					❖
Cabin	Stabile		Guest	T					❖
Casita	Stabile		Guest	T					❖
Granny flat	Stabile		Specific Elder of adult children	T				❖	
shack	Stabile		Specific	T				❖	
Carriage house	mobile		Families	T					❖
R.V.	mobile		Travelers	T			❖		
trailer	mobile		Travelers	T			❖		
Houseboat	mobile		Travelers	T			❖		
Shipping container	Stabile or mobile		Not specific	T or p			❖		
Tree house	Stabile		traveler	T			❖		
Yurt	Stabile		Not specific	T			❖		

3.2 HISTORICAL VIEW TO THE ORIGIN AND DEVELOPMENT OF SMALL HOUSES CONCEPT

The concept of smaller houses has become a more popular choice in the 20th century and has gained some of its inspiration from 19th century romanticism. The main statement that influenced this is less more. Several usages have been proposed
temporary housing and guest homes [15] it's also considered as a solution for housing in urban areas that host large populations in limited space [16], [17], [18]. Small houses might have only started gaining popularity in recent times, but they have been around for a very long time. Settlers in the very early days started the concept, and these houses emerged from igloos, huts, wigwams, and tents [10].

The earliest groups to own small houses were the Inuit's, Sioux, and Samoans. A thousand years before Christ (BC), people established Gers as small homes that were more practical in Mongolia. Later, in 500 BC, small portable houses were built by Native Americans. These were both waterproof and heat resistant. In the 1800s, Shot Gun Houses—inspired by the Haitians in the South—began to appear. In order to help him promote his art, artist Allan Wexler explored the idea of living in a tiny, smaller-than-normal place when the 1970s arrived. This concept was developed and made more well known in 1973 when Bob Easton and Lloyd Kahn published their book, Shelter. The concept of tiny living space was later advocated by more authors, for example, Lester Walker and Henry David. Another artist from the '90s, Andrea Zittel, also embraced this idea in her work and rekindled the tiny house trend. It might be said that the tiny house trend, which is currently popular, got its beginnings in 1997. First, there was Sarah Susank, a writer who went on to publish a book called "The Not So Big House," in which she emphasized the environmental advantages of compact homes. This brought about a tiny house crusade. There was also John Shafer, who in 1997 built his very own tiny house on wheels. After some years, John started a company called the Tumbleweed Tiny House that provides different plans when it comes to building a tiny house and information on other aspects of tiny homes. Through this, he showed people that they could either give away or sell some of their belongings, either unnecessary ones or the unwanted and move into smaller living spaces. These tiny living spaces are eco-friendly and less expensive than regular houses but still provide a lot of different options for the owners' futures. John Shafer later created another company named Four Lights Tiny House, which further propelled the idea of tiny house living. The tiny homes trend continued to rise, and

over the years, different TV shows and movies have promoted it further. An example includes "The Little House on The Prairie," a show that was a great hit. Henry David Thoreau and Marie Antoinette also built tiny historical homes, and every year, people are given tours as a way of inspiring them to adopt that kind of lifestyle. It's evident that the tiny house movement emerged from the wish to live a more straightforward and ecologically conscious lifestyle. Furthermore, it lessens the financial burden. Both waste production and energy use are reduced in tiny houses [10].

Prior to delving into the construction of tiny homes, the fundamental concept of living areas had to do with characterizing human ease and difficulty. This concept developed outside of natural bounds. These dwelling spaces, which evolved from places like caves to those produced by carved rocks, have been expanded into larger areas in recent centuries to provide them with a more ecological atmosphere. Our tiny house was constructed with basic materials, but today we have houses on wheels! We haven't been able to maintain organic coherence for very long because of inorganic settlements [25].

Near the modern city of Xi'an, the Banpo people lived during the dawn of Chinese civilization about 3500 BCE. They built about 3.5 m^2 of circular mud and wood houses with thatched roofs covering a fire pit in the center, as shown in [Figure3.8]. We established an organic way of building dwelling sites at around the same time in Catalhoyük, Turkey, which is near the modern city of Konya [Figure 3.9]. The city consisted of rectangular, flat-roofed houses packed into one architectural mass; there were no streets or passageways. Residents were able to access their roofs and enter their homes by climbing rooftops using ladders. The typical house measured thirty square meters on average, with [11]. The concept of smaller houses has become a more popular choice in the 20th century and has gained some of its inspiration from 19th century romanticism. The main statement that influenced this is ‘less is more’

Figure 3.8: Mud and Wood House With Thatched Roofs At Banpo, China In 3500 BCE [17].

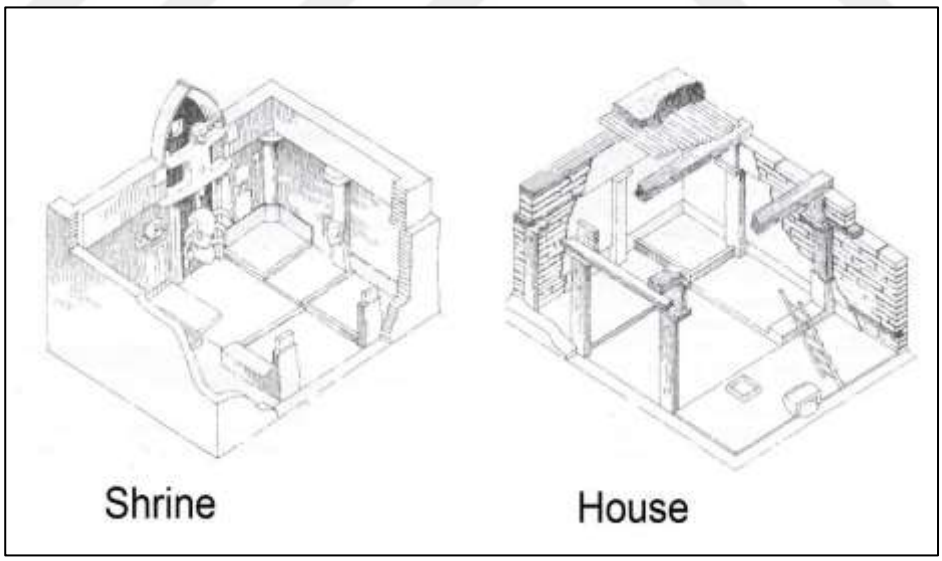


Figure 3.9: Typical House at Catalhoyük In 3500 BCE [17].

3.3 THE CHARACTERISTICS OF SMALL HOUSES

A quick review of literature indicates that small houses have common characteristics. These characteristics can be classified as:

a. Creative Storage Designs and Solutions: A tiny house has limited space. It also involves finding more ways of storing your items, for example, hanging them neatly, or storing them in decorative trunks, so that you make good use of the available space in the most
b. Creative way. Because compact homes have limited space, the functional components of the house should be arranged in a way that maximizes its architectural design. Interior design will have a big impact on space management [1].

Figure 3.10: Storage Under the Bed [56].

Figure 3.11: Storage in Stairs [16].

Figure 3.12: L Storage Wall [6].

Figure 3.13: Storage In Floor.

Figure 3.14: Storage In Ceiling [57].

a. Multipurpose Rooms or Areas (multifunctional spaces): A small house does not have many rooms, therefore, be very flexible. This means some of the rooms will have more than one or two users. For instance, a kitchen can serve as both a working and a dining room. A bedroom can serve as both an office and a place for the kids to play. It is

therefore essential to pay closer attention to the type of furniture or kitchenware in these rooms [25].

b. Multi-Use Type of Appliances: A compact dwelling requires making innovative use of the little space available. Using appliances that are multitasking is another requirement for this. The research indicates that in 2024, a lot of manufacturers are inclined toward the concept of making smaller appliances for tiny homes, allowing a room to be outfitted with just one set. An excellent illustration would be a stacking washer that doubles as a dryer. Moreover, foldable furniture serves the key role. The capacity of collapsible furniture to be folded and expanded makes it useful. Multipurpose furniture helps maintain more areas because it can be used for multiple purposes by only rotating or rearranging individual pieces [1].

Figure 3.15: Office Under the Bed and Bunk Bed.

a. Sliding Doors: A typical door requires space since it must pull in order to open. Certain tiny homes utilize sliding doors as a way to conserve space. They have a distinctive appearance [12].

b. A Lot of Natural Light: Due to their compact size, tiny houses are often designed to let in an abundance of natural light. Along with this, owing to the limited area of each functional room in the house, lighting, windows, mirrors, and colors all play significant roles in small house design. Vibrant color creates an ambiance that is more eco-friendly [26].

c. Benefits of a Tiny House: Although large houses have numerous advantages, compact homes also have some of their own, which include:

i. Promotes a Simple Life: A tiny house cannot accommodate excess stuff. Therefore, many who live in them reduce their belongings to just the essentials. Most of these tiny home dwellers or owners also realize that the standards of living in these modern days do not necessarily express who they are. To avoid a conflict of values, they have fewer possessions that are materialistic and choose to keep only those belongings that enrich their lives. With this, you also get fewer distractions and live more consciously.

ii. Promotes Sustainability and Reduces Carbon Footprint: For a very long time, the earth has been mistreated. But a lot of people have understood this and are trying harder to live more sustainably now. This is made possible by the fact that many recycled and repurposed materials may be used to build tiny houses. Which results in reduce production of garbage than a typical household. Additionally, these materials will decrease the amount of new building materials needed while also giving homes a distinctive appearance.

iii. Saves Energy: In comparison to conventional dwellings, tiny houses utilize less energy and resources of construction and operation. It requires more compact appliances that will function well. Moreover, Electricity expenditures will be considerably lower with a small home [27].

iv. Tiny house allows to declutter life: Everything has a place, which gives the appearance of organization in the vicinity. Additionally, it won't need much cleaning solution or other supplies, so won't need to buy them as frequently. Additionally, cleaning entire house will just take a few minutes, and dusting it will take even less time.

v. Greater Financial Freedom: The amount of financing required to build or purchase a tiny house will be far less than that required to build a conventional home. Because of this, repaying it will be simpler, and it will be debt-free sooner rather than later. Additionally, it will require less appliances, furniture, equipment, and decor.

vi. Allows to Develop More Social Connections: A tiny house makes you spend more time outdoors compared to a regular house. Kilman (2016) emphasizes that leading a modest lifestyle can encourage more personal interactions with nature in addition to offering new chances for people to engage and/or interact with others in their local communities.

vii. Gives You Freedom of Movement One of the best things about a tiny house is that you can move with it. A tiny house can be built on wheels. That means in case you are going

to a new spot for a vacation or would just like to move to a new place, you can always move it there. It makes things easy as you can park it in your new location with ease.

3.4 FUNCTIONAL SPACES (MEANING, HIERARCHY, TYPES)

Functional space means a single room (spaces or the space between ceiling and the floor or roof deck above) or homogeneous area, mutual rooms, that is designated by designer to prepare management plans, and conduct response actions [12]. A kitchen, for instance, is a practical area intended for food preparation and cooking. A bedroom is a practical area intended for resting and sleeping. Considering functional rooms when designing home to create a more efficient and orderly living space is main element [13]. The dwellings' spaces with functions have been used to describe the housing space standards and occupants' behavior that is shown in Table 3.2 it lists the various purposes that dwellings serve [19].

Table 3.2: The Classification of Functions And Relative Activities.

Functions	Activities
Sleeping	• Double • Twin • Single
Cooking	• Food storage • Food preparation Personal hygiene 8. Circulation a)
Eating	• Quick meals • Dining
Living	• Watching tv, social communicating
Play, study, work	• Children play • Adolescent play/study • Adult play/work
Clothes care	• Laundry • Drying clothes • Ironing clothes • Sewing

Table 3.2: The Classification of Functions And Relative Activities ”Table Continued”.

Personal hygiene	• **Bath/shower** • **Toilet** • **Health care**
circulation	• Entrance • Communication/separation
Domestics management	• Cleaning • General storage • Control of the environment
Outside in private space	

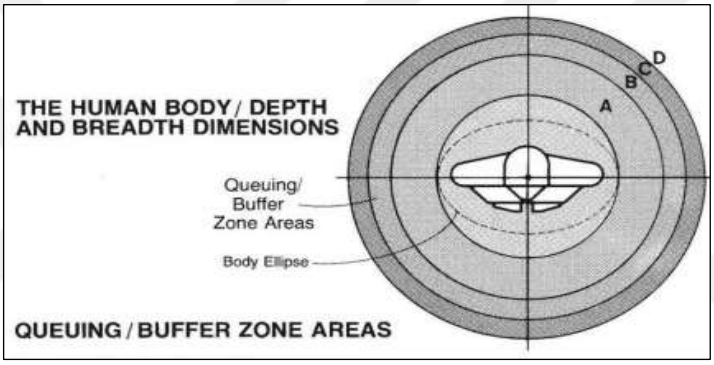


Figure 3.16: The Human Buffer Zones [22].

QUEUING DENSITY ANALYSIS*

DESIGNATION	DESCRIPTION	RADIUS in	RADIUS cm	AREA sq ft	AREA sq cm
A. Touch Zone	Below this area of occupancy, frequent unavoidable contact between people likely. No possibility of circulation within this zone. Movement restricted to shuffling. Occupancy similar to slightly crowded elevator.	12	30.5	3	.28
B. No-Touch Zone	Contact between people can be avoided as long as movement within area is not necessary. Movement possible as a group.	18	45.7	7	.65
C. Personal Zone	At this spacing a full body depth separates standees. Limited lateral circulation between people possible by moving sideways between them. Within range of spatial occupancy that has been selected in experiments emphasizing comfort standards.	21	53.3	10	.95
D. Circulation Zone	Circulation within queuing area possible without disturbing others.	24	61	13	1.4

Figure 3.17: The Human Buffer Zones [22].

The house spaces have nine meanings could founded like: social relations, social networks, self-identity, privacy, continuity, personalization, activity base, childhood homes, and physical structure [5]. Rapaport argued that physical space design has relationship with organizational behavior, which means houses could be affected by social organizational cultures and values that people belong to configure their houses in different types. Additionally, depending on environmental and sociocultural elements, such as privacy, which is utilized to govern personal space (human buffer zones), the hierarchy of spatial organization can be constructed [5]. It enhance family safety and separates personal life from public associations, that include: controlling visibility and safety, privacy of family members, noise control to solidify acoustic privacy, and odor control to prevent smells from spreading to spaces where guests are entertained [15]. The hierarchy of functional spaces in small houses are determined as: public spaces, semi-public, semi-private, private, and transition spaces. Which are represented in Figure 3.18 and Figure 3.19

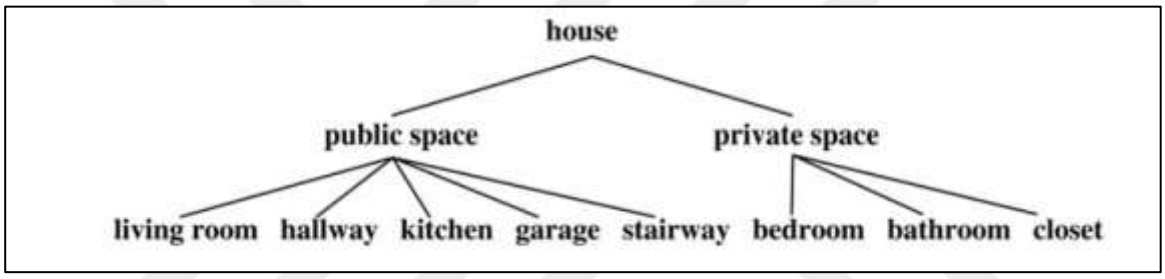


Figure 3.18: Hierarchy of Functional Spaces in Small Houses [54].

Figure 3.19: Image Clarifies the Quantity of Hierarchical Spaces in the Selected Detached House [8].

3.5 THE STANDARD OF FUNCTIONAL SPACES

Minimum criteria for habitability were established as space standards. These standard are positive indicators dwelling quality [16]. They used to determine users' needs (number of people who are expected to occupy the dwelling), this functional criterion of residential units have two levels of quality (basic, and minimum). Which reflected the range of household pleasure and satisfaction to fulfillment their needs. These two levels are set as:

a. The basic level is a limit of area fitting for human needs' which prevent occupants to suffer any physical or mental hurt. This level is usually used to check whether an existing building is fitting human needs or not [16]

b. The minimum level is a limited occupants common needs are fulfilled in daily life style. This level is to ensure preventing of construction of new or harmful buildings to occupants or urban quality [16].

These levels are measure of the dwelling acceptable capacity of occupation in the prevailing cultural, social, climatic, economic and technological requirements in a society context. The useful design of circulation spaces that could be achieved by studying a progressive increase in users' requirements and spaces using the number of occupants is depicted in the accompanying diagram and table. Different combinations of single, twin, and double beds are available in dwellings to accommodate the needs of the same number of inhabitants. Housing standards are typically lower than what most occupants would like to see in order to ensure the best use of the resources at hand and the affordability of social aspects in the home, such as occupant satisfaction needs over the course of the occupant's lifetime and choosing a dwelling that fits their specific needs without being larger than necessary, who have the financial means and education required to choose the dwelling that best fits their specific needs [16].Given tables 3.3 and 3.4 show the basic and minimum levels of area for all functions.

Table 3.3: Basic Level of Area (M^2)

Function			Number of occupants								
			1	2	3	4	5	6	7	8	9
1	Sleeping	Double		8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
		Twin				7.0	7.0	7.0	7.0	7.0	7.0
		Twin						7.0	7.0	7.0	7.0
		Twin								7.0	7.0
		Single	4.0		4.0		4.0		4.0		4.0
2	Cooking	Food storage	0.5	0.5	0.5	0.5	0.5	1.0	1.0	1.0	1.0
		Food preparation	2.5	2.5	3.0	3.0	3.5	3.5	4.0	4.0	4.5
3	Eating	Dining	2.5	3.0	3.5	4.5	5.5	6.5	7.5	8.5	9.5
4	Living		4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
5	Play/study/work	Adult play/work	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
6	Clothes care	Laundry	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
		Drying clothes	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
7	Personal hygiene	Main	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0
		Second						1.5	1.5	1.5	1.5
8	Circulation	Entrance	1.0	1.0	1.0	1.5	1.5	1.5	2.0	2.0	2.0
		Communication	1.0	2.0	3.0	3.5	4.0	4.0	4.0	5.5	6.0
9	Domestic manag.	General storage	0.5	1.0	1.0	1.5	1.5	1.5	1.5	2.0	2.0

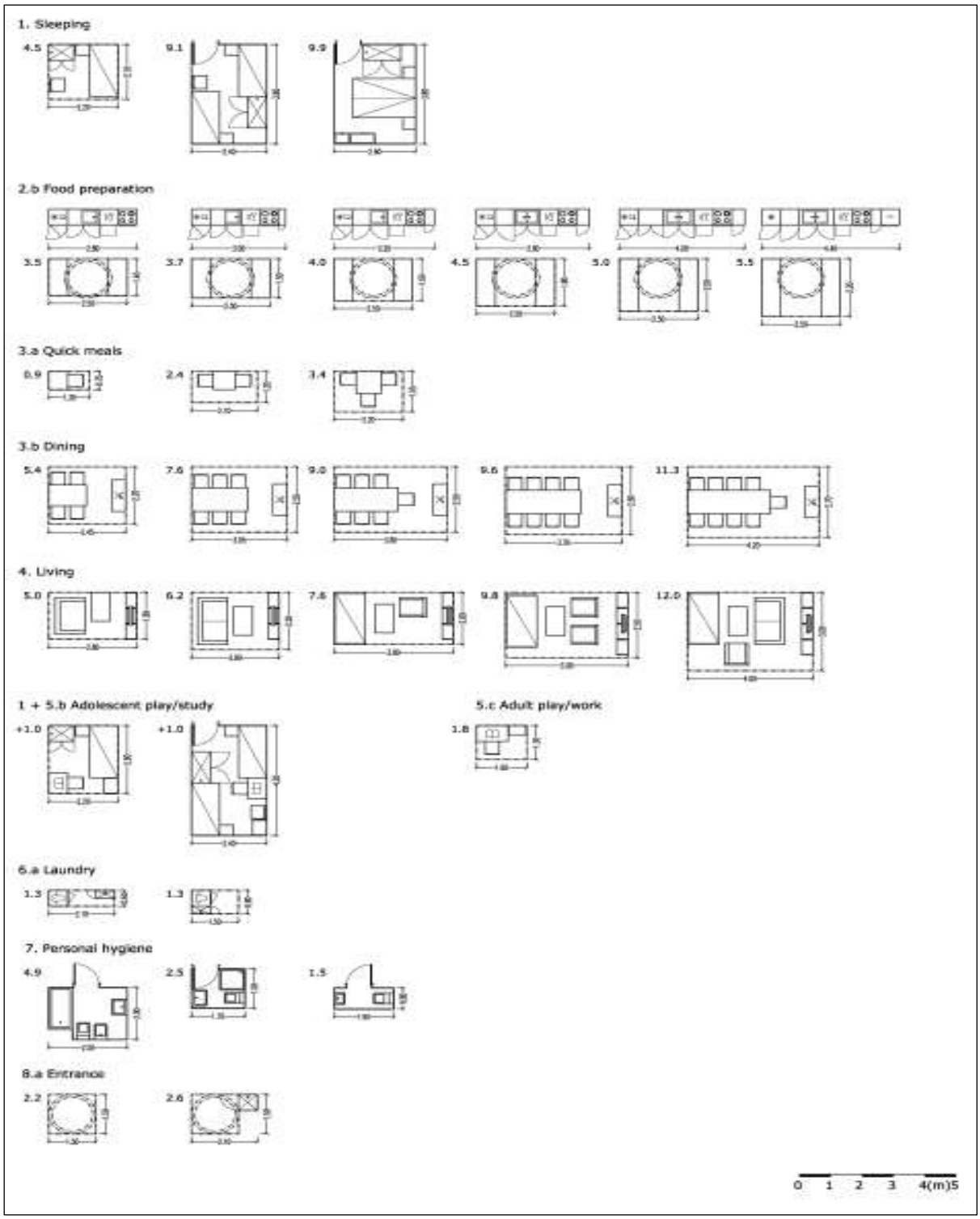


Figure 3.20: Minimum Level – Models of Functional Spaces And Their Area (M²) [21].

Table 3.4: Minimum Level of Area (M^2)

Function		Number of occupants								
		1	2	3	4	5	6	7	8	9
1 Sleeping	Double		10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
	Twin				9.0	9.0	9.0	9.0	9.0	9.0
	Twin						9.0	9.0	9.0	9.0
	Twin								9.0	9.0
	Single	4.5		4.5		4.5		4.5		4.5
2 Cooking	Food storage	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
	Food preparation	3.5	3.5	4.0	4.0	4.5	4.5	5.0	5.0	5.5
3 Eating	Quick meals		1.5	2.0	2.5	2.5	3.0	3.0	3.5	3.5
	Dining	5.0	5.0	5.5	6.0	7.0	8.0	9.0	10.0	11.0
4 Living		6.5	6.5	7.0	8.0	9.0	10.0	11.0	12.0	13.0
5 Play/study/work	Adolescents			1.0	1.5	2.0	2.5	3.0	3.5	4.0
	Adults	1.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0
6 Clothes care	Laundry	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Drying clothes	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5
7 Personal hygiene	Main	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	Second					1.5	2.5	2.5	2.5	2.5
	Third									1.5
8 Circulation	Entrance	1.5	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5
	Communication	1.5	3.0	4.5	5.0	5.0	5.5	5.5	6.5	6.5
9 Domestic manag.	General storage	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.5	2.5

It is not about breaking the law to live in a modest house; rather, it is about escaping the bonds of debt and conformity. Tiny home owners make this decision for a variety of reasons, including personal freedom, affordability, altering the environment or just their life. By putting projects and trends in its field into perspective, comprehending them, and incorporating newly developed technologies, interactive architecture presents a vision for the future [29].

4. INTERACTIVE SPACES IN SMALL HOUSES

4.1 INTERACTIVE ARCHITECTURE MEANING

The general goal of architecture has been and continues to be to offer a stable, perfect solution, presuming that future conditions are generally fixed and have little chance of changing. A new approach to design, interactive architecture is centered on the interaction between the user and the space, the space's real-time responsiveness, its capacity to better meet the various and ever-changing needs of its users, and the creation of an ongoing relationship between society and the built environment [29].

The interactive building could be planned with a functional objective in mind, including enhancing the functionality of self-operating systems and functional areas, or providing the structure more flexibility and adaptability so that people can use it more efficiently. The degree of interaction is what distinguishes interactive architecture from adaptive space, as earlier trends relied on the user to manually alter the size, color, shape, and placement of the space's constituent elements as well as the project's geometric component shapes [30].
Although this architectural movement is relatively new, it has the potential to alter how people interact with their built environments [20]. It is still in its early stages of development and is a relatively young field. It meant using digital technologies, smart systems, and information technology to interface with modern humans and design requirements. It can fulfill multiple functions and reaches the maximum level of comfort [32].

4.2 INTERACTIVE SPACE DEFINITION

The creation of surroundings that adapt to their users is the focus of interactive space. Numerous techniques are available for accomplishing this, including the use of interactive technology to give users power over their surroundings or the use of sensors to monitor movement. Louis Sullivan used the phrase in his paper "form should not just follow function but also combine with it" describe how a space's shape should not only respond to its intended use but also be aesthetically pleasing, immersive, and reflective of the activities that take place there[21]. So that make the Interactive space to be defined as a spaces and objects that can physically re-configure themselves to meet changing needs. The model of Maslow hierarchy of human needs in architectural context of space design put the psychological and physiological needs as essential to survival and primary goals of

domestics spaces [18]. The essential pleasure in architectural environments developed from safety and comfort are fundamental survival instinct requirements. Pleasure is a positive psychological, physiological, and cognitive reaction that also shows aesthetic preferences in spaces [33].

Contemporary trends aim to erase the boundaries between static things and motion, still and reactive, inner spaces and outside, virtual space and real space, by using new technologies which actually allowed to reduce these boundaries and enhancing spaces at the same time, by using the development ambient displays, which are combined computing paradigms and calm technology in a pleasing and attractive way [22]. Here term 'display' in this context refers to any construction, which translate any user information to visible effect presented in a variety of ways, such as lights, sounds, movement, or non-traditional shapes[34]. It probably looked like a dynamic light installation, water waves in a fountain, or any other artifact that could display information. In most cases, information is displayed indirectly by varying a variety of characteristics, such as motion, sound, light, and its component arrangements. In addition, the residential development began to take virtual activities into account in addition to tangible ones [19]. To address this challenge, several studies created ambient displays, which use subtle alterations in movement, sound, and light to provide users with unconsciously absorbed

information about their environment, demonstrated in Figure 4.1.

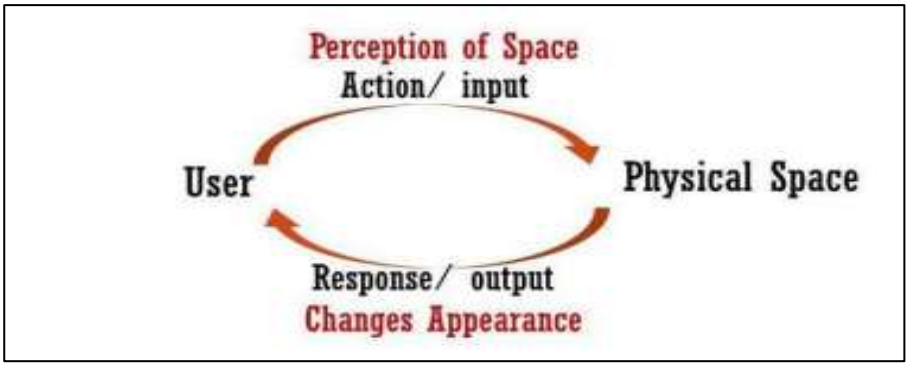


Figure 4.1: The Meaning of Interactive Space.

4.3 INTERACTIVE SPACE ATTRIBUTES

Interactive architecture is based on the idea of dialogue between architecture and man on the one hand, and architecture and the environment on the other hand, in order to reach a

better state and greater comprehensiveness [23]. It is architecture that has relative reaction with its occupants, climate, and context through using technological, social, and contextual changings to achieve operational, and functional goals [24].

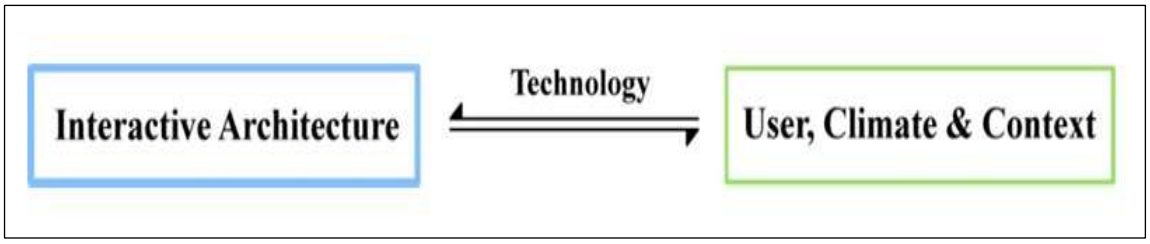


Figure 4.2: Interactive Architecture Responsive.

Interactive space created an environment that immerses the user in a setting tailored for particular tasks carried out there, reflecting data to provide the user with information in its ultimate form [19]. Once inside, the user responds to an invitation to interact with the space by having a conversation about information, hidden or visible modes of operation, new activities, social communications, enjoyable situations, playful activities, and references that visitors generally understand to be relevant to their culture, intelligence, mood, or other factors. Social ties are viewed in this way as components of a common network where human users and visitors coexist with non-human actors in space and are all endowed with agency. The ability of all elements, human and non-human, to exhibit agency, generating original scenarios and conversations in real time, is known as interactive behavior. The following social conditions can be mirrored through architectural space:

c. Configure that adjusts to satisfy users' needs (sustainable space)
d. Adaptable and multifunctional space for various activities (flexible space)
e. Areas, gadgets, or individuals linked to remote (smart space, smart furniture)[16].

The fields of architecture, industrial design, computer programming, engineering, and physical computing have all contributed to this architecture. Key points included in interactive architecture are sustainability, flexibility, adaptability, usage of smart technology and smart furniture.

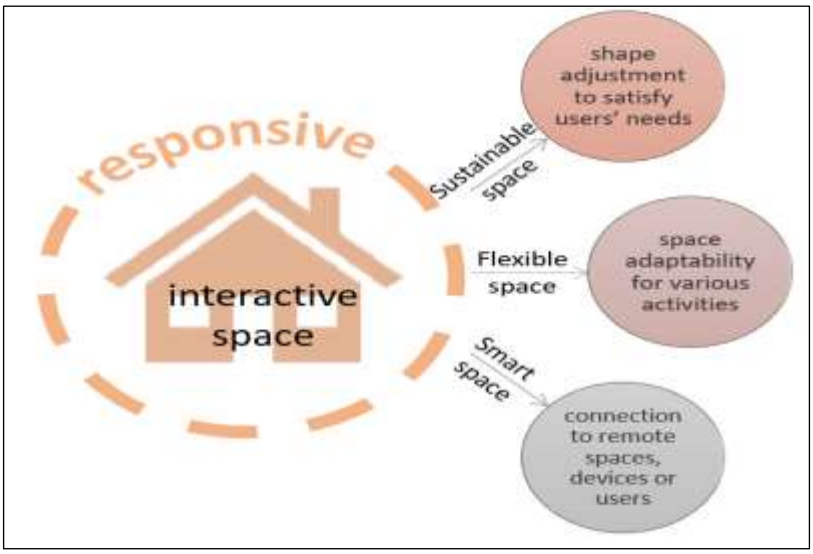


Figure 4.3: Interactive Space Attributes by (author).

4.3.1 Sustainable

Sustainable interior design is any design that thoughtfully considers how each of its components and functions will affect the environment at large. Three criteria's have been used to demonstrate how environmental components of interior design are: The effectiveness of ecological factors comes first, followed by economic effects and, last, social organization considerations. These factors pertain to the interior space quality and how it affects the psychological and physical comfort of the occupants [25].

An interior designer should prioritize the health of the environment above all else. A few elements that contribute to a healthy room are air quality, heating, ventilation, lighting, and acoustics [38] and environmental aspects of sustainability in inner space can be achieved: by cutting down on waste, utilizing renewable resources, and conserving water and energy when developing homes [20] shared in determined factors that related with sustainable inner spaces mentioned as (saving space) which are:

a. Reducing devices in the house (combined furniture)
b. Mixing several zones by multitasking zones (multifunctional spaces)
c. Use of virtual space by several tele-activities like smart panels, wall and floors (smart technology).
d. Using flexible furniture and multifunctional devices [20].

The interaction between the size of living spaces which should be free from risks to one's physical or mental health and the necessities of human wellbeing is referred to as social aspects in sustainable design. These components evaluate mental and bodily functioning [7]. Also, Max-Neef pointed to the fundamental human wellbeing needs related with small living spaces and furniture are: Subsistence, Protection, Affection, and Identity. All these needs determined the mental comfort listed in table below [21].

Table 4.1: Human Wellbeing That Related with Living Space.

Fundamental Human Needs	Being (qualities)	Having (things)	Doing (actions)	Interacting (settings)
Subsistence	Physical and mental health	Shelter	Feed, rest, work	Living environment, social settings
Protection	Care, adaptability	Security	Co-operate, plan, take care of, help	Social environment, dwelling
Affection	Respect, sense of humor, generosity, sensuality	Friendship, family	Share, take care of, make love, express emotions	Privacy, intimate spaces of togetherness
Identity	Sense of belonging	Home, work, customs, values	Make choices, grow	Places one belongs to, everyday settings

Factors pertaining to interior settings that impact mental comfort include ambient temperature, humidity, and air movement. Therefore, social, health, economic, and environmental factors also affect one's degree of comfort. Furthermore, the idea of comfort will be regarded as one of the primary concerns, depending on quantifiable factors like the physical surroundings and the needs of the human body. More precisely, the primary field of interest that may be drawn from this domain is ergonomics, whose primary goal is to study the human body and its behavior in order to produce pertinent information on how to create environments that are comfortable for humans and conducive to their well-being [11]. Human requirements remain the same despite the fact that living conditions are changing. Our behavior and perception of the environment can be influenced by our attitude toward the physical surroundings and our physical surroundings. Convenient size has become a crucial requirement because small apartments are often packed and disorganized, which may cause residents to feel pressured, cramped, and claustrophobic. As a result, a healthy and comfortable environment is required [7].

Explain the degrees of users' satisfaction are related with the living space size which presented in Figure 4.4.

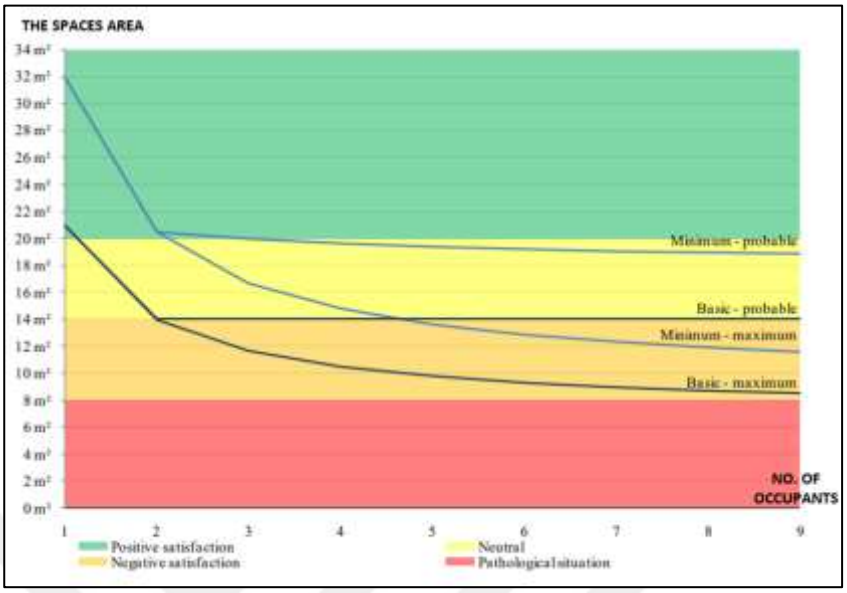


Figure 4.4: The Relation Between Net Areas of Inner Spaces With No. Of Occupants [21].

The concept of functional sustainability, which prohibits the classification of members of society into categories such as the old, the disabled, and families with young children, etc. has been explained in a paper [33]. Most people's time spend indoors, whether it be at home, at work, or in schools. The interior designer should prioritize the health of the environment above everything else, even if it should come last [16]. A person's degree of contentment with their environment can be used to define the term "Comfort Space" in the simplest sense; while the discontent is the reverse of contentment. Furthermore, "the sense of well-being of the individual; satisfaction or dissatisfaction of the individual from his or her life" is referred to as the level of comfort. As a result, it is highlighted that each person's perceptions and senses have a role in their quality of life in this particular situation. "As an interaction of social, health, economic, and environmental conditions that have an impact on the development of the individual and the society" is the second definition of quality of life [11].They minimize the need for relocation and enable people to age in place within their social networks. These specially constructed dwellings remain unaffected by the changes brought about by life's activities [28].

Need for Sustainability:

Buildings are constructed in a variety of styles by civilizations, which reflect the development of cultural values. Space organization and use are strongly associated with cultural traditions, which are best understood by the local populace. One major barrier to home satisfaction is the disregard for socio-cultural elements, such as size, religion, family values, and ethnocentric behaviors [40]. The International Right to sufficient Housing [41] highlights cultural adequacy as a critical requirement for sufficient housing. Sustainable housing has the potential to significantly reduce problems associated with poverty, urbanization, population increase, and climate change. By adding a planning element, it pushes governments and other stakeholders to think creatively about provision, shifting the emphasis back to the complexity of housing and the experiences of the urban poor. While integrating several components of sustainability is necessary for sustainable housing, it is not often implemented in low- and middle-income countries. Research shows that ignoring one sustainability factor increases the vulnerability of dwellings in numerous ways [42].

4.3.2 Flexible and Adaptable Space

The modernists' theories on universal housing design served as the basis for today's concepts of flexible space, which can adjust to the needs of a variety of users. However, these ideas also change over time as a result of the family's life cycle and the aging of the residents, making it difficult to design a space that can accommodate the needs of multiple family members [43]. The ability to quickly and easily divide, expand, and organize space, as well as the ability to downsize without sacrificing utility, are examples of how flexible living space can be. These characteristics, as well as the notion of sustainable development, are consistent with the tenets of universal, inexpensive, accessible design [26].

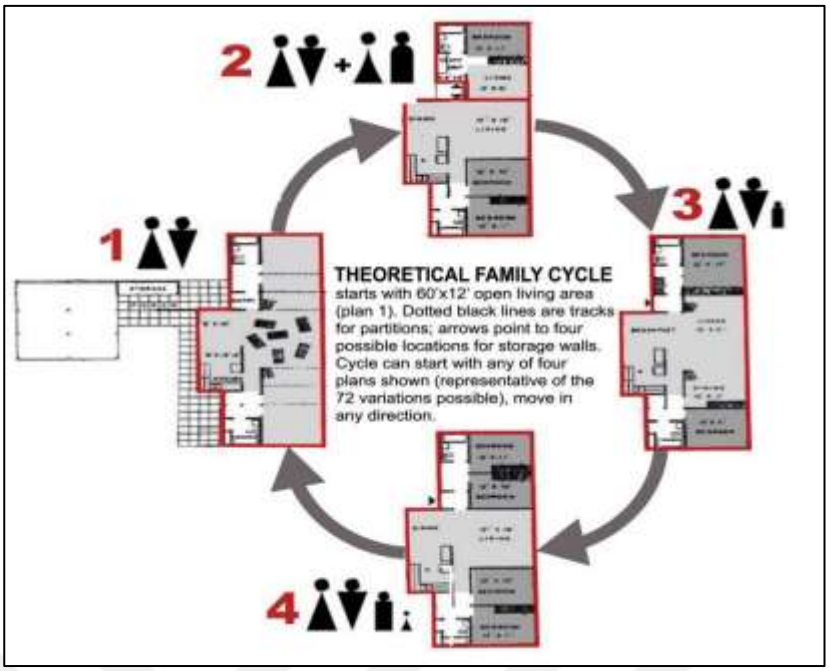


Figure 4.5: Modifying Plan to Adjust With Family Life Cycle Changing Needs [30].

The ability to easily adapt interior spaces to changing application and performance needs is a key component of interior architecture's flexibility. Interior spaces should be physically defined and limited by elements such as walls, ceilings, floors and so on, but they should also be planned in a way that allows for changes in flexibility [27], [28], [29]. The primary design presumptions considered how people use space differently throughout the day and at night. By utilizing fold-out mattresses and partitioning the area with sliding walls in a way that assures seclusion and solitude, the architect attempted to accommodate more occupants in the flat. The ability of a building to adapt to the shifting demands of people and the environment in a way that is both economically and environmentally feasible, as evidenced by the use or location of the building. The degree to which living environments can be physically altered to suit demands can be used to characterize their flexibility. There are four possible mechanisms for these changes to occur, and they are not exclusive: transformation, adaptation, mobility, and interaction [30], [31]. Leupen (1997) provides examples of different levels of architectural design flexibility. From left to right, the performative and technical progressions are more complex due to the distribution's reliance on inventive and performative aspects that exhibit certain features[26]. Figure 4.6 demonstrate the flexible space changing degrees

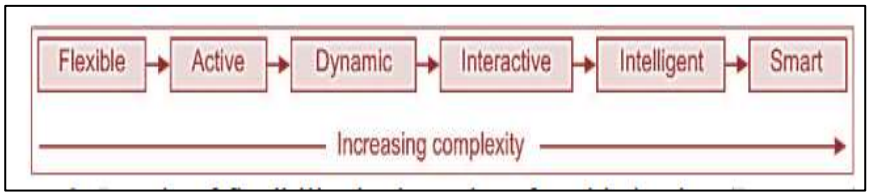


Figure 4.6: The Flexibility Degrees According to Leupen [32].

The degree of adaptability is contingent upon the speed and ease of modification. The building's structure and the amount of accessible space are the primary determinants of this. By adjusting sensory design aspects like color, light, texture, and surface material qualities, an open plan can be made to have different spatial qualities and be able to accommodate different uses without requiring any physical alterations or reconfigurations of the space. For example, interior color or light levels can be changed [10]. Considering the instances [17], [10] sort the many types of flexibility according to the type and extent of the modifications. Included in the basic ability division are the following: Location flexibility, sometimes referred to as structural flexibility, is the flexibility of interior size and arrangement, sometimes referred to as spatial reconfiguration, and functional flexibility, sometimes known as flexible or multipurpose rooms. Open plans can be divided into sections using kinetic elements, such as movable, folding, or sliding walls, doors, and furniture, to alter the spatial configurations. Spaces can change instantly and continuously in size and shape with human input. In order to optimize space and support different activities and crowd sizes in one area, like convention halls, kinetic components are also utilized. Different functions are supported by these elements in the same space. In 1942, Fred J. Mac Kie Jr. and Karl F. Kamrath demonstrated in "Movable Space Dividers" how moveable partition walls, which could be stowed in closets when not in use, might be utilized to divide a modular grid of one large open space into numerous combinations of smaller functional spaces which presented in Figure 4.7 [6].

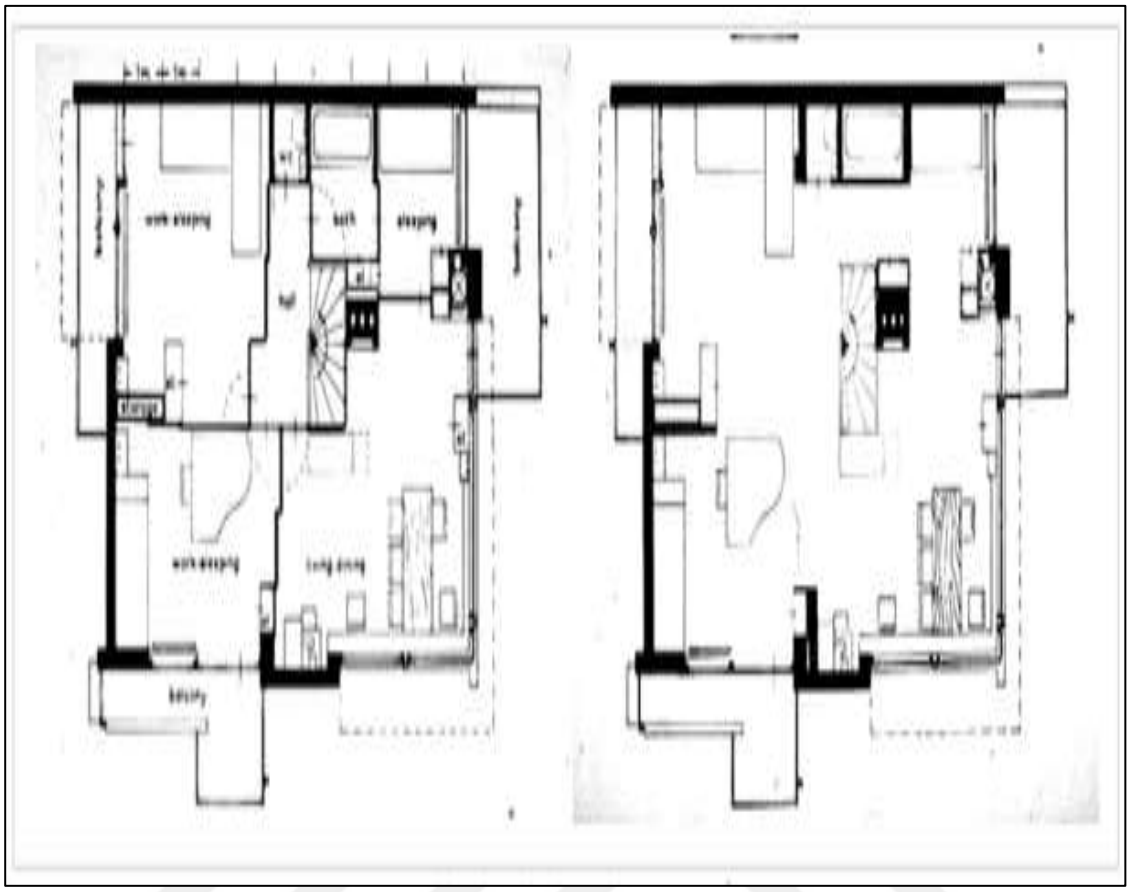


Figure 4.7: Gerrit Rietveld, Schroeder House Layout Transformation [6].

Foldable house designs are becoming more and more common despite site flexibility or structural flexibility, which refers to the addition of structural features that may or may not be load-bearing. They are able to move or be transported on their own. Werner Aisslinger's "Loft cube" is one of them. Its interior is adaptable, with sliding walls and multipurpose furniture. But the most crucial feature is the object's ability to be moved. The "Loft cube" project tackles the challenge of designing a contemporary, minimalist home for those staying temporarily in big, densely populated cities strives to have distinct and detachable structural layers and less load-bearing walls or columns.

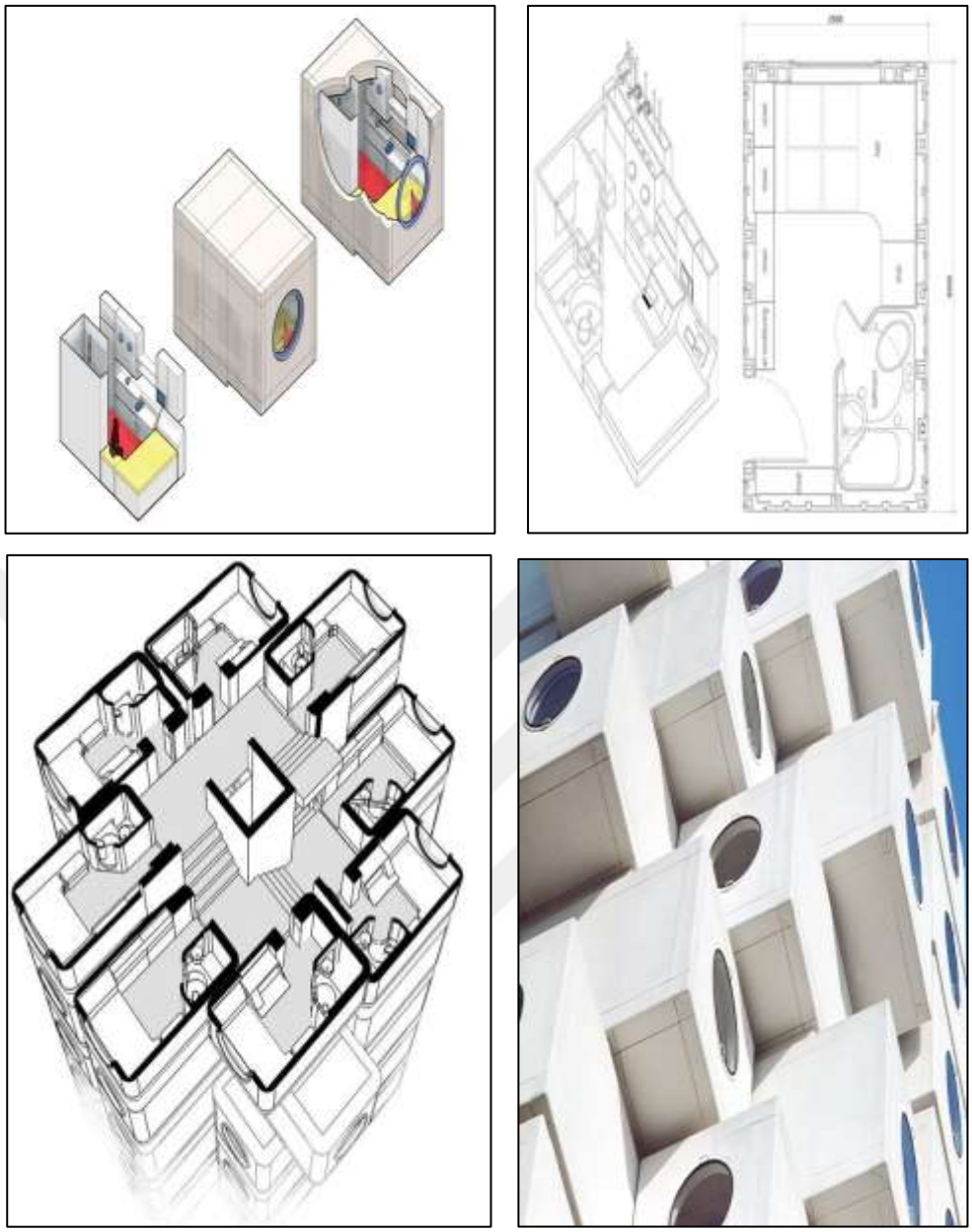
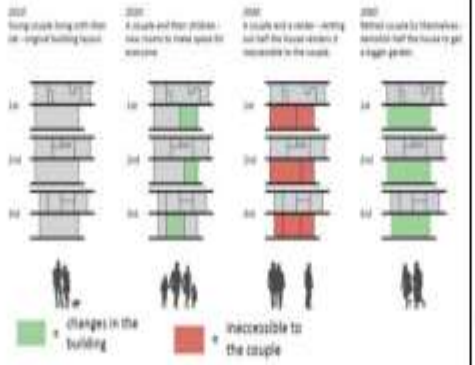


Figure 4.8: The Structural Flexibility In Nakgin Tower [30].

Loadbearing columns and beams, sometimes referred to as frame construction, are the supporting components that open plan designs typically use to provide an extensive span of uninterrupted space with a center that houses access and utilities [10] and functional flexibility (adaptable space): or Versatile space, which offers opportunities for many uses and activities in space [15]. It provides a way to design buildings and structures that are flexible enough to react to the quick changes in social and economic conditions in high-density locations [32]. These received the names "Changeable flats" and "Inflectional apartments," which could be adjusted to suit the needs of the elderly and disabled as well as

the family life cycle. Size flexibility, also known as spatial-dimensional flexibility, encompasses modifications including splitting, merging, and enlarging space[15]. By using a summary scheme and table, a thorough systematics that includes a graphical representation of each type of flexibility is shown Table 4.2.

Table 4.2: The Types of Flexibility in Housing Spaces.

Functional flexibility with various plan configurations	*Spatial-dimensional flexibility with various spatial opportunities for diversified users and needs*	*Structural flexibility with technical and structural opportunities*
		
		

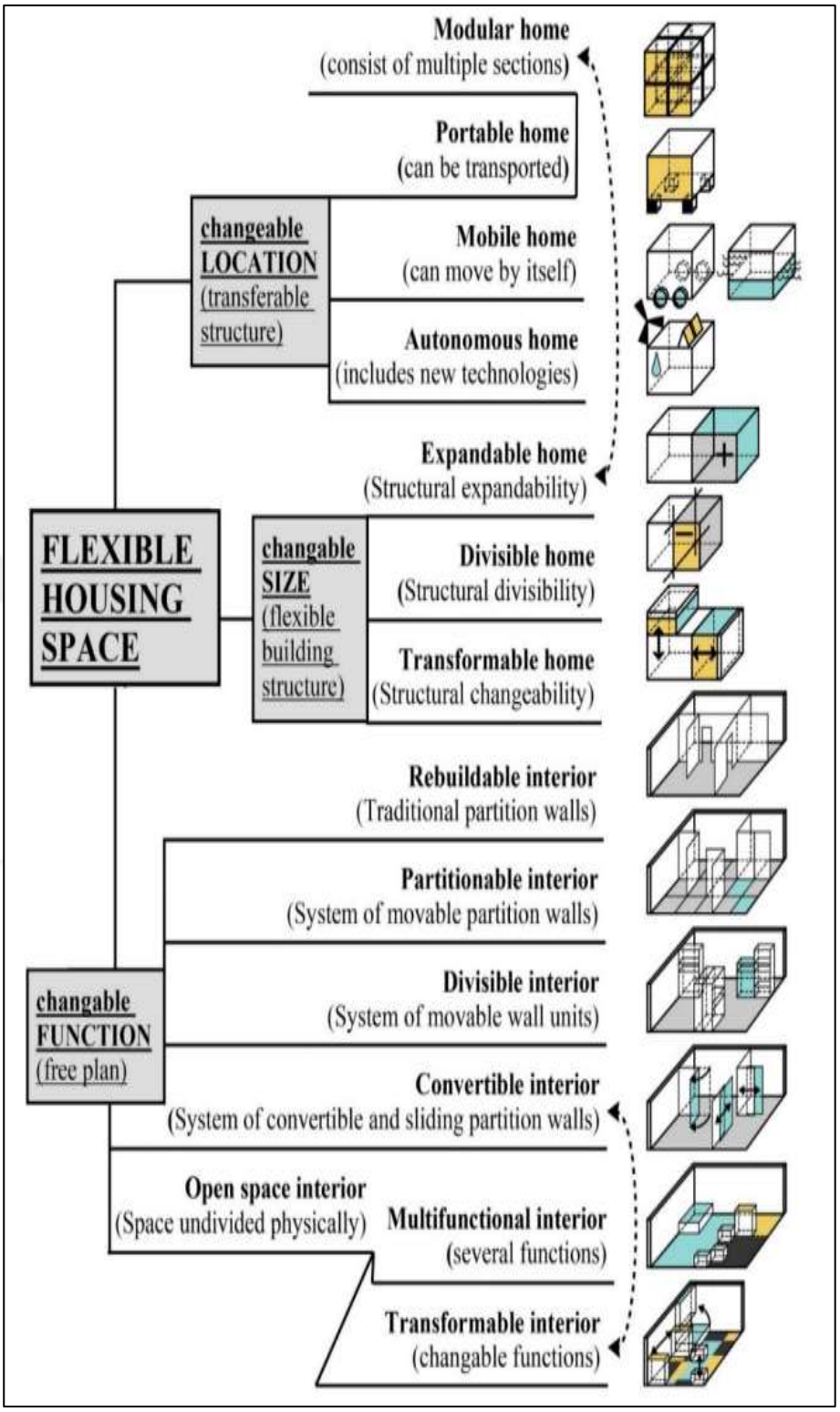


Figure 4.9: Types of Flexibility Depending On The Nature And Scale Of Changes [31].

Another way to facilitate flexibility is through a modular design approach. The house has rooms composed of a set of tatami mats, the dimensions of which are depending on their

normal size. The plan's openness and the frame's design imply that functional and social changes can be readily accommodated, whether they occur on a daily, periodic, or even longer-term basis. Opening and shutting sliding screens can be used to establish connections between rooms, quickly altering the size and purpose of a space. Sliding walls can be used to create connections between rooms. These walls can quickly alter a space's size and purpose. For example, two separate rooms can be joined by simply opening two moveable walls, combining a few small spaces into a single large room that can be used for a family gathering or a specific celebration [33], [34], [35], [36]as it is represented in Figure 4.10.

Figure 4.10: Movable Wall To Hide Living Room (Dividable Horizon) [62].

Figure 4.11: Multi-Functional Room (Dividable Vertically) [16], [63].

Multipurpose furniture: Foldable tables and chairs are only a couple of the many space-saving furniture options that are available nowadays. The sofa-bed, which doubles as a sofa and a bed, is one of the most popular space-saving furniture items in everyday usage in residential structures. Those that live in small apartments with limited room benefit from these adaptable furniture pieces [23].

Figure 4.12: Sofa Transform to Bed [5].

Figure 4.13 : Example of A Transformable Room [5].

They can be easily converted into beds at night and swiftly rearranged to become sofas during the day. For example, a sofa-bed is comfy and adaptable. A furniture place that can be transformed is the basic idea. Throughout the duration of a day, functions can change. Bunk bed dividers can be a good option when there is enough room and certain requirements are met, particularly if there are two children—one girl and one boy. This allows each child to have their own space in the room as shown in Figure 4.14.

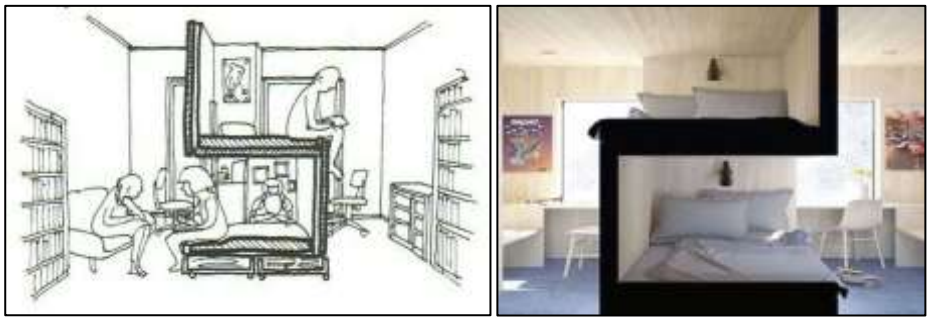


Figure 4.14: Divide The Room By Bunk Bed.

Figure 4.15: Transform Sofa To Be Bunk Bed.

The furniture must be carefully planned to accommodate various conditions in order to convert the space into multiple uses [35], [37]

Figure 4.16: Transform Table to Desk.

Multifunctional furniture is known by several names: space-saving furniture, convertible furniture, and general-purpose furniture. Furniture designed to serve multiple activities and objectives can be performed simultaneously [36], [38]. Another solution for small spaces is multifunctional convertible furniture that fits in your apartment. In such a solution the built-in wall consists of several pieces of furniture. Pull out the bed at night after opening the door. Just shut the door to use the back of the bed as a table, wardrobe, etc. throughout the day [39].

Figure 4.17: Bed Build in Wall [37].

Multipurpose furniture that is custom-made is one of these alternatives. Its name implies that it is intended to be utilized simultaneously by many programs, requiring varying amounts of space. Multi-purpose furniture is a clever idea that alleviates many problems in tight spaces

as it takes up very little space, but it also offers other uses that make users feel more comfortable using the space.

Figure 4.18: Example of A Multifunctional Furniture [2].

Because furniture takes up a lot of room, is expensive, and has a lot of imperfections, it not only makes organizing a space more difficult but also makes daily living more difficult in relatively tiny areas. Multipurpose furniture can give small areas a sense of balance while enhancing their efficiency and beauty. Modern multipurpose furniture is among the greatest choices for spaces that are small in size [19]. For example, movable kids' bedroom furniture shown in Figure 4.19 that is on wheels, including a bed and table, allows people to share and change the space in homes and apartments that are small[40].

Figure 4.19: Beds, Desks, Chairs, And Wardrobes That Are Movable In A Kid-Friendly Setting With Limited Space [36].

Additionally, it is modular furniture, which is defined by the points listed below:

a. Segment able and Joinable: Modular furniture is made up of separate elements that are put together in a way that allows it to be readily and frequently split and assembled together without sustaining significant harm.
b. Modularity: Since all of the components of modular furniture are machine-made, they are all interchangeable. One cabinet's side plate, for instance, can be swapped out with another cabinet's side plate. As a result, marking the sides and other parts is not an issue.
c. Design flexibility is made easier and better by the two previously mentioned factors. The furniture can have its shape altered, reduced, or expanded as needed [20].

Figure 4.20: Modular Furniture Design For Kids' Room [61].

Figure 4.21: Multi-Functional, Movable And Modular Furniture Which Becomes Bed, Sofa, Table And Closet [60].

Figure 4.22: Multi-Functional, Foldable, And Modular Furniture That Can Be Converted To A Sofa, Bed, Bunk Bed And Table In A Limit Space [40].

4.3.3 Smart Technology

Architecture can become the science of dynamic structures and environments running in one time. The intersections of multiple concepts to produce an environment with instantaneous response and action, such as intelligent and flexible [41]. “Smart” in this context means the integration of sensors, databases, and wireless access to collaboratively sense, adapt, and provide services for users in the home environment [41].

Smart structure in wall

a. My Green Space uses a display wall to create a scene of a forest that changes perspective based on the viewer's position, effectively extending a space visually. As showed in Figure 4.23.
b. Meeting Me Eating allows two people to eat together remotely while they are both seated alone in front of a huge display.
c. Ubi GUI is a graphical user interface, specifically designed for large, wall-sized displays also interfaced for medical health care applications that allows multiple input methods and is optimized for large screens [42]. An ongoing research project uses the wall as an interface to connect users and the system, adding additional functionalities to the rooms, which has been designed and employed it for the purpose of organizing and showcasing different medical devices. Nevertheless, UbiGUI can also be used as an interface for other programs, such as games, presentations, and smart home controllers [21].

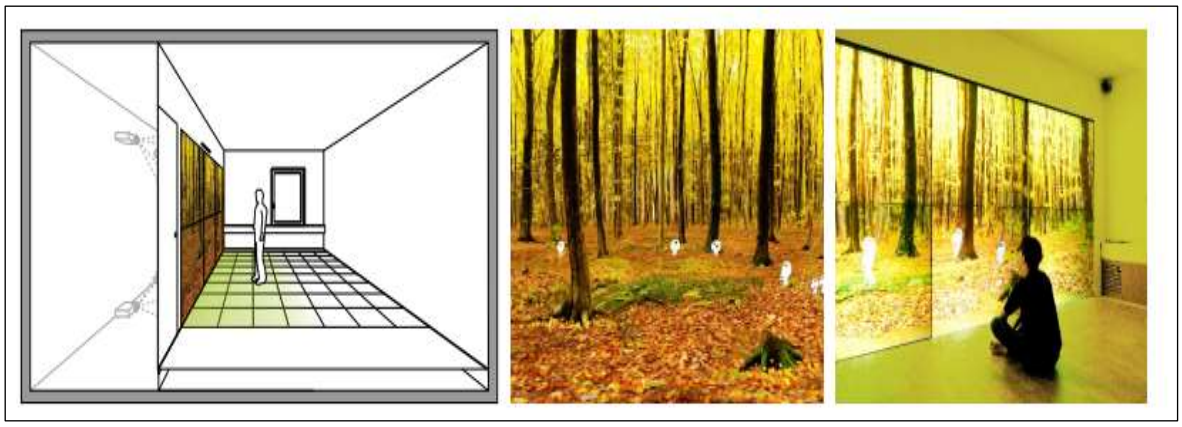


Figure 4.23: Section Through The System Setup (Left), Screenshot Of My Greenspace (Center), And Person Sitting In Front Of The Display Wall Showing My Greenspace (Right) [42].

Figure 4.24: System Concept (Left), Person Sitting In Front Of Display Wall, Which Is Showing The Video Stream Of The Dining Partner (Center), And Integration Into Virtual Scene (Right) [42].

In lighting: the flexibility to alter the illumination in every area. The types of lighting that are offered are cube light, which is illumination produced by fixtures like lamps, spot lighting, which includes recessed or hanging lights, and fluorescent pointing lighting. By choosing several lighting combinations, including the glow intensity of the light (50, 100, and 150%) and the quantity of lights for each room, a user can customize the quality of light in any location. The user will be able to see the various material and lighting combinations, the general ambiance, and the overall appearance and feel of his or her future house [43].

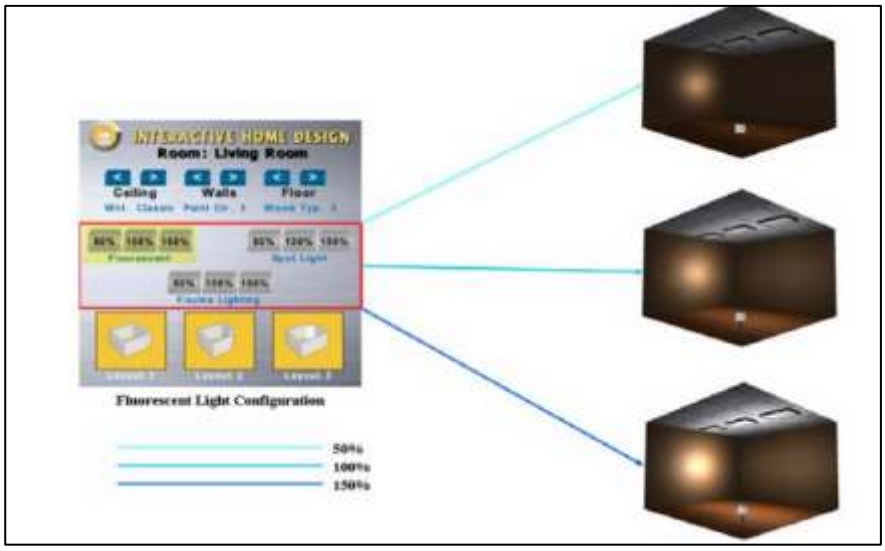


Figure 4.25: Interactive Lighting Conditions [32].

Although smart walls are a popular topic, there are movable furniture solutions for the floor and ceiling that offer significant space-saving benefits [16].

Smart furniture: A model for the influence of smart materials on interior design solutions was proposed by Ruuska and Hakkinen in 2014. Intelligent materials have at least one property that can be significantly altered, such as opacity, consistency, color, and form. There are many varieties of smart materials, and the focus here is on their actuation properties and spatial responsiveness, which are utilized as dynamic, self-acting surfaces in interior design. The primary attributes of smart materials are their reversibility, discrete size/location, energy exchange capability, and property modification capability.

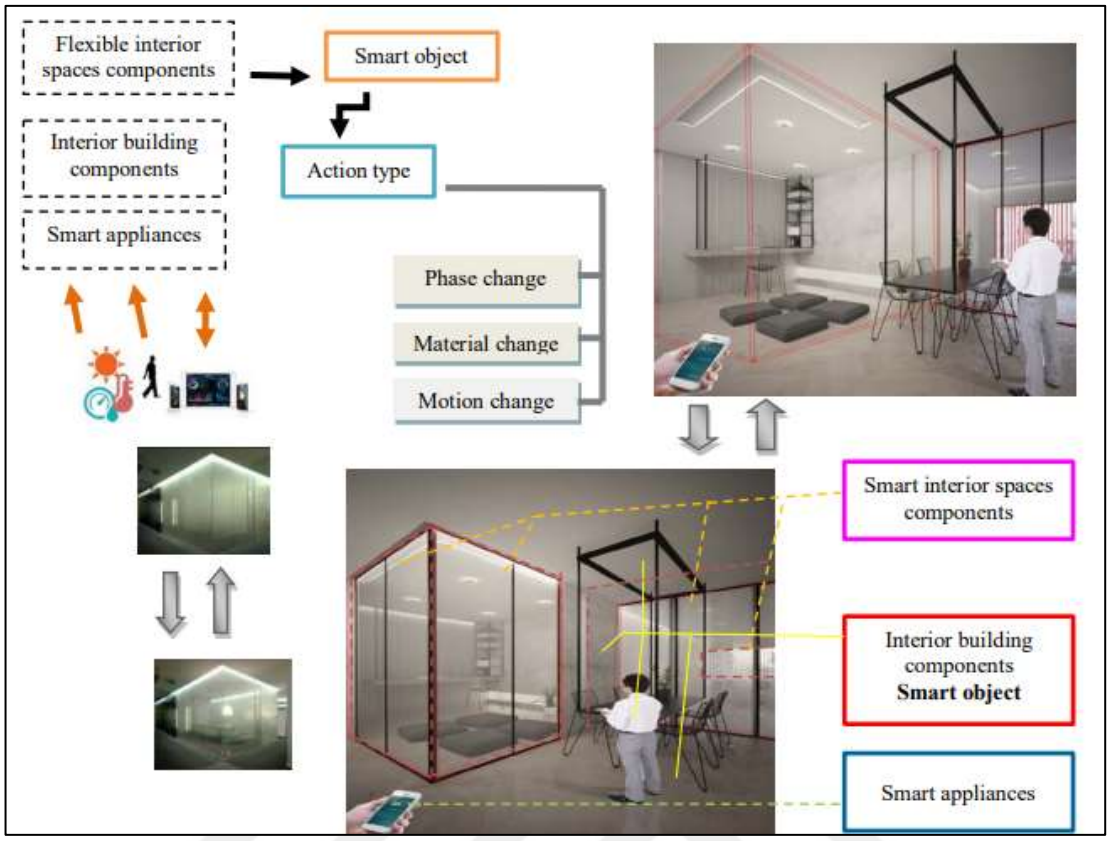


Figure 4.26: Smart Objects in Living Space [30].

Ori Living and Bumblebee have created state-of-the-art smart furniture that demonstrates how actuators may be used to make furniture moveable and adaptable. Furniture, storage, exercise equipment, lighting, office supplies, and entertainment systems are all incorporated into a movable wall system in the City Home project by MIT Media Lab, which gave rise to ORI furniture.

In addition to the Pocket Studio and Pocket Office smart walls with built-in beds and office tables, the product line of the year 2023 includes the Cloud Bed, a bed that is suspended from the ceiling. It is important to remember that while movable furniture alternatives installed on the ceiling or the floor are presently offered by manufacturers, smart walls are frequently regarded as the most eagerly awaited feature. These options allow for significant space savings. Increasing the functionality of living spaces with multifunctional, intelligent furniture that can instantly rearrange the interior arrangement of the room is the shared objective of the ORI and Bumblebee systems [17].

Figure 4.27: ORI Cloud Bed, ORI Pocket Studio, Bumblebee Bed And Table.

Form previous literatures the research summarized the characteristics of interactive functional space in table 4.3 as below.

Table 4.3: Characteristics of Interactive Functional Spaces.

Characteristics of interactive space in small house	Sustainable space	Environmental aspects	Comfortable ambiance	[3] [13]
			Good light	
			Good view	
		Social aspect	Convenient size (according to the standards)	[11]
			Saving space by adjusted to multitasking or activities	[17]
	Flexible space	Changeable size (spatial flexibility)	Dividable (horizontal or vertical)	[21] [27] [20] [24] [28] [29]
			Movable wall or partition	
			Open plan	
		Changeable location (structural flexibility)	Automated change	
			Mobile space	
		Changeable function (functional flexibility)	Adaptable space (multi-functional space)	
			Multifunctional furniture	
	Smart space	Smart furniture	Automated furniture, beds, chairs, curtains,	[21]
		Smart structure	Smart ceiling, wall, and floor, and lights	[26]

The next chapter is case study which involves the study of three projects which are being designed following the small house design. Project A is indicating the lack of smart features and flexibility, Project B with few adaptabilities. While Project C is of intricate design with all smart features and sustainabilities.

5. CASE STUDY: COMPARATIVE STUDY

Case study: The research chooses three residential projects to investigate a genuine problem inside a specified setting by using range of data source.

5.1 GENERAL VIEW ABOUT SELECTIVE PROJECTS

5.1.1 Project (a): Ciel et Terre Residential Tower / Molestina Architekten

Figure 5.1: Ciel Et Terre Tower.

SKYSCRAPERS, RESIDENTIAL DÜSSELDORF, GERMANY

Architects: Molestina Architekten

Area: 30000 m²

Year: 2016

[44]

Dusseldorf's former freight rail station is home to an 18-story residential high rise. From the exterior, its design distinguishes it from other tall buildings in the area. It has a different internal organization. As a result, a terrace-belt of varied depth surrounds each apartment, giving the impression that the unit is larger than it actually is and enabling residents to customize their outside area, which includes a sizable terrace with stone walls. A developer high-rise typically has a floor layout that is repeated from bottom to top. On the other hand, this structure is thought of as a vertical town, where different kinds of housing draw diverse kinds of residents, just like in a town. Mixing several housing types in one structure promotes social variety. The building's first two stories are made up of tiny units with separate private entrances from the street [25].

The following five floors above have smaller flats perfect for single or twin households, while floors seven through fifteen have larger apartments perfect for families. Two-story "patio houses" with a covered outdoor area are located at the very top. There are 155 dwelling units overall. The skyscraper takes up the middle part of the block, with two additional eight-story apartment building "wings" on either side [25].

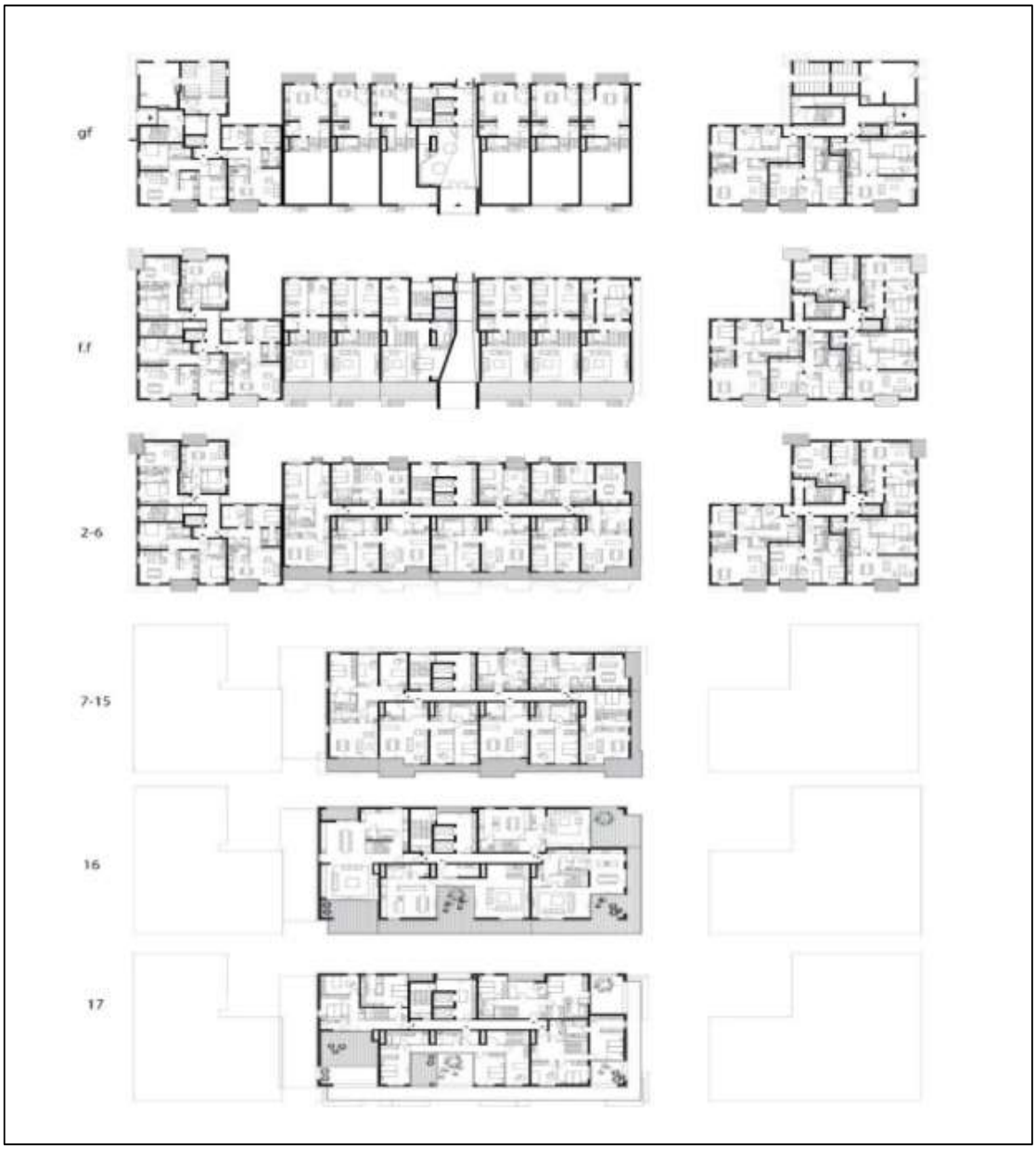


Figure 5.2: Plans of Ciel Et Terre Residential Tower.

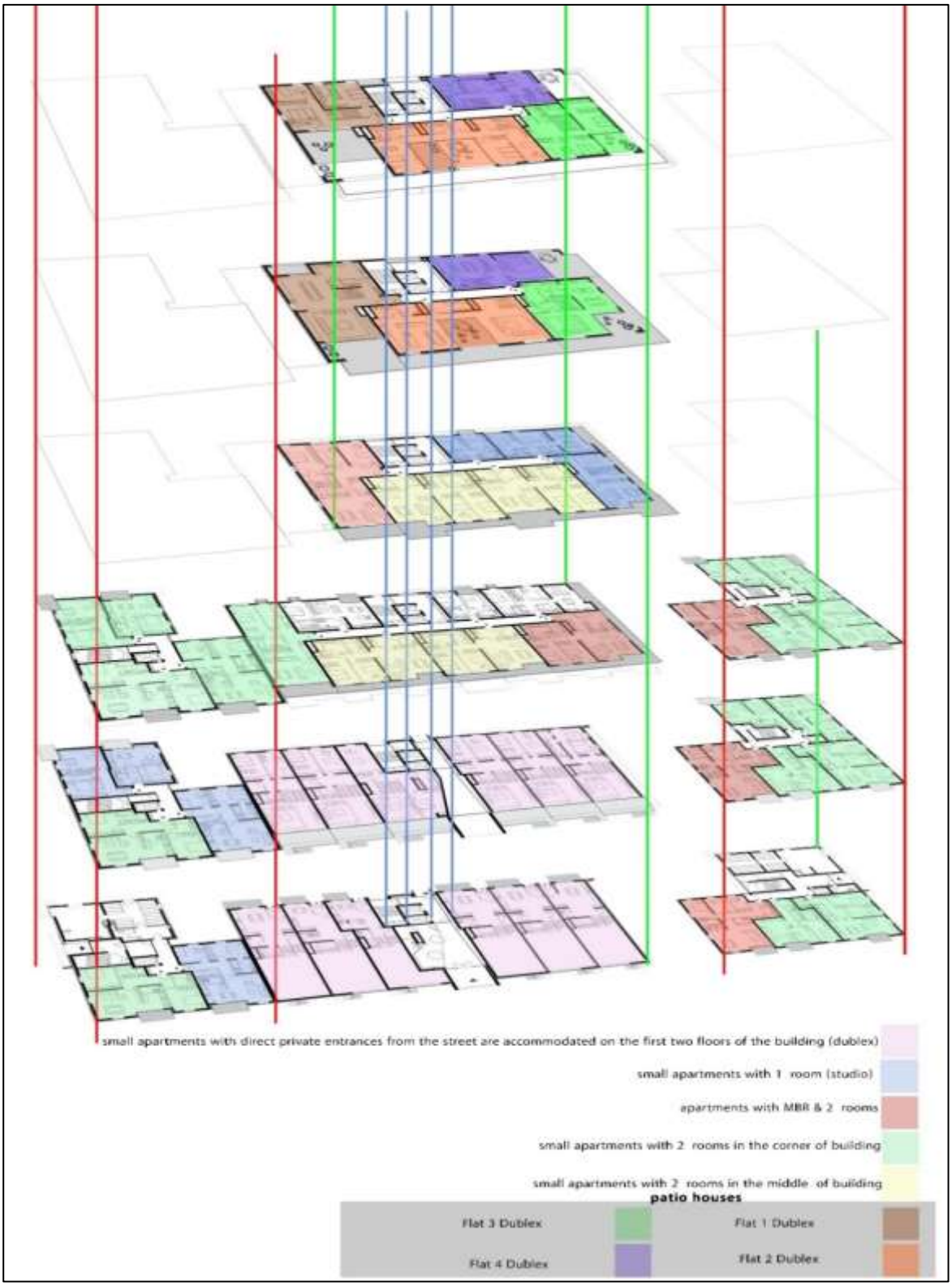


Figure 5.3: Stacking Diagram Plan.

5.1.2 Project (b): Via Verde—The Green Way

Figure 5.4: Via Verde Apartments New York, United States.

a. Architects: Dattner Architects, Grimshaw
b. Area: 294000 m²
c. Year: 2012

Situated on a brownfield site in the South Bronx, New York, Via Verde became victorious in an eco-friendly public housing design competition sponsored by the New York City Department of Housing Preservation and Development and the AIA New York Chapter, defeating over thirty other concepts. Because of its length and narrowness, the site proved somewhat difficult, according to William Stein, FAIA, of Dattner. In response, he and his design group made a construction that is lightweight and wide and can be folded up like a paper clip. According to Stein, "eco roofs step up from a central courtyard, which serves as the project's structural center" [45]
The layout of Via Verde, which includes a common courtyard and big windows, encourages cross ventilation between two external exposures, improving the natural flow of fresh air

throughout the residences and lowering the need for air conditioning. In addition to supplying Via Verde with solar power and panels are integrated into the stunning south-facing façade and outdoor pergolas, bringing the materials into the daily life of all occupants [45], [46].

A 20-story tower at the north end of the property, a 6-to 13-story mid-rise duplex apartment component, and 2- to 4-story townhouses to the south around a series of gardens comprise the three different building styles that house the 222 apartments. They provide a walkway for the residents, beginning at a ground level courtyard and upward through a series of designed roof gardens facing south. A community health center, retail stores, and live-work units on the ground floor provide a lively street presence. With a building-integrated photovoltaic system of 66 kW system, onsite cogeneration, green roof, communal vegetable gardens, green interior finishes, rainwater collection, and drought-tolerant plants, the complex achieved LEED NC Gold certification. [46], [47].

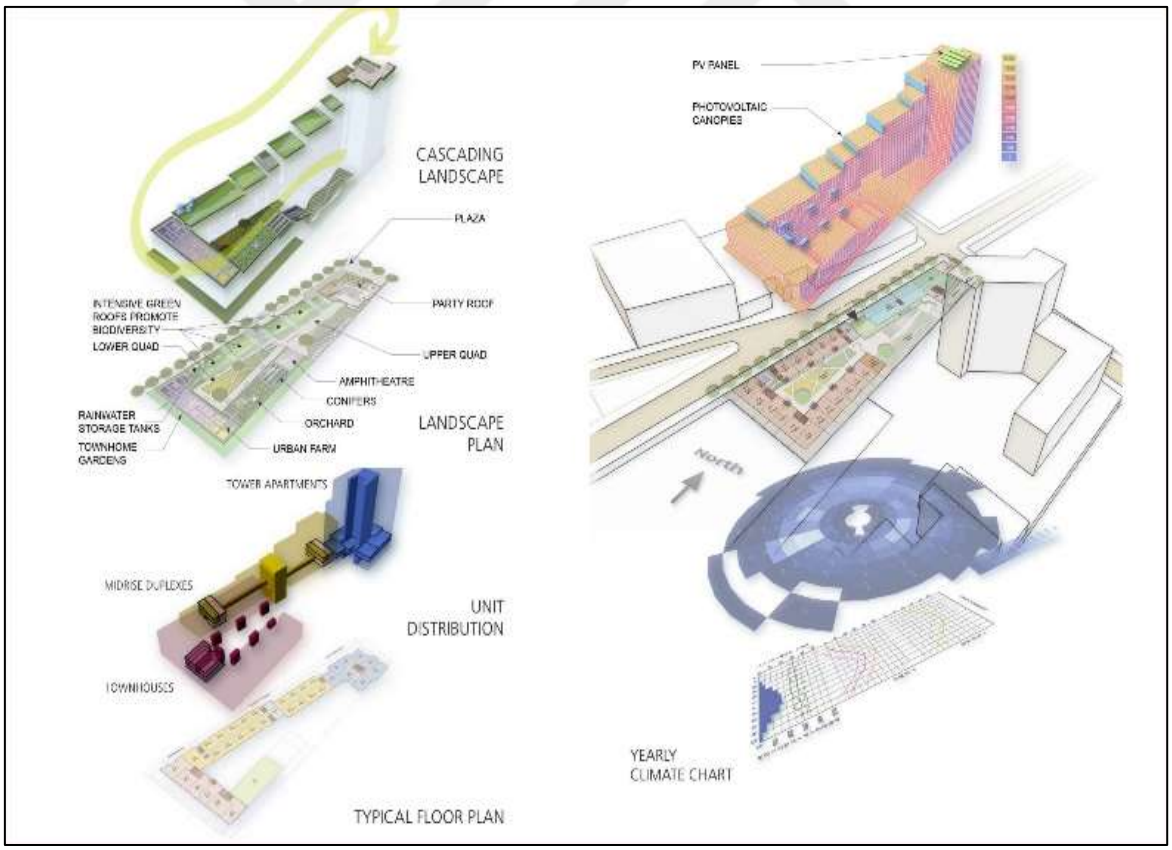


Figure 5.5: Distribution of Project.

Figure 5.6: Axonometric Diagram.

Key points of Figure 5.6:

I. Form
II. Roof gardens
III. Facade
IV. Ground floor
V. Townhouses: The project's townhouses include a combination of one-, two-, and three-bedroom garden and walk-up style units with social stairs.

a. Midrise duplexes: The duplex housing typology is achieved with central access corridor on every other floor and varying the width and depth of the first and second floors of each unit.
b. Tower apartments: The 20-story building houses rental apartments with studio, one, two, and three bedrooms.
c. Penthouse
d. Photovoltaic sunshade

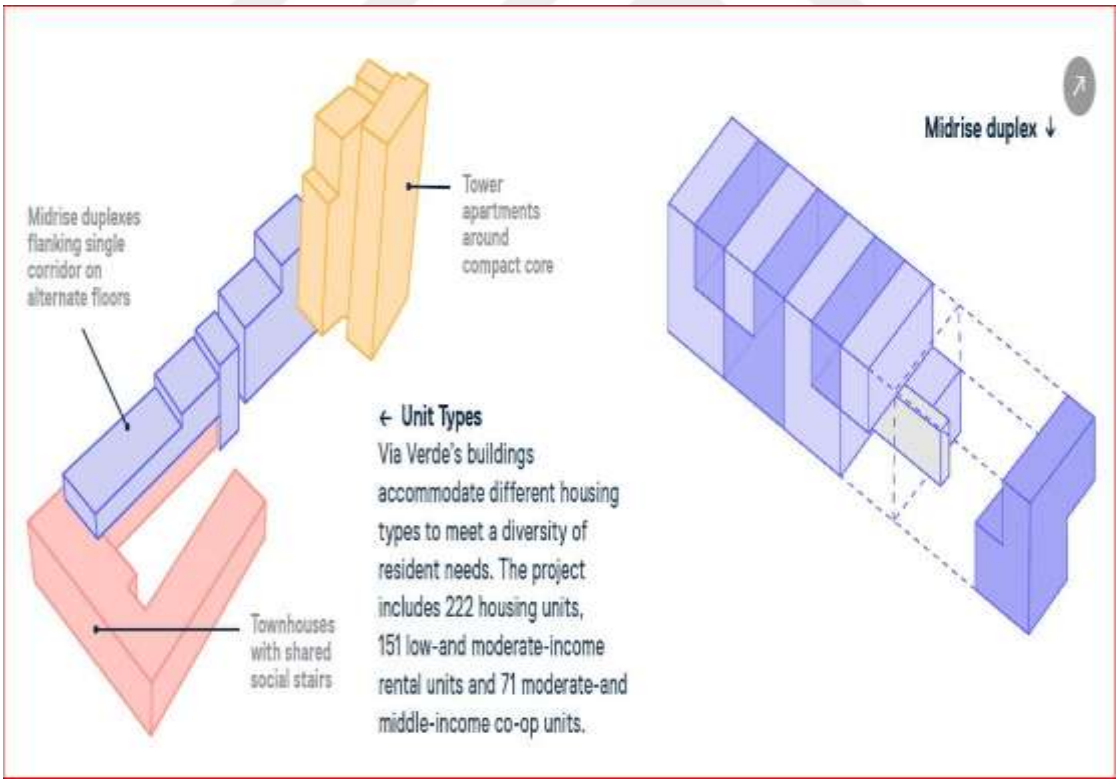


Figure 5.7: Unit Types.

Figure 5.8: Plan of Project (B) Via Verde.

Figure 5.9: Details Plans for Each Apartment Style.

Design of Unit. The designers used a range of unit types, including townhouses, two-story duplexes, and single-story flats, to maximize the site's limited area. In the mid-rise building,

duplex apartments. Each unit's entry level floor has one exposure and is equipped with an open living, dining, and kitchen space as well as a powder room. There are stairs leading to the upper level, which spans the building block and offers two exposures in addition to bedrooms and a complete bathroom [48].

Figure 5.10: Plan Of Duplex Apartment In Townhouse

Figure 5.11: Existing Photo From Apartment.

There are 17 three-bedroom units and 74 two-bedroom units. Among them are open living spaces where the living room and kitchen are connected by a wall. The open kitchen is meant to give the space a more expansive appearance and better suit contemporary expectations and lifestyles. [17]

Figure 5.12: Existing Kitchen and Bedroom From Apartment.

area is used by the remaining rental flats, which include studios and one-bedroom units. In addition to improve stainless steel appliances, all cooperative apartments feature washers and dryers. [18]

Figure 5.13: The Entrance with Open Kitchen and Bathroom.

5.1.3 Project (c): MVRDV Unveils Design for New Residential Complex in the Enterprise Research Campus in Boston

Figure 5.14: What The Building Looks Like From The Outside.

The architecture of a new residential complex by MVRDV has been made public. It is situated next to the Harvard Business School on the Enterprise Research Campus in the Allston area of Boston, Massachusetts. Three halves of the 343 apartments are currently under construction and designated as categorized as reasonably priced dwelling. Aiming to create an inclusive and enjoyable place within the new urban zone, it also features retail spaces for small local businesses and amenities for the people [49].

Figure 5.15: 3d Masterplan.

The MVRDV design borders the Greenway and is positioned in the center of the concept. Two apartment blocks, an eight-story mid-rise, and a 17-story tower with a 58-meter height are all part of the project. These buildings' ground floors, along with the nearby hotel created by Marlon Blackwell Architects, are joined by a one-story layer of common areas that the apartment complex's occupants can utilize, such as a meeting rooms, game room, gym, and co-working space [50].

Figure 5.16: Masterplan.

Apartments in the property range in size homes with two bedrooms to studios. Each apartment type comes in three different sizes. Small protrusions and indentations that give the building's picture texture characterize its design. The bay windows of old houses in Boston, which are frequently covered in green copper, served as the inspiration for the color scheme. The concept also aims to encourage resource efficiency and carefully selected, designed materials [65].

Figure 5.17: Facade Concept.

Apartments from the project consist of one-bedroom, two-bedroom, and studio units. The three distinct sizes of each apartment type push the façade inward and outward, giving the structures their appearance. The exterior design of the buildings is characterized by subtle protrusions and indentations that give them a fascinating texture. Additionally, by adding more flats with corner windows, these indentations maximize the views for each occupant [66].

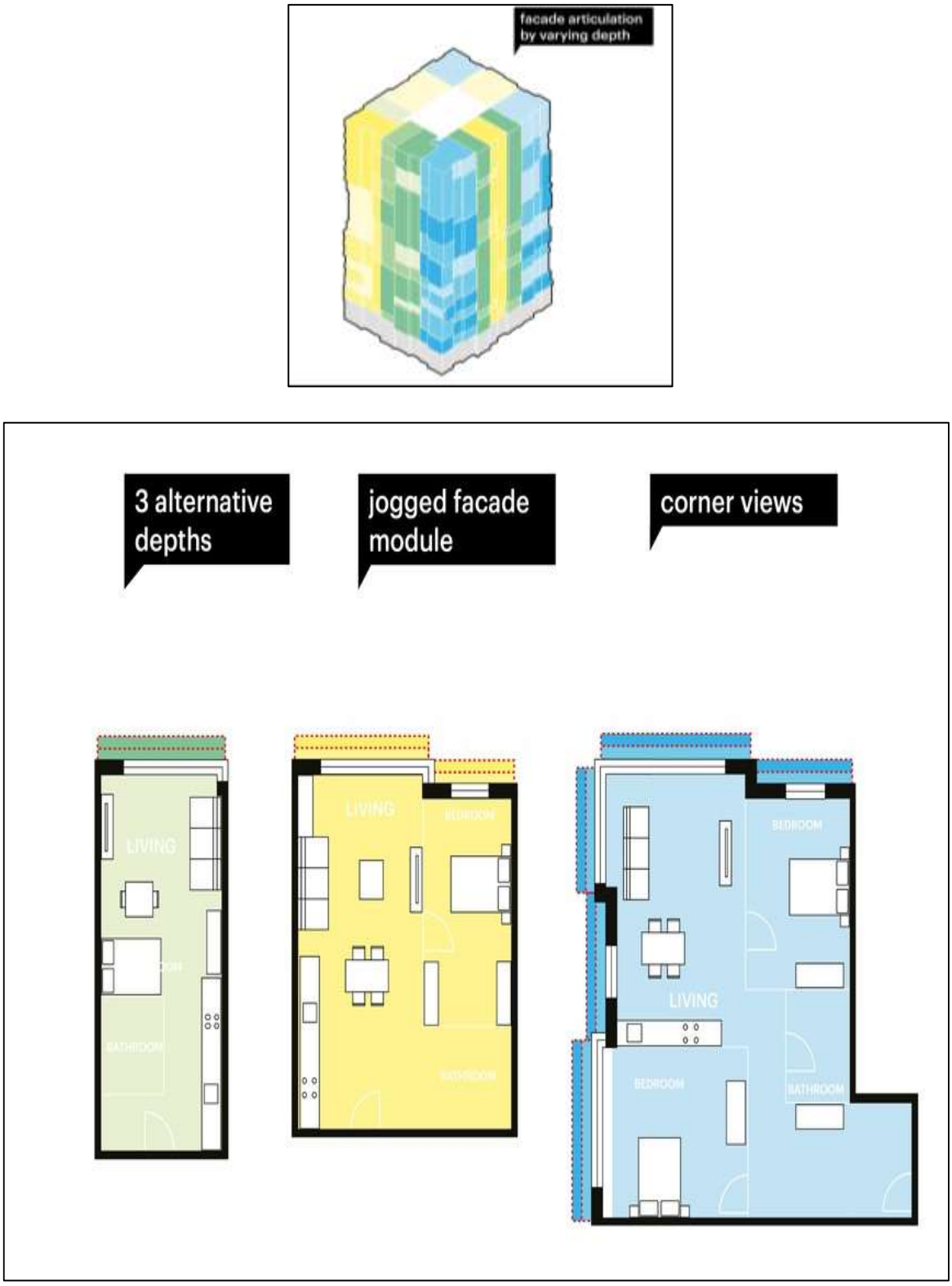


Figure 5.18: Plans for Apartments Studio/One Room And 2 Bedrooms.

5.2 COMPARISON OF MULTIFUNCTIONAL SPACES IN SMALL APARTMENTS ACROSS THREE PROJECTS

This comparison analyzes the use of multifunctional spaces within three contemporary residential projects: the Ciel et Terre Residential Tower by Molestina Architekten in Düsseldorf, Germany; Via Verde by Grimshaw and Dattner Architects in New York, United States; and a new residential complex by MVRDV in the Enterprise Research Campus in Boston. The focus is on evaluating each project's approach to space utilization and the integration of multifunctional spaces within small apartments, underlining the architectural strategies employed to enhance living experiences in urban environments [67].

Ciel et Terre Residential Tower / Molestina Architekten

Space Utilization:

The Ciel et Terre Tower is designed with an emphasis on vertical living, integrating green spaces at various levels to create a sense of openness and connectivity with nature. The tower's apartments feature flexible layouts that allow residents to customize and adapt their living areas to suit changing needs, effectively addressing the challenges of limited space in urban settings.

Multifunctional Spaces:

Key to the Ciel et Terre's design is its creative use of common spaces that serve multiple purposes. These include communal facilities, indoor gardens, and work spaces that expand living quarters beyond individual apartments, promoting a community-centric approach to urban living.

Via Verde / Grimshaw + Dattner Architects

Space Utilization:

Via Verde stands out for its judicious use and environmentally friendly design of space in a dense urban context. The project incorporates a mix of housing types, from low-rise townhouses to a high-rise tower, each designed to maximize natural ventilation and illumination. The architectural layout prioritizes spatial economy, with apartments featuring open-concept living spaces areas that seamlessly blend into private spaces.

Multifunctional Spaces:

The hallmark of Via Verde is its green rooftops and communal gardens, which are not only critical for the building's sustainability strategy but also serve as vital communal living spaces. The project further includes multipurpose community spaces and exercise areas, designed to foster a sense of community and well-being among residents.

MVRDV Unveils Concept for New Residential Building at Boston's Enterprise Research Campus Space Utilization:

MVRDV's design for the new residential complex is a testament to innovative space utilization, featuring a modular design that offers a great deal of versatility in terms of apartment sizes and configurations. This flexibility is essential for meeting the many needs of city inhabitants, from singles to small families, in limited spaces.

Multifunctional Spaces:

A defining feature of the focus of the MVRDV project is on developing "living hubs"—areas where residential, commercial, and recreational activities are all combined inside a complex. By making services and facilities conveniently accessible, these hubs aim to improve the quality of life for inhabitants by obfuscating the boundaries between livings, working, and recreational activities within the complex.

5.2.1 Comparative Analysis

Approach to Space Utilization: All three projects prioritize efficient use of space but employ different strategies to achieve this goal. While Via Verde blends eco-friendly architecture with clever layout planning, the Ciel et Terre Tower emphasizes vertical integration and public green areas, and MVRDV's residential complex makes use of modular construction for flexibility.

Integration of Multifunctional Spaces: Each project showcases a unique approach to multifunctional spaces. While Via Verde prioritizes communal living and environmental sustainability, Ciel et Terre encourages community connection through shared amenities, and MVRDV's design incorporates living hubs to accommodate a variety of activities, showcasing a progressive approach to multifunctional urban living.

Evaluation Summary:

a. Ciel et Terre Residential Tower: Scores remarkably innovative and effective use of architectural space, with a focus on vertical living and green communal spaces. However, it has room for improvement in adaptability and the integration of multifunctional spaces.
b. Via Verde: Excels in environmental sustainability and the creation of community spaces, reflecting an effective and innovative use of space. While it has a strong emphasis on common and verdant areas, there could be more focus on the adaptability of individual living spaces.
c. MVRDV Residential Complex: Stands out for its adaptability, flexibility, and integration of multipurpose "living units," showcasing a forward-thinking approach to residential design. While it scores slightly lower in community spaces compared to Via Verde, it leads in innovation related to the adaptability of spaces.

Creating a comparative analysis of multifunctional spaces within small apartments, with a focus on sustainability, flexibility, and smart space utilization, necessitates examining how each project integrates these aspects into their design. The projects selected for this comparison are notable for their innovative approaches to modern living challenges in dense urban environments.

5.2.2 Detailed Comparative Analysis

Sustainable Space

a) Ciel et Terre Residential Tower demonstrates a commitment to environmental sustainability through its use of green terraces that promote biodiversity and irrigation systems that gather rainfall. Social sustainability is addressed by creating communal spaces that encourage interaction among residents, fostering a sense of community within an urban setting. The project's design allows for ample natural light, improving energy efficiency and lowering the requirement for artificial lighting.

b) Via Verde sets a benchmark for sustainable living in urban environments with its comprehensive approach to green design. The building incorporates solar panels, green roofs, and a rainwater collection system that not only reduce the building's environmental impact but also contribute to the health and well-being of its residents. Socially, Via Verde promotes a community-oriented lifestyle through its inclusion of shared outside areas and meadows designed to support social interaction and physical activity.

c) MVRDV's Residential Complex in Boston emphasizes sustainability through innovative energy-conserving innovations and the use of sustainable materials. The design includes communal spaces that are intended to foster social interaction and community engagement, promoting an integrated approach to sustainable urban living. The complex's layout and orientation are strategically planned to maximize natural ventilation and daylighting, further contributing to its sustainability credentials.

Flexible Space

a) Ciel et Terre Residential Tower presents modular components that provide some spatial freedom within a set architectural framework and may be rearranged to meet the needs of shifting residents. The adaptability of the space is, however, somewhat secondary due to its major focus on sustainability, which is mostly achieved through the building's adjustable communal areas rather than within individual units.

b) Via Verde excels in offering tenants spatial flexibility by offering a range of apartment layouts, allowing them to select a place that best suits their needs right now, with the option to reconfigure it later. The project's design incorporates multipurpose common areas that can change to meet the community's evolving needs.

c) MVRDV's Residential Complex stands out for its dedication to designing environments that are naturally flexible. With components that can be moved or repurposed as occupants' demands change, the design allows for future modifications in how space is used. This is demonstrated by the addition of adjustable furniture and movable walls.

d) Different uses, allowing for a great deal of flexibility in the use of spaces.

Smart Space

a) Ciel et Terre Residential Tower incorporates a few smart home technologies designed to increase occupant comfort and energy efficiency. It has sophisticated construction materials and environmental control systems, but it lacks many intelligent furnishings and highly adjustable structural components.

b) Via Verde makes use of intelligent building management systems to minimize its environmental impact and preserve comfort levels throughout the year. The project is a

step toward smarter living environments even if it does not specifically focus on smart furniture. Instead, it makes intelligent use of available space and environmental systems.

c) MVRDV's Residential Complex is leading the way in incorporating smart space concepts, emphasizing technology-driven furniture and structural design solutions. It is a leader in smart space innovation with features including smartphone app-controlled appliances, lighting systems that change based on the time of day, and smart climate control.

Creating a detailed comparative analysis in a table format allows for a clear, at-a-glance understanding of how each project aligns with the principles of sustainable, flexible, and smart design within the realm of multifunctional spaces in residential architecture. Below is a structured comparison across the specified criteria for the Ciel et Terre Residential Tower, Via Verde, and MVRDV's Residential Complex:

Table 5.1: Detailed Comparative Analysis.

Criteria / Project	Ciel et Terre Résidentiel Tower	Via Verde	MVRDV Residential Complex
Sustainable Space - Environmental	-Verdant roofs to promote biodiversity - Materials that use less energy - Gathering rainwater for gardening	- Renewably powered photovoltaic panels; green roofs; rainwater collection systems	-Green roofs the use of eco-friendly materials - Energy-conserving innovations
Sustainable Space - Social	-Green spaces throughout communities -Encourage resident engagement	- Community gardens - Outdoor communal spaces for fitness and socializing - Health-focused amenities	- Interaction spaces in the community - Mixed-use areas for community involvement
Flexible Space - Size	- Modular units are available, but their ability to be reconfigured is limited.	- A range of apartment designs to accommodate various needs - A possible reorganization of space	- Extremely flexible living areas with repositionable furniture and walls
Flexible Space - Location	-a set architectural structure with some movable social spaces	- Fixed design with a focus on the adaptability of the common areas	- A flexible use of space that permits the addition of new functions

Table 5.1: Detailed Comparative Analysis “Table Continued”.

Flexible Space - Function	-Common spaces made to accommodate many purposes	- Outdoor areas created for a variety of social and recreational purposes	- Areas with flexible design that allow for seamless switching between uses
Smart Space - Furniture	- Insufficient emphasis on smart furniture	- Uses intelligent building management technologies in place of furnishings	-Comprising of app-controlled smart furnishings
Smart Space - Structure	-A few smart home solutions for comfort and energy efficiency	- Intelligent environmental systems for efficient use of resources - Climate control and intelligent lighting systems	-Cutting-edge smart home technology incorporated for responsive and dynamic spaces
Achievement	- Focuses on the community and uses environmental design to achieve sustainability - It has little flexibility and clever integration.	- Robust in terms of sustainability - Community development, somewhat flexible -Integrating some smart systems	-Leads in flexibility, sustainability, and efficient use of space, establishing the standard for upcoming projects

5.3 DISCUSSIONS OF RESULTS

The comparative analysis demonstrates how the sustainable, adaptable, and intelligent design approaches used in each project the MVRDV Residential Complex, Via Verde, and the Ciel et Terre Residential Tower distinctly handle the demands of urban living. While all the buildings share a dedication to sustainability, MVRDV leads the way in incorporating these elements to provide a progressive paradigm for urban residential development. The designs also differ in terms of flexibility and the usage of smart technologies. This analysis emphasizes how important multipurpose spaces are to contemporary urban design and shows how adaptability and technology innovation will drive residential construction in the future, surpassing aesthetic and environmental concerns.

The projects highlight the growing demand for efficient and flexible solutions that can adapt to the changing urban context and show how architects and designers are being called upon to respond to the complex difficulties of urban life. Future architectural undertakings can benefit greatly from the insights gained from these projects, which advocate for a comprehensive strategy that integrates sustainability, adaptability, and intelligent design. In addition to providing a standard for upcoming projects, this is an essential tool for continuing research and development in the area of architecture, which aims to create living

environments that adapt to the changing demands of city people. The study concludes by highlighting the role that multifunctional spaces have had in developing urban residential architecture and providing a model for the design of livable, sustainable, and community-focused surroundings.

Comparative Table:

Project 1 (Ciel et Terre Residential Tower)

Project 2 (Via Verde)

Project 3 (MVRDV Residential Complex)

Table 5.2: Comparative Table.

	Project name	Project 1	Project 2	Project 3
Criteria				
Sustainable Space -Environmental	- Green roofs	1	1	1
	- Rainwater system	1	1	1
	sustainable materials	1	1	1
	Total sum	3	3	3
Sustainable Space - Social	- Communal green spaces	1	1	1
	- Mixed-use spaces for community engagement	1	1	1
	Total sum	2	2	2
Flexible Space (Size)	reconfigurable layouts	-	1	1
Flexible Space (Location)	adaptable areas	-	-	-
Flexible Space (Function)	multiple uses for functions areas	1	1	1
	Total sum	1	2	2
Smart Space (Furniture)	smart furniture	-	-	1
Smart Space (Structure)	Smart environmental systems	1	1	1
	Total sum	1	1	2
	Total	7	8	9

Project 1:

a) Sustainable Space - Environmental: 3/3 = 100%

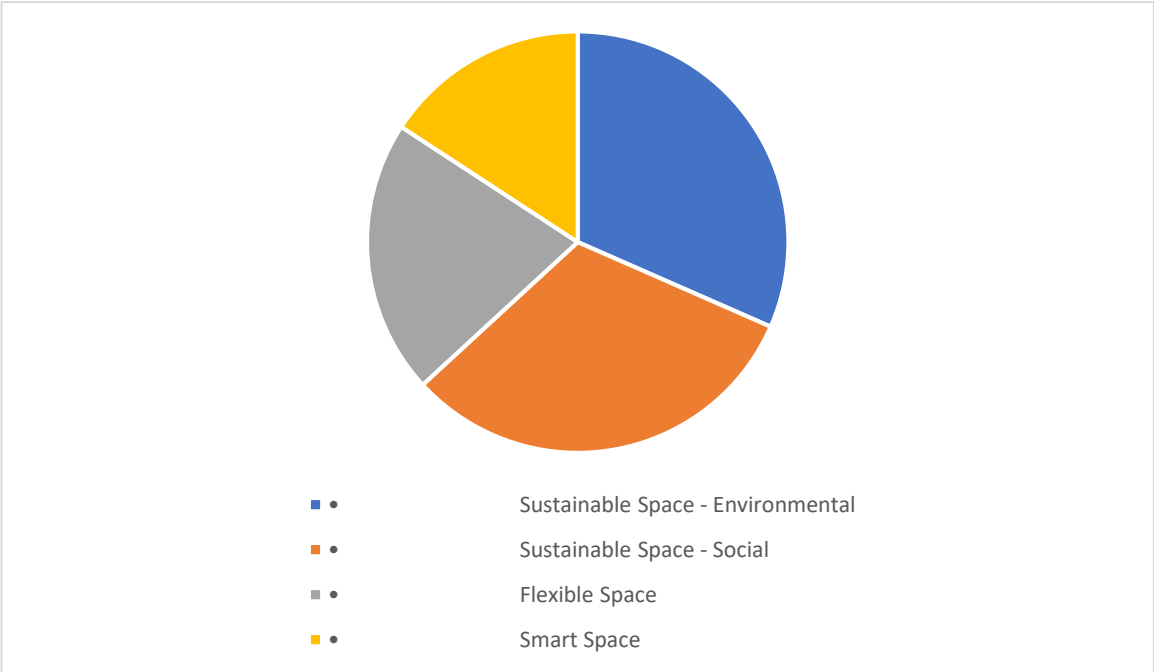
b) Sustainable Space - Social: 2/2 = 100%

c) Flexible Space: 1 (Size) + 0 (Location) + 1 (Function) = 2/3 = 66.67%

d) Smart Space: 0 (Furniture) + 1 (Structure) = 1/2 = 50%

e) Total: 7 points across all criteria

Chart 5.1: The Characteristics of Interactive Spaces Percentage In Project 1.



Project 2:

a) Sustainable Space - Environmental: 3/3 = 100%

b) Sustainable Space - Social: 2/2 = 100%

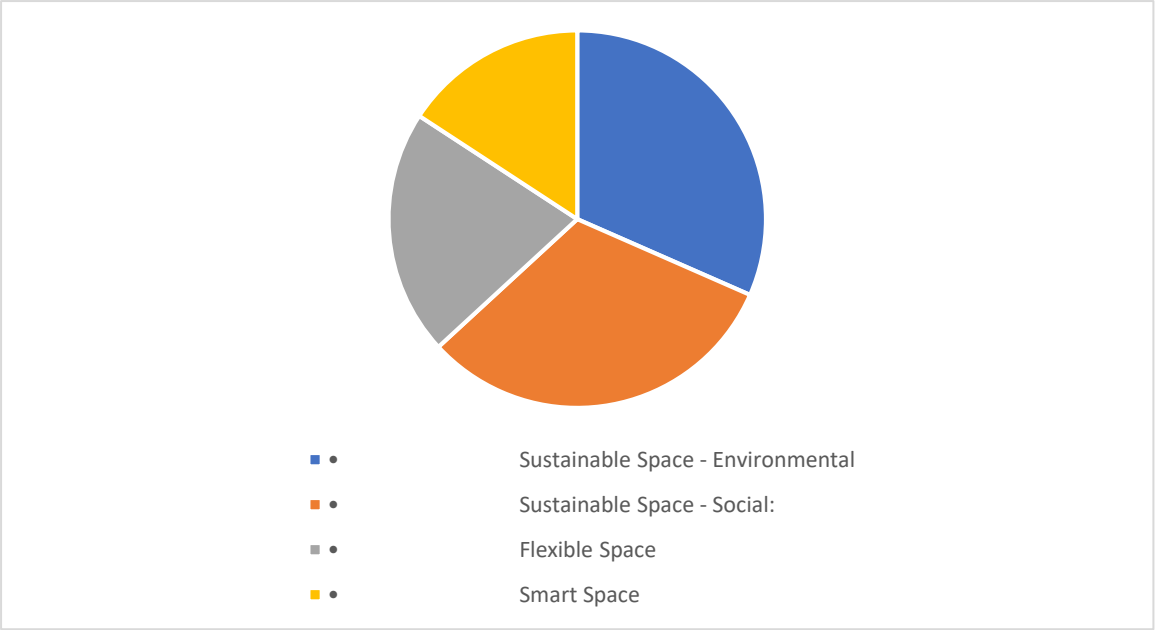
c) Flexible Space: 1 (Size) + 0 (Location) + 1 (Function) = 2/3 = 66.67%

d) Smart Space: 0 (Furniture) + 1 (Structure) = 1/2 = 50%

e) Total: 8 points across all criteria

f)

Chart 5.2: The Characteristics of Interactive Spaces Percentage in Project 2.



Project 3:

a) Sustainable Space - Environmental: 3/3 = 100%

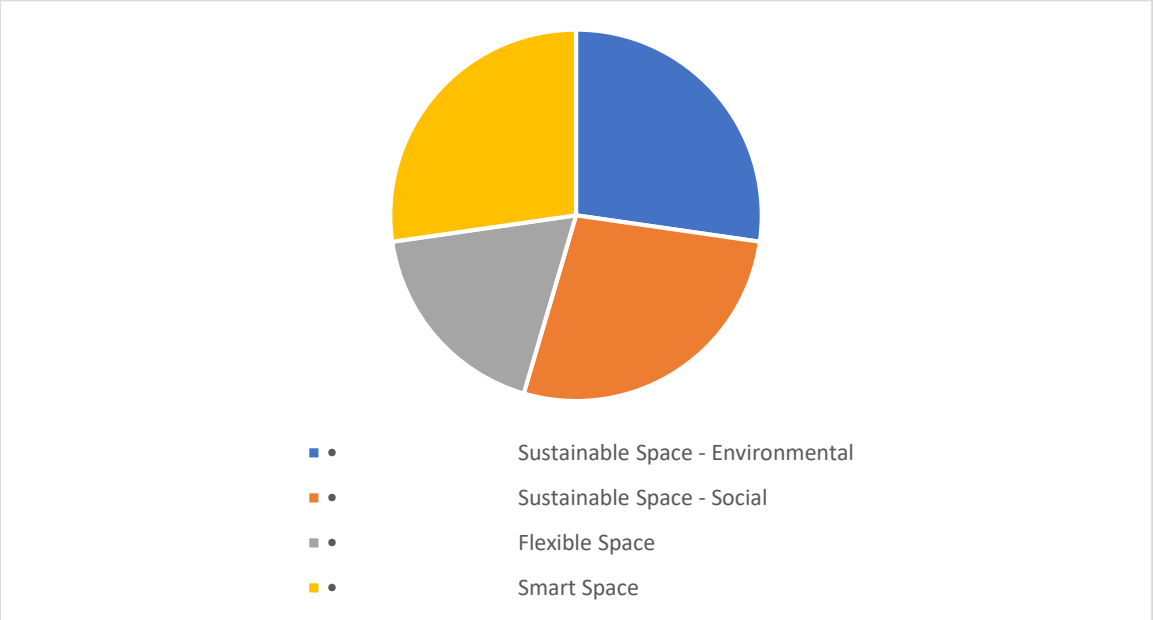
b) Sustainable Space - Social: 2/2 = 100%

c) Flexible Space: 1 (Size) + 0 (Location) + 1 (Function) = 2/3 = 66.67%

d) Smart Space: 1 (Furniture) + 1 (Structure) = 2/2 = 100%

e) Total: 9 points across all criteria

Chart 5.3: The Characteristics of Interactive Spaces Percentage In Project 3



Percent Chart:

Assuming that the maximum points possible for each category are as follows: Sustainable Space (Environmental and Social) is 5 points each (3 for environmental and 2 for social), Flexible Space is 3 points (for Size, Location, and Function), and Smart Space is 2 points (for Furniture and Structure). The total maximum points for each project would be 10 points (5 for Sustainable, 3 for Flexible, 2 for Smart)

Table 5.3: Percent Chart of Criteria About 3 Projects.

Criteria / Project	Project 1	Project 2	Project 3
Sustainable Space - Environmental	100%	100%	100%
Sustainable Space - Social	100%	100%	100%
Flexible Space (Total)	66.67%	66.67%	66.67%
Smart Space (Total)	50%	50%	100%
Overall Total	70%	80%	90%

Discussions: The comparison table quantitatively analyzes each project across the criteria of sustainable, flexible, and smart spaces. Each project has been scored with a '1' for meeting the specific sub-criteria and a '0' for not meeting it.

a) Ciel et Terre Residential Tower scores well in sustainable space by providing a comfortable ambiance, good lighting, and views, as well as spaces that support multitasking and activities. However, it lacks significantly in both flexible and smart space categories, with no evidence of adaptable furniture or smart technology integration in the structural design.

b) Via Verde demonstrates a strong commitment across all sustainability criteria and also provides a high degree of flexible space through the inclusion of dividable areas, movable partitions, and an open plan. It features some smart space elements but is not as comprehensive as the MVRDV Residential Complex.

c) MVRDV Residential Complex achieves the highest score, showing strengths in all categories. It not only provides sustainable living conditions emphasizing social and environmental factors while making the most of flexible space with features that are mobile, movable, and multipurpose. Furthermore, it is the leader in smart space design with automated furniture and integrated smart structures.

The MVRDV Residential Complex sets a benchmark in terms of multifunctionality, aligning with current trends in urban residential architecture that prioritize versatility and technological integration to enhance the living experience in small apartments.

Comparative Analysis Table:

Table 5.4: Comparative Analysis Table.

Criteria/Sub-criteria	Ciel et Terre	Via Verde	MVRDV Residential
1. Sustainable Space			
- Comfortable Ambiance	1	1	1
- Good Light	1	1	1
- Good View	1	1	1
- Convenient Size	0	1	1
- Space Saving (Multitasking/Activities)	0	1	1
Total for Sustainable Space	3	5	5
2. Flexible Space			
- Dividable (Horizontal/Vertical)	0	1	1
- Movable Wall/Partition	0	1	1
- Open Plan	1	1	1
- Automated Change	0	0	1
- Mobile Space	0	0	1
- Adaptable Space	1	1	1
- Multifunctional Furniture	0	1	1
Total for Flexible Space	2	5	7
3. Smart Space			
- Smart Furniture (Automated Furniture, Beds, Chairs, etc.)	0	0	1
- Smart Structure (Ceiling, Wall, Floor, Lights)	0	1	1
Total for Smart Space	0	1	2
Overall Total	5	11	14

Key: 1 = Criteria met 0 = Criteria not met

a) Sustainable Space: 5 points

b) Flexible Space: 7 points

c) Smart Space: 2 points

The total possible points across all categories would be 14 points.

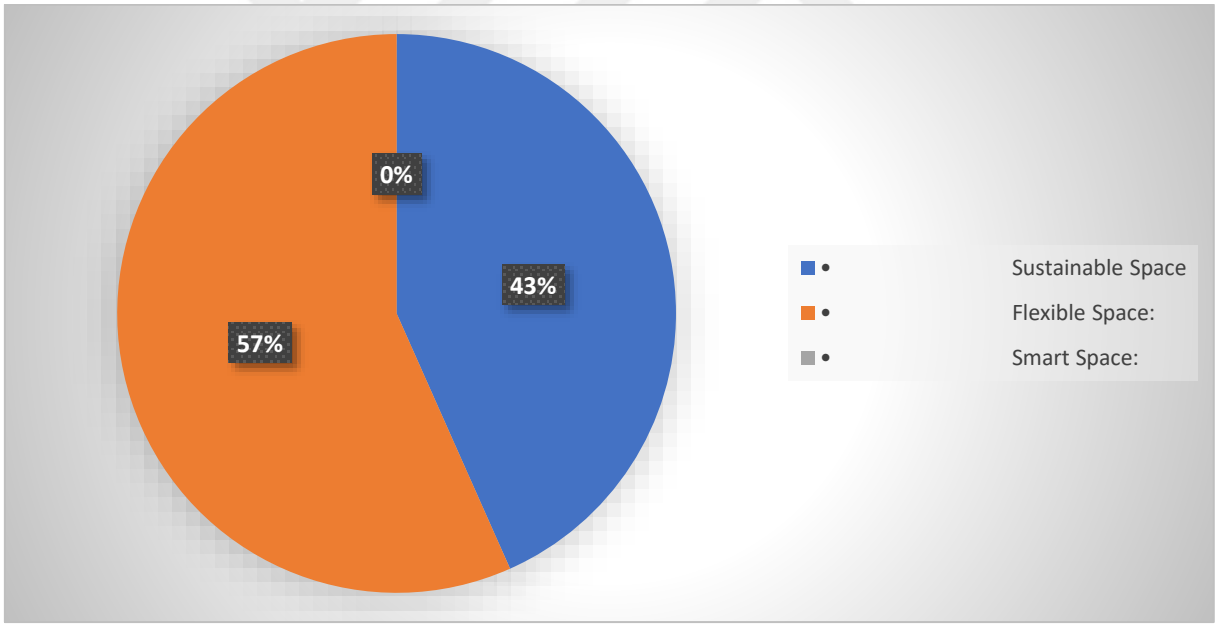
Project 1: Ciel et Terre Residential Tower

a) Sustainable Space: 21%

b) Flexible Space: 28%

c) Smart Space: 0%

Chart 5.4: The Percentage of use Sustainable Space / Flexible Space and Smart Space About Project 1.



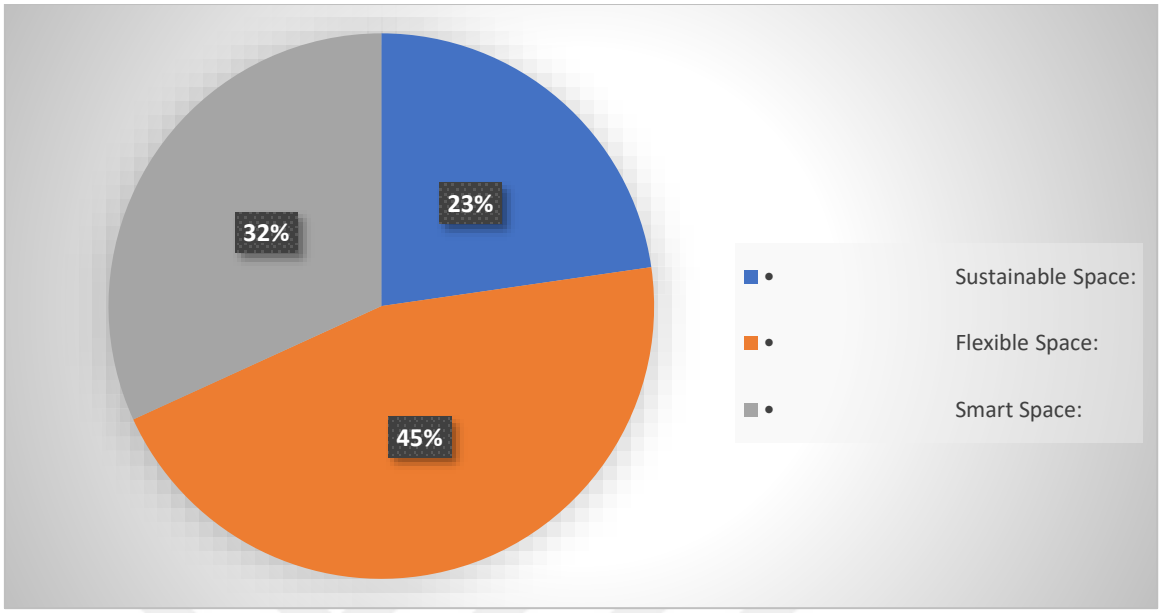
Project 2: Via Verde

a) Sustainable Space: 35.7%

b) Flexible Space: 71.4%

c) Smart Space: 50%

Chart 5.5: The Percentage of use Sustainable space / Flexible Space and Smart Space About Project 2.



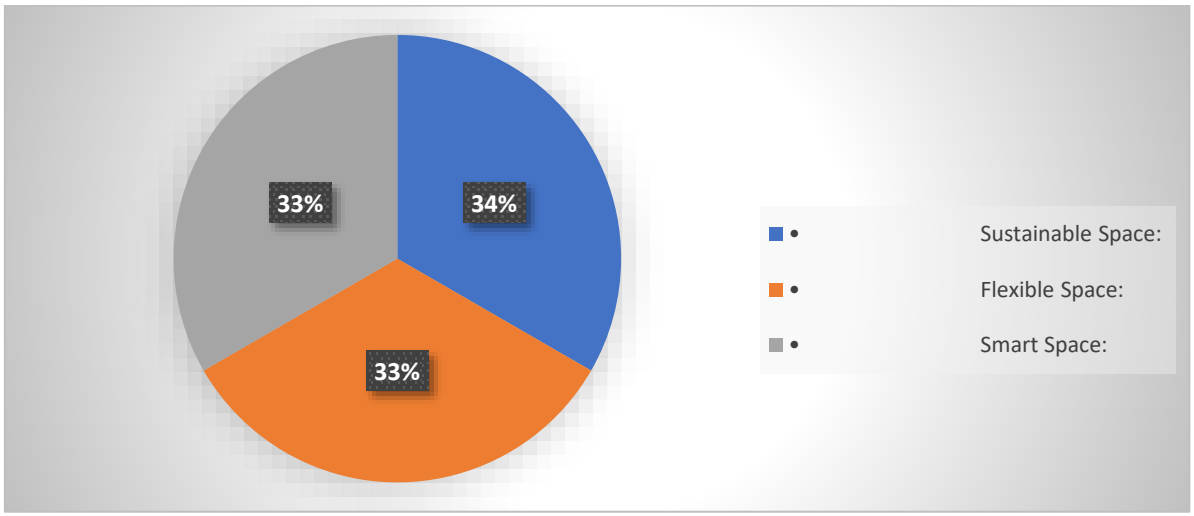
Project 3: MVRDV Residential Complex

a) Sustainable Space: 100%

b) Flexible Space: 100%

c) Smart Space: 100%

Chart 5.6: The Percentage of Use Sustainable Space/Flexible Space And Smart Space About Project 3.



Discussions of results from table Comparative

In terms of Sustainable Space, all projects perform well in providing a comfortable ambiance with good light and views, but Ciel et Terre falls short on size convenience and space-saving through multitasking, which Via Verde and the MVRDV Residential Complex meet successfully.

For Flexible Space, Via Verde and MVRDV's design both offer a range of adaptable features including dividable spaces and movable walls, contributing to a higher score compared to Ciel et Terre. The MVRDV Residential Complex stands out with the highest flexibility score, integrating automated and mobile spatial solutions.

When assessing Smart Space, the MVRDV Residential Complex excels in both intelligent structures and furniture, whereas Via Verde scores lower with only smart structures implemented. Ciel et Terre does not seem to incorporate smart space elements as per the criteria listed.

In conclusion, while each project has its merits, the MVRDV Residential Complex is the most comprehensive in meeting the multifunctional space criteria, followed by Via Verde and then Ciel et Terre. These findings suggest a trend towards integrating flexible and smart design solutions to enhance the functionality and sustainability of living spaces in dense urban environments.

The comparative analysis of the Ciel et Terre Residential Tower, Via Verde, and the MVRDV Residential Complex offers insights into the integration of multifunctional spaces within residential architecture. Discussing the results from the table reveals several key points about the design strategies and priorities of each project.

Ciel et Terre Residential Tower Discussion: Ciel et Terre achieved 60% of the sustainable space criteria, indicating a reasonable focus on environmental aspects and social spaces. However, the tower falls short in flexible space (28.57%) and lacks entirely in smart space categories. This suggests that while there is an effort toward creating a comfortable and ecologically considerate environment, the design has not placed as much emphasis on adapting to changing needs over time or integrating technology into the living space. The overall score of 35.71% reflects a potential gap in addressing the full spectrum of modern

urban living demands, particularly the growing need for spaces that can dynamically respond to user requirements.

Via Verde Discussion: Via Verde scores strongly in sustainable space with a perfect 100%, indicating that it excels in providing a comfortable environment with good lighting and views while adhering to size standards and allowing for activity-based space saving. In flexible space, it achieves 71.43%, which shows that it includes features such as dividable spaces and movable partitions, although there's room for improvement in fully automated or mobile spatial solutions. With a 50% score in smart space, Via Verde indicates a moderate application of technology in furniture and building infrastructure. The overall score of 78.57% suggests that Via Verde is a strong model for multifunctional residential spaces but could benefit from greater integration of smart technology.

MVRDV Residential Complex Discussion: The MVRDV Residential Complex leads with 100% in all categories, indicating a comprehensive approach that incorporates sustainability, flexibility, and smart design at high levels. The perfect score reflects a commitment to not only environmental responsibility and social interaction but also to a high degree of adaptability in the size, location, and function of spaces. Furthermore, the full integration of smart technology in both furniture and structural design suggests a forward-thinking approach to residential living that values automation and technological convenience. The overall score of 100% sets MVRDV's complex as the benchmark against which future multifunctional residential spaces might be measured.

6. CONCLUSIONS

This research culminates in a presentation of numerous findings in two areas: theoretical and practical. Regarding the former, the following are included in the theoretical section:

a. The development of the idea of small houses, with their different styles and uses, and the change occurring in their spaces over time, came as a response to continuous change and the development of the requirements of that change over successive eras of time, and the transformation of their spaces from a mono function to a multi-function.
b. An interactive functional space is that space that achieves responsiveness in meeting the user's needs by creating an environment that is appropriate in size and has comfortable environmental conditions (sustainable), and is subject to change in its function and size (flexible) by adopting smart technologies.
c. Multi-use or multi-functional furniture is a smart, interactive solution that responds to constantly changing user environmental and functional requirements within small homes.
d. Multifunctional space, diverse space, or open space is a basic and smart solution in achieving a comfortable and convenient environment for use without feeling cramped, stressed or uncomfortable due to small spaces in small homes.
e. Within the family life cycle, the need arises to change spaces by increasing the number of family members to suit the new requirements with the change occurring in the family life cycle and to preserve the social aspects of the family and the privacy of the individuals in it. Design for everyone and not for a specific group is an interactive and flexible design that aims to produce a comfortable and interactive environment that meets all different human needs.
f. Smart technologies such as automatic furniture, smart appliances, smart home technologies, and smart panels are ways that can be adopted to achieve a comfortable and interactive indoor environment with the user.
g. Providing smart solutions to solve the storage problem in small homes, such as using walls as storage areas, or using floors and ceilings as storage areas, which plays a role in achieving an interactive and comfortable living environment.

h. Open space is one of the solutions that modern trends and designers tend toward to solve the problem of small-sized spaces, as open space provides the possibility of multiple functions and design solutions for one space without any cost or efforts expended.
i. Flexibility and adaptability is another important feature along with sustainability of house that is mainly beneficially for poor and urban cities. Flexibility includes the implementation of Open designs that allow to change the way spaces are arranged by incorporating furniture, doors, and moveable, folding, or sliding walls.
j. Houses with small size is not inappropriate always, in converse that these small-sized spaces are the biggest challenge for designers and architects to find smart and sustainable solutions that are flexible in achieving an appropriate and comfortable environment and take social and privacy requirements of the users in consider.
k. The functional hierarchy of the spaces came according to the individual privacy and activities of users. The functional transformation of the space from monofunctional to multi-functional did not eliminate consideration of privacy, but rather created solutions to collect spaces that could be combined and this did not affect anyone's privacy.
l. Multifunctionality in the interior space is an interactive solution that enables the user to exploit the space optimally and effectively without the need to move between spaces. Taking into account the basic and minimum spaces that must be available for each space.
m. Considering its environmental benefits, because of its smaller size and lower energy requirements for heating and cooling, compact homes are a smarter option. Additionally, a defining feature of the tiny house movement, is essential to lowering carbon emissions and promoting environmental health.
n. Although building prices per square meter for tiny houses can be significantly more than for more conventional housing, they can still be a very affordable option to buy a place to live. Because conventional housing finance might be difficult to come by, financing for the purchase or construction of a tiny house usually involves some savings, discretionary cash, or relatively stable employment income.

While the conclusions that related with practical aspect are followed as:

The results point to a broader trend in urban residential design where sustainability remains a critical component. However, the increasing demand for flexible and smart spaces suggests that future developments should prioritize adaptability and technology to meet the evolving needs of urban dwellers. While Ciel et Terre presents foundational qualities of sustainable

design, its lack of flexibility and smart features may limit its appeal to residents looking for dynamic and responsive living environments. Via Verde offers a balanced approach but could push further in smart space integration. The MVRDV Residential Complex appears to set the standard for multifunctional living, providing actionable insights for architects and designers to create spaces that are not only habitable but truly aligned with contemporary lifestyles.

To sum up, tiny homes present a strong substitute for conventionally larger homes. They can improve relationships, encourage a more sustainable way of living, and help save money. They free up time and resources for the things that really count by taking up less room and demanding less upkeep. A modest house could be the ideal choice for those who are seeking for a more effective and satisfying way of life.

These discussions indicate that as cities become denser and technology continues to advance, residential spaces will likely need to be more versatile and intelligent to accommodate the varied and changing ways in which people live and interact with their homes[51].

7. DISCUSSION

As the saying goes, location, location, location is one of the main pulls to micro-housing, according to the well-known Millennial-focused website Micro Lifestyles. The close proximity to a city's cultural centers makes the space sacrifice beneficial, especially for budget-conscious millennials.

Living in a little house is nothing new. Living quarters for a large number of people worldwide would be deemed small by North American or Australian standards nowadays. Many others also live in transient homes that are easily moved as needed, either to accommodate a nomadic lifestyle or because they occasionally encounter obstacles that necessitate relocation. Some individuals live in tiny homes that will eventually grow larger, and even in Australia, it is common practice to add to homes as finances permit and household composition and size requirements dictate [68].

The small-home movement is becoming more and more popular these days since it transports people to more carefree eras. It's amazing to see how some tiny homes have been tastefully and imaginatively created, demonstrating that comfort and flair can coexist in a smaller space. As purchasing a home or apartment in the modern world is getting more and more expensive.

Many people are looking for more inexpensive housing options as a result of rising living expenses and rising rents. This is where the allure of tiny houses enters the picture; they provide an affordable lifestyle that is becoming more and more popular. Mini homes offer an economical alternative to the high cost of regular dwelling, frequently with creative prefab extensions. These small living areas can reduce costs and increase efficiency [69].

In addition, a wide range of individuals, including seniors and young professionals with small families, are drawn to the tiny house trend. These dwellings' flexibility and affordability provide a sense of financial freedom that is difficult to obtain in traditional living.

I have chosen this topic to be part of small homes movement, to give awareness regarding economical and healthier life style of smaller homes [69]. Discussing about case studies, I have selected them to point out spaces with modern life style comprising of all flexibilities and undeveloped spaces not properly facilitating with flexibilities smart approaches.

Discussing about its future aspects, the market for tiny homes has a bright future ahead of it, with various avenues for expansion [19]:

i. Technological Advancements: The sustainability and usability of tiny homes will be improved by the integration of energy-efficient solutions and smart home technologies.
ii. Customization and Innovation: By continuing to prioritize customization and creative design, the industry will be able to reach a wider range of consumers with a greater variety of tastes.
iii. Extension of Community Living: Tiny home villages and communities are becoming more and more well-liked because they provide people looking for a caring atmosphere with shared resources, opportunities for social interaction, and a feeling of community.
iv. Regulatory Support: As a result of their realization of the advantages of tiny homes, governments and towns may implement laws, zoning modifications, and financial incentives to stimulate the market.
v. Due to variables including cultural standards, housing cost, and regulatory settings, the desire for tiny dwellings differs by region. This is a market analysis by region [38]:
vi. Americas, North: North America's tiny home market has grown significantly, with the US and Canada being the main growth engines. The market is growing as a result of the growing demand for cheap homes and the emphasis on sustainable living.
vii. Europe: The idea of tiny homes has been adopted by nations like Sweden, Germany, and the Netherlands. The region's focus on minimalist living and sustainability drives market expansion.
viii. Asia-Pacific: The market for tiny homes has unrealized potential in the Asia-Pacific area. Adoption is anticipated to be fueled by rapidly increasing urbanization, rising housing costs, and shifting demographics in nations like South Korea, Australia, and Japan.
ix. Rest of the World: Other continents are beginning to investigate the possibilities of tiny dwellings, including South America and Africa. Market dynamics are influenced by cultural conventions, housing difficulties, and economic concern.

REFERENCES

[1] A. Ghafouri and C. Weber, “Multifunctional urban spaces a solution to increase the quality of urban life in dense cities,” *Manzar, The Iranian Academic Open Access Journal of Landscape*, vol. 12, no. 51, pp. 34–45, 2020.

[2] K. Thøgersen, “Small spaces need smart solutions,” *Journal of Design Department*, pp. 1–12, 2013.

[3] N. Balint, “As Apartments Are Shrinking, Seattle Tops New York with the Smallest Rentals in the US,” *RentCafe Blog*, 2018.

[4] S. Halliday and R. Atkins, *Sustainability: RIBA Plan of Work 2013 Guide*. RIBA Publishing, 2019.

[5] H. A. Husein, “Multifunctional Furniture as a Smart Solution for Small Spaces for the Case of Zaniary Towers Apartments in Erbil City, Iraq,” *Int. Trans. J. Eng. Manag. Appl. Sci. Technol*, vol. 12, pp. 1–11, 2020.

[6] M. Gjakun, “Flexibility and comfort in limited dwelling interior,” *Updated considerations regarding technical possibilities, functionality, trends and impacts on contemporary living since the period of 1970s*, pp. 38–190, 2015.

[7] J. Hanson, *Decoding homes and houses*. Cambridge university press, 2003.

[8] S. A. M. Al Husban, A. A. S. Al Husban, and Y. Al Betawi, “The impact of the cultural beliefs on forming and designing spatial organizations, spaces hierarchy, and privacy of detached houses and apartments in Jordan,” *Space and Culture*, vol. 24, no. 1, pp. 66–82, 2021.

[9] D. YASMIN and F. NILUFAR, “Morphological adjustments of domestic spaces: Spatial adaptations in the apartments of the lower-middle-income group in Dhaka.,” in *Proceedings of the 13th International Space Syntax Symposium, Bergen, Norway*, 2022.

[10] H. M. Madsen, M. M. Andersen, M. Rygaard, and P. S. Mikkelsen, “Characterizing Climate Change Adaptation in Copenhagen,” in *Sustain 2017*, Technical University of Denmark, 2017, p. Sustain-Abstract.

[11] O. Mahmoud Mohammed Ahmed, “Modern Design for Studio Spaces and Unique Residential Architecture [Studios, Lofts, Apartments, Condos, Units (Multi-Storey/Duplex-Family Dwelling/Single-Family Dwelling/Triplex/Fourplex/Penthouses)],” *Journal of Design Sciences and Applied Arts*, vol. 3, no. 2, pp. 47–73, 2022.

[12] L. Mundet, M. Grijalvo, and J. Marin, “Are camper travel lovers the New wave of tourism? A growing trend for destinations,” *International Journal of Hospitality & Tourism Administration*, pp. 1–22, 2023.

[13] D. M. T. C. Farina, M. Vrbinc, and A. Vrbinc, “Problems in online dictionary use for advanced Slovenian learners of English,” *International Journal of Lexicography*, vol. 32, no. 4, pp. 458–479, 2019.

[14] H. Rong, “Compact Living as a Lifestyle: Scenario-based Interior Design for Chinese Urban Tenants.” 2019.

[15] B. Abi *et al.*, “Deep Underground Neutrino Experiment (DUNE), far detector technical design report, volume II: DUNE physics,” *arXiv preprint arXiv:2002.03005*, 2020.

[16] T. A. Lagace *et al.*, “Secreted PCSK9 decreases the number of LDL receptors in hepatocytes and inlivers of parabiotic mice,” *J Clin Invest*, vol. 116, no. 11, pp. 2995–3005, 2006.

[17] S. Levmore, “Securities and secrets: Insider trading and the law of contracts,” *Va Law Rev*, pp. 117–160, 1982.

[18] J. Tao *et al.*, “Wood biomimetics: Capturing and simulating the mesoscale complexity of willow using cross-correlation reconstruction algorithm and 3D printing,” *Mater Des*, vol. 228, p. 111812, 2023.

[19] J. António Costa Branco de Oliveira Pedro, “How small can a dwelling be? A revision of Portuguese building regulations,” *Structural Survey*, vol. 27, no. 5, pp. 390–410, 2009.

[20] E. B. Ukabi and A. Ö. Akçay, “Conserving the Historical Identity of North Nicosia Walled City: Exploring Design Approaches and Implications from 1983 to 2003,” *Buildings*, vol. 13, no. 9, p. 2199, 2023.

[21] K. Boychenko, “Re-defining the Role of Interactive Architecture in Social Relationships,” 2021.

[22] C. Röcker and K. Kasugai, “Interactive architecture in domestic spaces,” in *Constructing Ambient Intelligence: AmI 2011 Workshops, Amsterdam, The Netherlands, November 16-18, 2011. Revised Selected Papers 2*, Springer, 2012, pp. 12–18.

[23] K. Jayatilake and R. Rajapaksha, “Interactive architecture and contextual adaptability: Issues of energy sustainability in contemporary tall office buildings in Colombo–Sri Lanka,” 2016.

[24] I. A. M. Al Khafaji and R. Kamaran, “The influence of spatial flexibility to improve sustainability of interior design by using smart technology (case study–future smart home in Iraq),” *European Journal of Sustainable Development*, vol. 8, no. 4, p. 438, 2019.

[25] D. Özinal and O. Erman, “Housing flexibility in terms of changes, opportunities, and sustainability of goals and values,” *Journal of Design for Resilience in Architecture and Planning*, vol. 2, no. 2, pp. 187–205, 2021.

[26] R. Kronenburg, “Flexible: architecture that responds to change,” *(No Title)*, 2007.

[27] R. Reuter, A. Snijders, and M. Bilow, “Space-saving techniques by the use of transformable architecture,” *Delft University: Delft, The Netherlands*, 2006.

[28] A. Salama, F. Wiedmann, and H. Ibrahim, “Migrant knowledge workers’ perceptions of housing conditions in Gulf cities. Journal of International Migration and Integration. ISSN 1874-6365,” 2017.

[29] R. K. M. Veneberg, M.-E. Iacob, M. J. van Sinderen, and L. Bodenstaff, “Relating business intelligence and enterprise architecture—a method for combining operational data with architectural metadata,” *Int J Coop Inf Syst*, vol. 25, no. 02, p. 1650007, 2016.

[30] H. A. Husein, “Multifunctional Furniture as a Smart Solution for Small Spaces for the Case of Zaniary Towers Apartments in Erbil City, Iraq,” *Int. Trans. J. Eng. Manag. Appl. Sci. Technol*, vol. 12, pp. 1–11, 2020.

[31] S. K. Bista, S. Nepal, C. Paris, and N. Colineau, “Gamification for online communities: A case study for delivering government services,” *Int J Coop Inf Syst*, vol. 23, no. 02, p. 1441002, 2014.

[32] S. Canepa, “Living in a flexible space,” in *IOP Conference Series: Materials Science and Engineering*, IOP Publishing, 2017, p. 052006.

[33] K. L. Grasby *et al.*, “The genetic architecture of the human cerebral cortex,” *Science (1979)*, vol. 367, no. 6484, p. eaay6690, 2020.

[34] M. Zanganeh, “Supervising Islamic Financial Institutions: Islamic Banking in The Countries Compared,” *Economic: Jurnal Ekonomi dan Hukum Islam*, vol. 5, no. 1, 2015.

[35] F. Martínez, “Full Journal (Vol. 15, Num. 2, 2018),” *Tekhnê*, vol. 15, no. 2, pp. 1–72, 2018.

[36] J. Swords and N. P. Townsend, “Mapping the Scale and Scope of the Creative Industries in Yorkshire and the Humber,” 2019.

[37] S. Wang, “An analysis of transformable space saving furniture,” 2013.

[38] T. Goessler and Y. Kaluarachchi, “Smart Adaptive Homes and Their Potential to Improve Space Efficiency and Personalisation,” *Buildings*, vol. 13, no. 5, p. 1132, 2023.

[39] C. Röcker and K. Kasugai, “Interactive architecture in domestic spaces,” in *Constructing Ambient Intelligence: AmI 2011 Workshops, Amsterdam, The Netherlands, November 16-18, 2011. Revised Selected Papers 2*, Springer, 2012, pp. 12–18.

[40] K. Kitchens and M. F. Shiratuddin, “Interactive Home design in a virtual environment,” in *7th International Conference on Construction Applications of Virtual Reality CONVR 2007*, 2007.

[41] R. Reuter, A. Snijders, and M. Bilow, “Space-saving techniques by the use of transformable architecture,” *Delft University: Delft, The Netherlands*, 2006.

[42] A. Salama, F. Wiedmann, and H. Ibrahim, “Migrant knowledge workers’ perceptions of housing conditions in Gulf cities. Journal of International Migration and Integration. ISSN 1874-6365,” 2017.

[43] R. K. M. Veneberg, M.-E. Iacob, M. J. van Sinderen, and L. Bodenstaff, “Relating business intelligence and enterprise architecture—a method for combining operational data with architectural metadata,” *Int J Coop Inf Syst*, vol. 25, no. 02, p. 1650007, 2016.

[44] S. K. Bista, S. Nepal, C. Paris, and N. Colineau, “Gamification for online communities: A case study for delivering government services,” *Int J Coop Inf Syst*, vol. 23, no. 02, p. 1441002, 2014.

[45] K. L. Grasby *et al.*, “The genetic architecture of the human cerebral cortex,” *Science (1979)*, vol. 367, no. 6484, p. eaay6690, 2020.

[46] M. Zanganeh, “Supervising Islamic Financial Institutions: Islamic Banking in The Countries Compared,” *Economic: Jurnal Ekonomi dan Hukum Islam*, vol. 5, no. 1, 2015.

[47] F. Martínez, “Full Journal (Vol. 15, Num. 2, 2018),” *Tekhnê*, vol. 15, no. 2, pp. 1–72, 2018.

[48] J. Swords and N. P. Townsend, “Mapping the Scale and Scope of the Creative Industries in Yorkshire and the Humber,” 2019.

[49] K. L. Grasby *et al.*, “The genetic architecture of the human cerebral cortex,” *Science (1979)*, vol. 367, no. 6484, p. eaay6690, 2020.

[50] F. Martínez, “Full Journal (Vol. 15, Num. 2, 2018),” *Tekhnê*, vol. 15, no. 2, pp. 1–72, 2018.

[51] J. Swords and N. P. Townsend, “Mapping the Scale and Scope of the Creative Industries in Yorkshire and the Humber,” 2019.