Iraqi Conventional and Future Smart Home Spatial Flexibility

Comparative Study

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Abstract:

Technological improvements in the past decade have altered individuals' preferences and lifestyles, necessitating their incorporation into the design and planning of urban areas. It is necessary to develop homes with enhanced agility, improved interrelationships among components, and more open systems. Traditional homes are exceedingly challenging to alter due to their rigid and unyielding structures. The predominant notion of space in contemporary residences is its classification by purpose, including bedrooms, bathrooms, and living areas. The new architecture should technologically adapt to promote building sustainability by assuring user wellness and safety, as well as the long-term value and efficiency of the structure, rather than necessitating users to conform to static environments. In this sense, Efficiency denotes Spatial Flexibility, which improves the quality of interior space. Spatial flexibility refers to the ability of interior spaces to be adaptive, responsive, and resilient. The primary issue of the research is the absence of definitive guidelines and experimental methods to elucidate how smart house design enhances the spatial flexibility of interior spaces in comparison to conventional residences. The researcher employed mathematical and graphical methodologies to evaluate hypothetical prototypes developed by the researcher and assess the influence of Smart technology on spatial flexibility in traditional houses and prospective smart houses in Sulaimaniyah (Kurdistan area of Iraq). The results indicate that smart houses exhibit enhanced spatial flexibility compared to traditional homes through the efficient utilization of space for a comprehensive array of purposes facilitated by smart devices.

Introduction

Recent decades have witnessed unparalleled social, technological, and economic transformations, requiring architectural innovation to meet society's changing demands. This innovation is essential since buildings increasingly necessitate adaptable structures and spatial arrangements to respond to swift changes in use and function [1]. The notion of "Spatial Flexibility" is based on the principle that spaces ought not to be limited by inflexible determinism. They should be built to accommodate evolving functions throughout their lifecycle, facilitating flexibility and preserving their value over time [2].

Traditional architecture, although somewhat adaptable, is chiefly constructed to meet the distinct requirements of a single period and function. Such spaces can support a restricted array of functions but frequently fail to address the challenges presented by swift and dynamic shifts in societal and technological demands. This constraint became increasingly apparent throughout the late 1960s and early 1970s, an era characterized by notable progress in artificial intelligence and information technology. These advancements led to the emergence of adaptive and responsive architecture, emphasizing adaptability and user-centered design [3].

The progression of smart house research in recent decades has emphasized the necessity of incorporating intelligent technology into architectural design. Future residences are anticipated to incorporate a decentralized network of smart devices that not only improve convenience but also fundamentally alter the utilization and perception of rooms. These devices will markedly contrast with conventional technology, merging effortlessly into their surroundings and facilitating intuitive human contact [4].

In this context, intelligent design has become a crucial method for attaining spatial flexibility, providing answers that traditional designs frequently lack. This study examines the principles of intelligent design and spatial adaptability, contrasting their implementation in traditional and smart residences. This document will delineate the research challenge, objectives, and methodology utilized to investigate this significant architectural development.

Research problem

There is an absence of definitive guidelines and experimental instruments to elucidate how smart house design enhances the spatial flexibility of interior spaces in comparison to traditional homes.

Research Aim

The research aims to develop guidelines on how smart house design can enhance the spatial flexibility of interior spaces in comparison to conventional housing, and to assess the potential for more efficient organization of future interior spaces through the application of smart technology, particularly in the Kurdistan region of Iraq.

Hypothesis

It is posited that smart house design enhances spatial flexibility by:

1. Increasing the ability to modify space regarding dimensions, configuration, and layout rearrangement.
2. Improved Activity-Space Interchangeability (tolerance) by offering many places for the execution of a single activity.

Methodology

A hypothetical prototype for both a conventional and a future smart home was built based on a literature review in the fields of smart home technology, spatial flexibility, and interior design, as well as the standards and guidelines of Iraqi urban development. The impact of smart technology on the spatial flexibility of the two prototypes was assessed using practical techniques. The employed Testing Tools are detailed below:

- Graphical scale to evaluate capacity for spatial modification regarding dimensions, configuration, and layout rearrangement:

  Various layouts of smart homes were examined by developing distinct scenes in hypothetical prototypes, demonstrating how smart technology enhances spatial flexibility by providing a high capacity for alteration in size and shape.

- Feasibility Matrix for assessing Activity-Space interchangeability (tolerance):

  Interchangeability for any set of activities and spatial schedules can be assessed using a feasibility matrix that connects the activities with Activity Stations. The entries in the feasibility matrix delineate the activities permissible in specific spaces. A white cell in the matrix indicates that the workstation is suitable for the activity represented by the row in the adjacent column; a tinted cell signifies otherwise. The degree of interchangeability between any collection of activities and any arrangement of spaces can be quantified by the number of viable allocations in the associated 0/1 feasibility matrix [5].

Inner Space's Spatial Flexibility

Spatial flexibility is an essential element of modern architectural design, allowing users to alter and adjust the configuration and organization of spaces to meet their evolving demands and preferences. This idea improves building use by providing open systems and more flexibility over the structural and functional arrangement of areas [1]. As structures encounter changing user requirements throughout time, spatial adaptability guarantees their enduring significance and functionality. The following discussion examines two fundamental concepts of spatial flexibility: Loose-Fit Flexibility and Activity–Space Tolerance.

Flexibility: Loose-Fit

Structures are fundamentally static and resilient, but human actions are dynamic and mutable. Throughout the lifetime of most edifices, the activities occurring inside them are likely to undergo substantial transformation. Although many new activities may be integrated into existing spaces, others may need alternative layouts, resulting in an activity–space mismatch. To tackle this difficulty, the notion of a loose-fit building—known as the Duffle Coat Strategy—highlights the design of areas that are not excessively customized for certain activities. This method entails establishing a degree of "slack" or surplus capacity inside areas, enabling them to adapt to unexpected changes in consumption over time. By eschewing excessively stringent design criteria, architects may guarantee that buildings stay versatile for various and changing activities, hence reducing the likelihood of incompatibility [5].

Flexibility: Activity-Space Tolerance

The Duffle Coat Theory posits that design flexibility is optimized when there are fewer different space types and a higher quantity of uniform or multipurpose areas. This activity-space tolerance allows areas to adapt to fluctuations in activities without requiring substantial structural modifications. For example, environments designed with flexible features, such as mobile partitions or adaptable configurations, may accommodate various activities without causing disruptions. Design flexibility enhances the variety of activities a building can accommodate, making it more adaptable and durable over time. Strategies to improve activity-space tolerance include the integration of moveable partitions, adaptable services, or inherent provisions for future expansion and alterations [5].

Within the framework of the information society, spatial flexibility is classified into three specific forms of space:

- Virtual Space (VS): Integrates components like intelligent walls and smart furniture linked to an information network, enabling virtual interactions and flexibility.
- Ambient Intelligent Space (AmI-S): Environments integrated with computing devices and sensors intended to facilitate everyday activities, like cooking, childcare, or personal duties, so providing a responsive and supportive environment.

- Physical Space (PS): Denotes conventional physical environments where individuals reside and engage with their surroundings directly [6].

Spatial Adaptability in Traditional and Smart Houses

The development of living spaces signifies an increasing need for flexibility in response to changing lifestyles and technology. Conventional houses provide designated functional areas for certain activities, such as bedrooms, living rooms, and kitchens, but smart homes present a novel paradigm characterized by interactive, responsive, and multipurpose environments. These areas may accommodate many activities, providing a dynamic and user-focused living experience.

Traditional residences are characterized by rigid space delineations and unchanging functionalities. Daily activities are segregated into separate rooms, limiting the home's flexibility and adaptability. This concept may be appropriate for traditional lives, but it does not meet contemporary requirements for flexibility and multifunctionality in living areas.

Conversely, smart houses transform spatial flexibility via the incorporation of sophisticated technology and intelligent systems. These residences enable occupants to customize and tailor environments to suit their interests and tastes. For example, smart houses may have elements such as moveable partitions, interactive smart walls, and furniture with programmed settings. These technologies allow rooms to fulfill numerous functions—such as a single room converting from an office during the day to a pleasure area in the evening—without necessitating structural alterations.

Essential technologies that augment spatial flexibility in smart homes comprise:

- Intelligent Adaptable Partitions: Mobile and customizable barriers enabling users to establish or combine areas as required.
- Intelligent Boundaries with Variable Transparency: Walls or partitions capable of altering their transparency to provide seclusion or openness.

- Intelligent Kitchen Tables: Featuring versatile cooktops, wireless power systems, and integrated digital networks, these tables improve utility and flexibility.
- Smart Walls: Interactive surfaces integrated with advanced intelligence technologies for entertainment, communication, or environmental management.
- Intelligent Furniture: Furnished with sensors and programmable settings, these items may adapt to various user requirements.
- Smart Floors: Integrated with sensors and intelligent networks to observe and react to human activity [7].

Smart homes are designed to provide a smooth and intuitive living experience, catering to the increasing need for adaptable and multipurpose environments. As everyday activities become more fluid and less anchored to particular areas inside a residence, the inflexible confines of traditional design are supplanted by environments that adapt and react to users' requirements in real-time. This transition signifies a fundamental reevaluation of residential architecture, emphasizing flexibility, interaction, and user-centric design.

Case Study: Sulaimani, Kurdistan Region of Iraq (KRG)

Designing Hypothetical Prototypes (Conventional and Smart)

This section delineates the approach used for constructing hypothetical models of a future Smart House and a contemporary Conventional House in Sulaimani, Kurdistan Region of Iraq. The prototypes were designed to meet the demands and desires of a particular target demographic: young people contemplating the investment in or purchase of their own houses. This group was selected for its receptiveness to new technology and its readiness to implement novel housing solutions.

Guidelines and Standards

The sample designs were created in accordance with the Urban Housing Standards published by the Ministry of Construction and Housing of the Republic of Iraq in October 2010 [8]. These criteria, derived from extensive research by Polservice Company inside Iraq's national housing initiative, provide crucial directives for the design of residential spaces that conform to local requirements, cultural norms, and economic circumstances.

Table 1. Minimum indoor usable floor space needed according to urban dwelling guidelines [8].

Category of Dwellings	**Occupancy rate**	**In-door useful floor area of a dwelling**	
	No. of persons/ dwelling	**One-family housing (m^2)**	**Multi-family housing (m^2)**
Small	--	--	57 - 63
	1-3	75 – 81	69 – 75
Medium	3-5	99 – 105	93 – 99
	5-7	114 – 120	108 – 114
Large	7-9	147 – 157	138 - 147
Extra Large	9-11	168 – 180	--
	11 and more	183 - 195	--

The S2 category of tiny residences, including one- or two-bedroom flats, is the most appropriate choice for the specified target demographic of young purchasers in this research. This category corresponds with the lifestyle, tastes, and financial capacities of this group. Thus, it was concluded that the prototype's area must comply with the maximum restriction set by the Urban Housing Standards, namely 75 m^2.

The norms and indicators established by the State Commission of Housing provide an area expansion of up to 20%, acknowledging the need for flexibility to current developments and requirements. This adaptability guarantees that the designs may meet contemporary requirements while adhering to official regulations.

In light of these concerns, two categories of hypothetical models were formulated:

1. Conventional Home (75 m²): Constructed with fixed and static areas characteristic of conventional residences, fulfilling the functional and spatial needs of a modest family.
2. Smart Home (75 m²): A technologically sophisticated design that incorporates interactive and versatile areas to improve flexibility, efficiency, and user experience.

Both prototypes are designed for a small family with one kid, offering a direct comparison between traditional and smart living solutions while conforming to the space limitations and flexibility permitted by housing requirements. The designs seek to emphasize the capability of smart technology to improve spatial flexibility and overall quality of life within the same area footprint.

Temporal/Spatial Schedule of Activities (Daily Scheduling Activities)

The integration of smart technologies into residential spaces is fundamentally reshaping how individuals interact with their living environments. In a Smart Home, all devices and spaces are designed to seamlessly support the performance of everyday activities, tasks, and rituals in an intuitive, efficient, and intelligent manner. This technological evolution significantly impacts the way of living at home, influencing not only spatial configurations but also the needs and preferences of its inhabitants.

The changes brought by smart technologies enable a higher degree of customization and adaptability, ensuring that spaces are responsive to the daily rhythms and routines of users. Smart Homes are designed to optimize spatial usage by accommodating overlapping activities, automating repetitive tasks, and providing personalized environments based on user preferences.

The following activities have been identified from an experimental study conducted by Heidari Jozam on Smart Home Design: Spatial Preference Modeling [7], which illustrates the interplay between spatial preferences and daily scheduling activities in a smart home:

1. **Morning Routine Activities**

- Automated lighting and temperature adjustments to suit wake-up preferences.
- Smart kitchen appliances, such as programmable coffee makers and flexible breakfast setups.
- Adaptive privacy settings in multifunctional spaces, enabling a smooth transition between personal grooming and communal activities.

2. **Work-from-Home or Study Activities**
    - Configurable workspaces with adjustable desks, lighting, and noise-canceling features.
    - Smart walls or partitions that transform spaces into temporary offices or study areas.
    - Seamless integration of digital tools, such as smart screens and wireless networks, enhancing productivity.
3. **Leisure and Relaxation**
    - Dynamic entertainment systems embedded in smart walls or furniture, adapting to user preferences.
    - Ambient settings with customizable lighting and soundscapes for relaxation.
    - Flexible living spaces that can shift between leisure zones and social gathering areas.
4. **Meal Preparation and Dining**
    - Smart kitchen technologies, including cooktops with automated temperature control and real-time recipe guidance.
    - Adaptive dining spaces that can expand or contract based on the number of users.
    - Energy-efficient appliances and waste management systems integrated into the kitchen design.
5. **Evening and Nighttime Activities**

- Automated systems that transition spaces to support winding down, such as dimmed lighting and lowered noise levels.
- Smart beds and furniture that adjust for optimal comfort during rest.
- Security systems ensuring safety and privacy throughout the night.

These scheduling activities demonstrate how Smart Homes transform spatial configurations to align with the temporal needs of users, maximizing efficiency, adaptability, and overall satisfaction. The next section will explore how these activities are accommodated within the spatial layouts of the Smart Home prototype, offering a comparative perspective against the Conventional Home design.

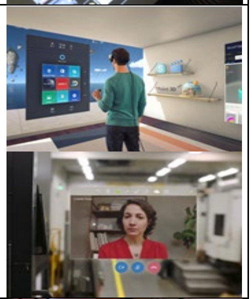
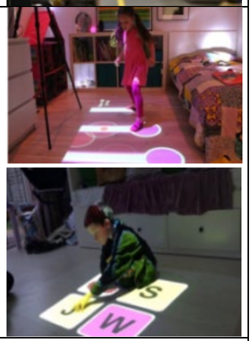
Table 2. Domestic activities [7].

Group 1	Group 2	Group 3	Group 4
Working	Food preparing	Sleeping	Tele-communication
Family gathering	Cooking	Rest	Tele –education
Watching TV	Dishwashing	Personal activities	Tele-shopping
E-meeting	Eating		Tele-health caring
Relaxing			
Entertainment			
Children activity			

Elements of the Intelligent Hypothetical Prototype

The following table delineates the essential elements included into the design of the conceptual prototype for the future Smart Home, emphasizing advanced technologies that improve space adaptability, functionality, and user experience. Each component is associated with the initiatives or products that motivated its incorporation:

Table 3. Illustration depicting components of a hypothetical smart home prototype.

No.	Component	Project Name	Description	Reference	Photos
1	**Smart Kitchen Table**	Whirlpool Interactive Cooktop	A table equipped with a cooktop that includes interactive displays, smart temperature control, and wireless power systems to assist in meal preparation and dining.	[9]	
2	**Smart Wall**	Touchscreen	An intelligent wall with touchscreen functionality for managing home automation, entertainment, and communication systems.	[10]	
3	**Smart Floor**	Lumo Play	Interactive flooring that incorporates motion detection and smart sensors, enabling dynamic user interactions and customized settings for different activities.	[11]	
4	**Smart Furniture**	Marvel Tech Group Touchscreen Furniture	Furniture embedded with touchscreens and smart sensors for multifunctional use, such as entertainment, workspace, or relaxation.	[12]	
5	**Smart Partition and Boundaries**	IKEA Movable Walls	Flexible partitions that can be reconfigured to create or divide spaces as needed, with adjustable transparency and mobility features.	Wall Street Journal 2015 [13]	

Design Instruments

The architecture of the proposed Smart Home prototype integrates diverse tools and tactics to attain significant spatial flexibility and adaptation. These technologies cater to the changing requirements of contemporary lives and strive to develop environments that are adaptable, multipurpose, and resilient for the future. The following is a comprehensive description of each design tool utilized:

- **Multi-use Plan**: Facilitates the alteration of interior spatial configurations to meet diverse user requirements and preferences. This adaptability allows spaces to fulfill many functions without necessitating structural alterations [14].
- **Flexibility in Furniture Design**: Integrates furniture that may be reconfigured, altered, or supplemented to facilitate diverse activities and dynamic arrangements, hence improving space adaptability [14].
- **Adapt**: Adaptation entails the architectural design of structures capable of accommodating various purposes, users, and climatic circumstances, hence guaranteeing sustained usability and durability across numerous environments [14].
- **Dividing**: Employs a framework for adaptability by segmenting the structure into many intervention tiers. This technique enables gradual modifications and adjustments as required [15].
- **Transform**: Denotes the ability of a building to modify its shape, space, form, or appearance by physical alterations to its structure, façade, or interior surfaces. This instrument guarantees that spaces retain versatility and functionality [1].
- **Moving**: Facilitates the transformation of rooms into hybrid spaces that integrate indoor and outdoor elements, fostering a dynamic engagement with the external surroundings [1].
- **Integrate**: Incorporates automation and intuitive reactions into the building's systems, enabling spaces to automatically adjust to user needs and improve user comfort [1].

- **Multi-functionality**: Ensures that rooms are created to accommodate several established uses, optimizing usefulness while preserving the architectural integrity of the design [1].
- **Trans-functionality**: Promotes the development of environments that accommodate indeterminate and unforeseen applications, reliant on the unrestricted engagement and interaction of users with the area [15].
- **Mobility**: Facilitates the movement, reorganization, addition, or removal of pieces within the structure, promoting flexibility and adaptability [16].
- **Divisibility**: Facilitates the partitioning of the building into distinct functional units, giving users more control over spatial allocation and use [15].
- **Elasticity**: Facilitates the extension or contraction of the structure, both horizontally and vertically, to meet evolving user demands or space requirements [16].

These technologies together facilitate the creation of a Smart Home prototype that is both responsive to current demands and capable of changing with future innovations and user requirements. By incorporating these concepts, the design attains equilibrium among utility, adaptability, and innovation, therefore guaranteeing a dynamic and user-centric living space.

Theoretical Models

Two hypothetical models were created to evaluate the flexibility and usefulness of Smart Home Design in comparison to Conventional Home Design, using the ideas outlined in sections 2.1, 2.2, 2.3, and 2.4. Both prototypes include a total area of 75 m^2, according to the previously described Urban Housing Standards, and are intended for a modest family of three individuals. **The prototypes are enumerated as follows:**

Prototype 1: Intelligent Residence (75 m^2)

- This model illustrates the potential of intelligent technology in improving spatial flexibility and adaptation.
- User Capacity: The residence is intended to house 3 people under typical conditions, although its adaptable rooms provide accommodation for up to 6 individuals for everyday usage.
- Event Capacity: The plan can host up to 15 people at special events, such as parties or gatherings, due to its adaptable rooms, adjustable walls, and flexible furniture.
- Principal Attributes:
    - Intelligent walls and partitions for the dynamic reconfiguration of space.
    - Versatile furniture that adapts to many requirements.
    - Intelligent systems that enhance space use by reacting to human inputs or automated protocols.

Prototype 2: Traditional Residence (75 m²)

- This model exemplifies a conventional architectural style characterized by predetermined space layouts and immobile furniture placements.
- User Capacity: Comparable to the smart home, the traditional design supports three people in a typical configuration and may be modified to accommodate up to six individuals with little adjustments.
- Event Capacity: In contrast to the smart house, the traditional layout lacks the adaptability to accommodate big gatherings efficiently, rendering it less appropriate for space-intensive events such as parties.
- Principal Attributes:
    - Static divisions and spatial demarcations.
    - Conventional furniture arrangements exhibiting little adaptability.
    - Restricted flexibility to evolving user requirements or actions.

Objective of the Theoretical Models

The main objective of creating these prototypes is to assess the efficacy of smart design concepts in enhancing spatial flexibility in a practical and quantifiable manner. To accomplish this, eight potential layouts were created for the smart house model, examining diverse configurations for various situations, including everyday routines, special events, and evolving family requirements. These layouts illustrate the capacity of intelligent design to improve efficiency, flexibility, and user happiness in contrast to traditional housing designs.

The following figure will show and compare the layouts and functionality of both prototypes, emphasizing their capacity to fulfill the space requirements of contemporary living while ensuring user comfort and practicality.

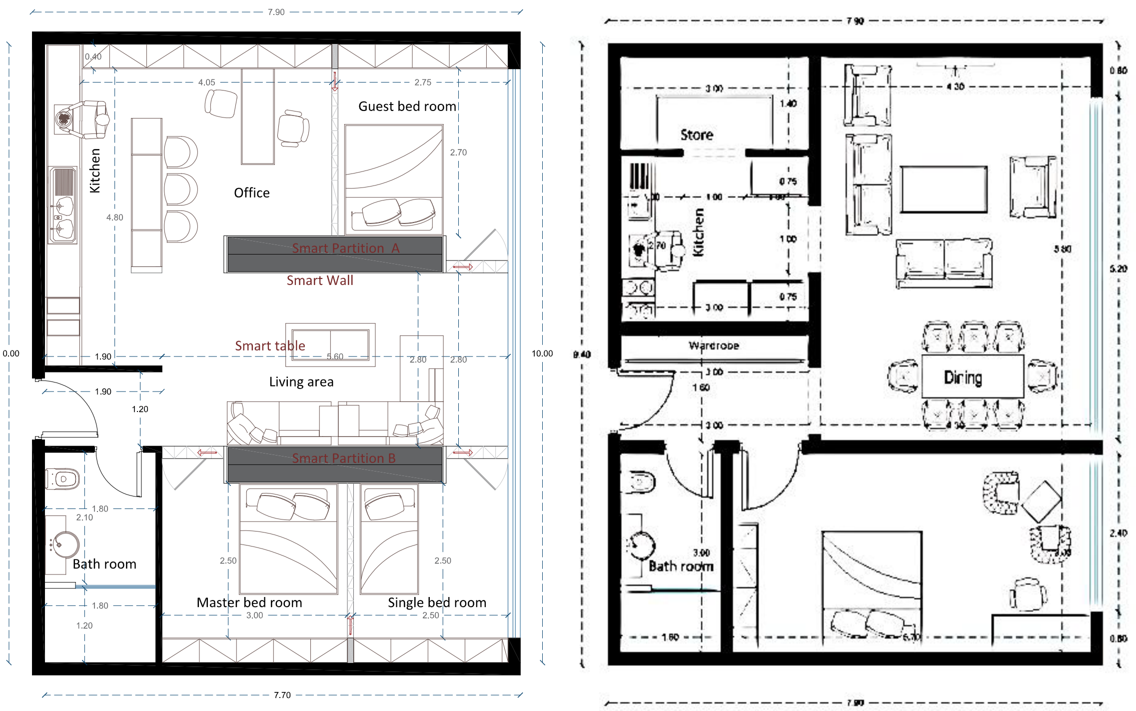


Figure 1. (a) Illustration representing the hypothetical prototype of a smart home by the researcher (b) Illustration of the Conventional Home Hypothetical Prototype.

Testing Spatial Flexibility in Smart and Conventional Hypothetical Prototypes:

This portion will include testing the Smart Apartment Prototypes and the Conventional Apartment Prototype, followed by a comparative study of the data acquired. The testing instruments are listed below:

- Graphical scale to evaluate capacity for spatial modification regarding dimensions, configuration, and layout reorganization.
- Feasibility Matrix to assess activity-space interchangeability (tolerance).

Graphical Scale for Spatial Modification Assessment

Hypothetical Prototype of a Smart House:

Through the creation of an intelligent hypothetical model, we saw that the capacity for alterations in size, form, connectivity, and layout became more efficient, expeditious, and provided more opportunities for spatial organization in Smart Homes. Standard apartments with a floor size of 75 m^2 can accommodate three people, but those with clever designs may host a minimum of three, an average of five, and up to fifteen for special events (such as parties).

1. The adaptable area in our conceptual prototype design may accommodate purposes that need comparable configurations with varying dimensions, and it can also alter its form to support diverse functions.
2. Linkage: Space may support various purposes by altering the connections among a succession of areas. Various methods exist to connect interior spaces:
    a. Establishing semi-private areas: Utilizing intelligent folding partitions and movable partitions.
    b. Establishing public and semi-public spaces: Employing smart furniture, space folding partitions, and movable sections.

In eight distinct layouts, we observed that spatial organization may be altered in many key areas, mostly impacted by emerging technologies in a Smart Home.

- **Smart Kitchen**: The smart kitchen of the future is anticipated to merge seamlessly with the living space, eliminating physical barriers to facilitate multitasking and accommodate activities such as entertainment, social interaction, virtual engagements, professional tasks, and family gatherings.
- **Smart Living and Workspace**: Future residences will feature smart living rooms enhanced by Smart Walls, Smart Partitions, and Smart Furniture, facilitating various activities such as television viewing, gaming for children, remote education, telecommuting, telecommunication, and internet browsing. The new interactive elements affect the positioning of the Smart Walls, the configuration of the surrounding furniture, and the overall spatial layout. These new designs will be substantially different from conventional living room arrangements.
- **Personal and wellness zones**: Rather of seeing a home as a collection of rooms designated for certain duties, it is more beneficial to consider it as an assemblage of multipurpose spaces where many everyday family activities may take place. Consequently, when activities transition from the bedroom to alternative places, the current design of bedrooms may become obsolete, with private sleeping areas likely to develop instead.

Figure 2. Reconfigurable Layouts for Hypothetical Smart Home Prototype.

- **Standard Residential Hypothetical Model**: Presented above are potential layouts for the Conventional Apartments Prototype. For example, in Conventional Prototype 1: A permanent blockwork partition may be erected to separate the Master Bedroom into a Master Bedroom and a child's bedroom.

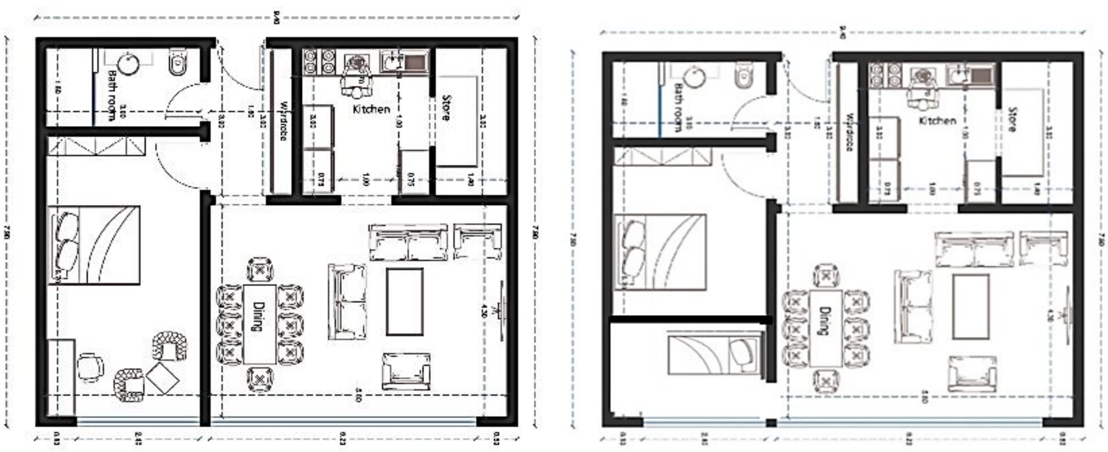


Figure 3. Rearrangement Capability in Layout for Conventional Home Hypothetical Prototype.

Outcomes from comparison assessments about the Testing Level of Flexibility via Layout Re-arrangement:

- Smart Homes provide several possibilities for efficiently and swiftly rearranging the layout. Smart technology enables the seamless transformation of a living room into a family area, workspace, guest bedroom, or an expansive venue for big gatherings. The change in layout is swift and reversible.
- Conventional apartments exhibit limited long-term adaptability, leading to permanent alterations in layout. Therefore, it can be said that Smart Homes exhibit flexibility in the rearrangement of layouts to accommodate current and future user requirements. This indicates that the notion of adaptation is more efficient than permanent structural change, hence enhancing the efficacy of adaptation methods.

Feasibility Matrix for Assessing Activity-Space Interchangeability (Tolerance)

Intelligent Theoretical Model:

Figure 4 illustrates the various activity areas and places under consideration.

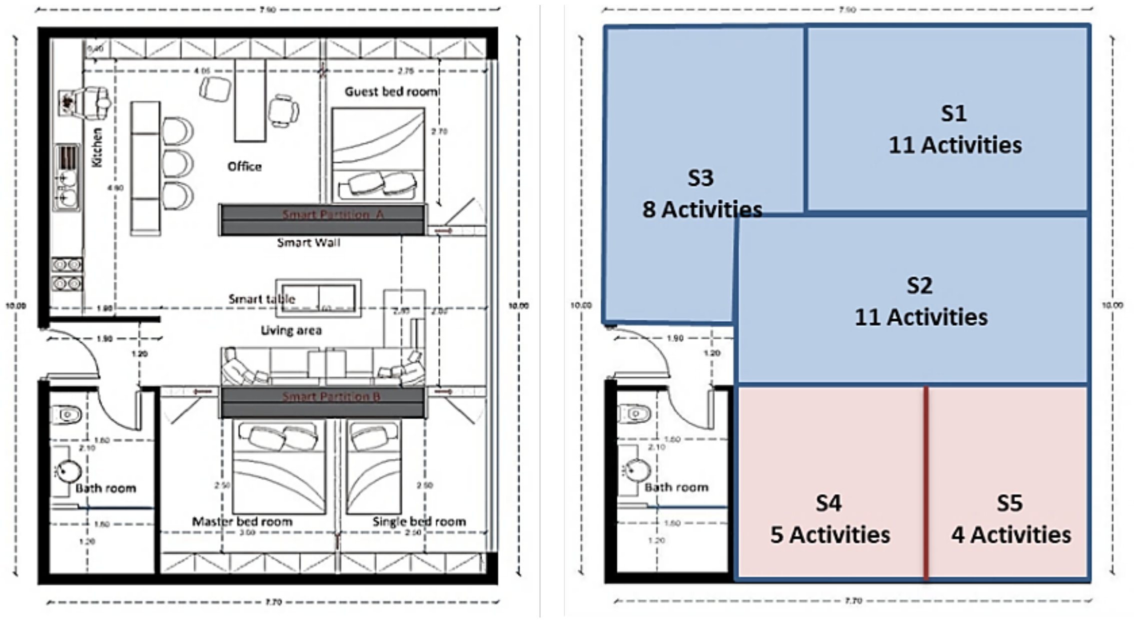


Figure 4. Spatial/Locational Definition for Hypothetical Smart Home Prototype.

The feasibility matrix assessed the activities from Table 3 in relation to each space, determining if the specified activity can be accommodated inside that particular space. For instance, relaxation is feasible in the public spaces/locations S1 and S2, shown by a check mark ( ) and a blank cell in the matrix. If an activity is unsupported by a certain workstation, the cell is marked in gray. Consequently, the relaxing spaces/locations S3, S4, and S5 have been marked in grey. The following graphic illustrates the feasibility matrix:

Table 4. Feasibility Matrix for Activity Space Derived from the Smart Home Hypothetical Prototype.

Activity	Public Zone			Private Zone		Inter-changeable Spaces	%Interchange ability
Description	S1	S2	S3	S4	S5		
Child Activities	✓	✓	✓		✓	4	80%
Study	✓	✓		✓	✓	4	80%
Working	✓	✓	✓	✓		4	80%
Family gathering	✓	✓				2	40%
Watching TV	✓	✓				2	40%
Relaxing	✓	✓				2	40%
Entertainment	✓	✓	✓			3	60%
Meeting	✓	✓	✓	✓		4	80%
Tele-communication		✓				1	20%
Tele –education	✓	✓			✓	3	60%
Tele-shopping		✓				1	20%
Guest Sleeping	✓					1	20%
Food preparing			✓			1	20%
Cooking			✓			1	20%
Dishwashing			✓			1	20%
Eating			✓			1	20%
Personal Activities				✓		1	20%
Sleeping	✓			✓	✓	3	60%
Inter-changeable Activities	11	11	8	5	4	Average	43%
%Interchangeable Activities	61%	61%	44%	28%	22%	Average	43%

Table 5. Feasibility Matrix of Activity Space Derived from the Conventional Home Hypothetical Prototype of 75 m².

Activity	**Public Zone**				**Private Zone**			**Inter-changeable Spaces**	**% Interchange ability**
Description	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**		
Children activities						✓		**1**	14%
Study							✓	**1**	14%
Working							✓	**1**	14%
Family gathering	✓							**1**	14%
Watching TV	✓							**1**	14%
Relaxing					✓			**1**	14%
Entertainment	✓							**1**	14%
Meeting		✓						**1**	14%
Tele-communication								**0**	0%
Tele –education								**0**	0%
Tele-shopping								**0**	0%
Guest space (sleeping)	✓							**1**	14%
Food preparing			✓					**1**	14%
Cooking			✓					**1**	14%
Dishwashing			✓					**1**	14%
Eating		✓						**1**	14%
Personal Activities					✓			**1**	14%
Sleeping					✓			**1**	14%
Inter-changeable Activities	**4**	**2**	**3**	**0**	**3**	**1**	**2**	**Average**	12%
%Interchangeable Activities	22%	11%	17%	0%	17%	6%	11%	**Average**	**12%**

Traditional Residential Hypothetical Model

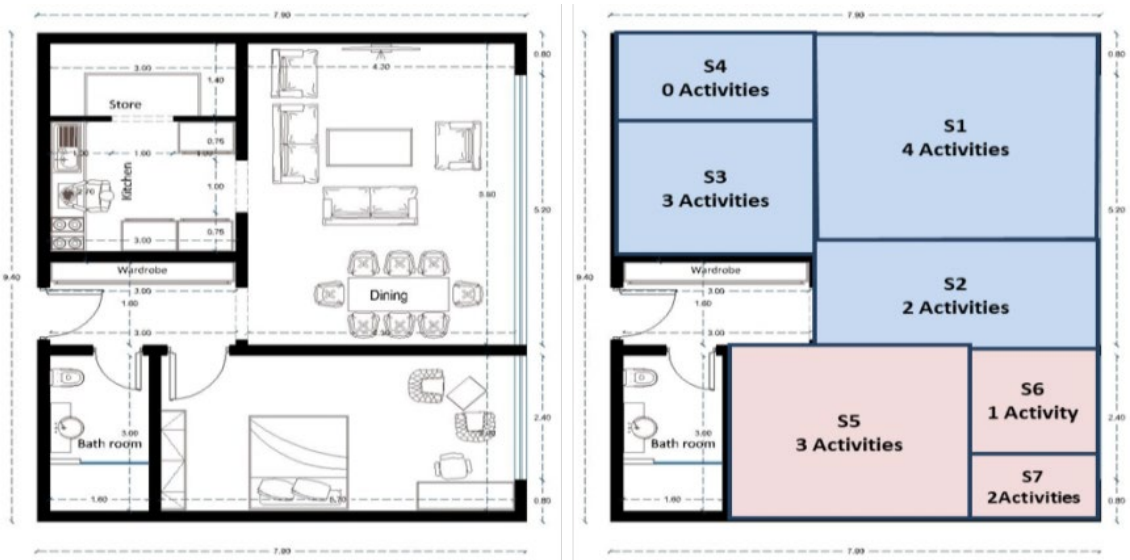


Figure 5. Spatial/Locational Definition for Conventional Home Hypothetical Prototype

Outcomes from Comparative Testing for Flexibility Level based on Activity Space Interchangeability (Space Conservation):

The results from the Activity Space Feasibility Matrix testing are shown for the Smart and Conventional Home Prototypes in Figure 6. It shows the comparative average percentages of interchangeability in space and activity for the Smart Home Hypothetical Prototype and the Conventional Home Hypothetical Prototype (75 m²). It has been noted that the:

1. The percentage of interchangeability in smart home environments is 43%, but in conventional spaces it is just 12%. The capacity to engage in activities across many places is much greater in a Smart home compared to a Conventional house.
2. The percentage of interchangeability in Activity for a typical house is 36%, however in a standard conventional home it is just 12%. Consequently, the capacity to engage in many activities at a single place inside a Smart house far surpasses that of a traditional home.

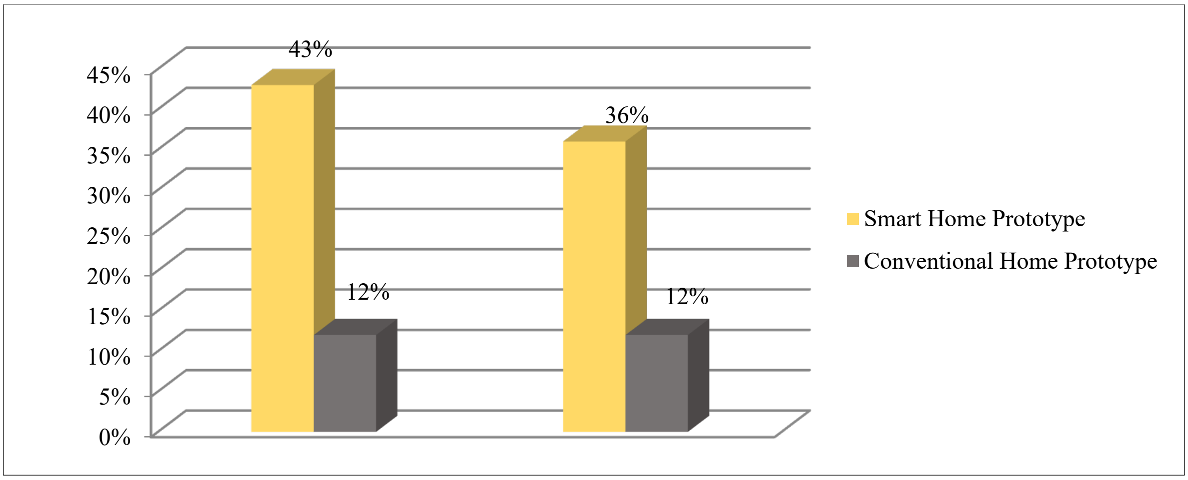


Figure 6. Comparison of interchangeability between Smart and Conventional Prototype 1.

Conclusion

The primary benefit of ambient intelligent technology in Smart Homes is the enhancement of flexibility in spatial organization and activity execution. Each residence enables users to enjoy an open and functional flow in the versatile smart spaces. The house encourages "flexibility in-between" for areas instead of confining inhabitants to static and constrained quarters. A Smart Home enhances the functionality of places via technology and multitasking, but the physical components of the space may be entirely or partly static. The ultimate outcome may be an open area with a multipurpose layout, furnished with adaptable smart furniture and interconnected equipment. Numerous contemporary studies are ineffective and lack a well-defined conceptual framework to articulate the effects of using smart technology to enhance the spatial efficiency of interior environments. Through our study, we endeavored to create a hypothetical model tailored to the lifestyle of the Iraqi population. Our testing indicates a good outcome for all research hypotheses, suggesting that smart home design enhances spatial flexibility by:

Hypothesis: Enhancing the reconfiguration capability of layouts.

Outcome: The use of Smart technology enables significant adaptability and flexibility in the layout possibilities for apartments. This flexibility is absent in Conventional Apartments, since alterations to layouts need permanent modifications such as construction or removal of blockwork.

Hypothesis: Enhancing the interchangeability between activity and space (Optimize Space).

Outcome: The findings of the Activity Space Matrix tests indicate that smart apartments exhibit more spatial flexibility, since their interchangeability surpasses that of conventional flats. Consequently, the use of Smart Technology enables:

1. Enhanced flexibility in performing activities across various places interchangeably, and
2. Increased flexibility in executing several activities at a single activity station interchangeably.

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