

Comparative Study between the Spatial Flexibility in Contemporary Apartments and Future Smart Apartments in Iraq

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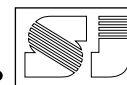
Abstract

Technological advancements over the last decade has led to changes in people's preferences and lifestyle which needs to be reflected in the design and planning of urban environments. It has become essential to pursue, create homes with greater agility, better interrelationships of components and more open systems. Contemporary homes are hugely difficult to modify as most building have fixed and static structure. The most common concept of space in current dwellings is its categorization by functions, such as sleeping rooms, bathroom and living room. Rather than requiring users to shift, twist, and surrender to fit into static environments, the new architecture should technologically adapt to support the building sustainability by ensuring users' wellbeing and safety, long term value of the building and its efficiency. In this context, Efficiency indicates Spatial Flexibility which enhances the quality of inner space. Spatial Flexibility is the capacity of inner spaces to be: Adaptive, Responsive and Resilient. The main aim of the research is: to clarify the impact of smart technology to improve flexibility in inner spaces and to evaluate the level of spatial flexibility between smart and contemporary apartment. The researcher employed qualitative analysis methodology to test experimental prototypes designed by researcher and investigate the impact of use of Smart technology on spatial flexibility in contemporary house and in future smart house in Sulaimaniyah (Kurdistan region of Iraq). The empirical nature of our case study led us to organize the research into two levels: theoretical level to form conceptual structure and practical level in which we chose two models smart and contemporary. Results explained that smart homes display an improved spatial flexibility than contemporary homes by the effective use of space for the full range of functions using smart devices.

1. Introduction

The last few decades have seen unprecedented social, technological and economic changes, and innovation in architecture is becoming critical as buildings need a flexible structure and flexible

spatial configuration in order to meet rapidly changing demands ^[1]. The elementary idea of "Spatial Flexibility" is that spaces should not be dominated by determinism. The functions a space needs to contain in the life span may change many times. Architects should design the space to



maximize the possibilities of change, so that the space could be more adaptable to maintain valuable all through the life span [2]. Contemporary architecture is inherently flexible, evolving according to the demands of a specified time and can accommodate a certain range of uses to a limited extent. However, it is not able to cope with the rapid changes due to which in the late of 1960s and early 1970s architectural field witnessed a great improvement of artificial intelligence and information technology, and in this time the concept of adaptive and responsive architecture were born^[3]. Research into smart homes has been going on for decades as a result, in the near future, our homes will have a distributed network of intelligent devices. Such intelligent devices will vary significantly from modern equipment through their appearance in an environment, and through the way users interact with them^[4]. Smart design, spatial flexibility in contemporary and smart design will be explained in the following pages which have been used to specify research problem –aim – methods.

Research problem: There is no clear guideline and experimental tools, which can be used to describe how smart home design can improve spatial flexibility of inner spaces compared to contemporary homes.

Research Aim: The research aims to establish a guideline to know how smart house design can improve spatial flexibility of inner spaces compared to contemporary house and to evaluate how the future interior space could be organized more efficient by using smart technology, especially in Kurdistan region of Iraq.

Hypothesis: It is hypothesized that smart house design improves levels of spatial flexibility by:

1. Improved capacity for changing space in terms of size, shape, and rearrangement of layout.
2. Enhanced Activity-Space Interchangeability (tolerance), by providing multiple locations for doing one activity.

Methodology: From literature review discussed in succeeding sections in the disciplines of, smart home technology, spatial flexibility and Interior design and standards and guidelines of Iraq Urban Development a hypothetical prototype for a contemporary and a future smart home was designed. Then with the use of practical tools impact of using smart technology on the spatial flexibility of the two prototypes was tested. The Testing Tools applied are as explained below:

– **Graphical scale to test capacity for changing space in terms of size, shape, and rearrangement of layout:**

Different Layouts of Smart Home were analyzed by creating different scenes in the Hypothetical Prototypes and displaying how smart technology can be used to improve level of spatial flexibility by giving high level of capacity of changing (size-shape layout).

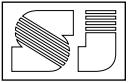
– **Feasibility Matrix to test Activity-Space interchangeability (tolerance):**

For any set of activities and schedule of spaces, interchangeability can be analyzed using a feasibility matrix that links the activities and Activity Stations. The feasibility matrix entries specify which activities can take place in which spaces. A white cell is assigned in the matrix if the workstation is feasible for the activity corresponding to the row to take place in the space corresponding to the column; and a tinted cell if not. The amount of interchangeability between any set of activities and any schedule of spaces can be measured by the number of feasible allocations in the corresponding 0/1 feasibility matrix^[5].

2. Literature Review

2.1 Smart Homes and Smart Interior Design

Research into smart homes has been going on for decades and detailed reviews of the literature that focused on active and assisted living for the



elderly or for people with special needs. With time, many of us are already living amongst an internet of some things; we have desktops, smart TV, laptops, smart phones, smart watches, and iPads. As a result, in the near future, our homes will have a distributed network of intelligent devices.^[6]

Smart interior design can be defined as the use of techniques to increase flexibility of building compartments in order to reduce the amount of constructed areas while maintaining the necessary requirements ^[7]. These techniques improve the flexibility and adaptability of buildings by increasing the number of possible uses of building compartments over time.^[8]

2.2 Spatial Flexibility of Inner Space

Spatial flexibility realizes the user's needs and desire to make changes in the compositions and arrangements of space. It provides the building with greater flexibility and open systems, which enable the users with more control over the structure of spaces ^[1]. Two main principles of spatial flexibility are discussed below:

a. Flexibility: Loose-Fit

Buildings are durable and static, activities are changeable, and therefore during the life of most building there will be a relatively large amount of activity change. New activities can often take place in the same accommodation that was previously used for different activities. But sometimes new activities need different accommodation, creating an activity-space mismatch. To minimize the risk of mismatch, the idea of a loose-fit building or Duffle coat strategy suggests that designers should avoid too tight a match between activities and spaces and create some (slack) which may be valuable when activities change ^[5]

b. Flexibility: Activity –Space Tolerance

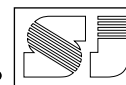
The duffle coat theory argues that loose-fit flexibility is maximized in designs that have few distinct types of space and many identical instances of these types. Loose-fit flexibility is enhanced when there is a high level of tolerance between the attributes of activities and spaces, so that small or large variations in activity attributed not cause a mismatch. With activity-space tolerance, it does not matter if the spaces are not identical in size. Design for flexibility means that designer should seek to extend range of activities that a building can accommodate by making provision for alterations for example by movable walls, relocation services or strategies for growth ^[5]. Space in the information society can be understood as three spaces:

- *Virtual Space (VS)*: Smart Wall, Smart Furniture which are connected to an information network.
- *Ambient Intelligent Space (AmI-S)*: The environment of the space is equipped with computer and sensors to assist in daily activities such as cooking, sleeping, washing and personal activities such as childcare.
- *Physical Space (PS)*: It's the traditional space where people actually are with their bodies ^[6]

2.3. Spatial Flexibility in Contemporary and Smart Home

A smart home should be a home and a place to live; but when the way of living inside the home changes, some modifications in the space are required to fulfill the new lifestyle of inhabitants.

In contemporary homes, daily activities are allocated to specific functional spaces. Whereas in the case of smart homes, the spaces can accommodate many action kinds and are multifunctional. Spaces are interactive, responsive, and capable to make different contexts for different activities. As an example, since daily activities become more flexible (e.g. people can



work in different location of a house), the space should support this flexibility and lets user adjust privacy of the space according to his/her activity. Hence, separated functional rooms with fixed boundaries seem to be no longer appealing in a smart home.

A smart home contains several highly advanced smart technologies and interactive interconnected devices. All the devices and spaces inside the smart home support people carrying out their everyday activities, tasks, and rituals in an easy, natural and intelligent way some of the new smart domestic technologies that are involved in a smart home, such as “smart flexible partitions”, “smart boundaries with adjustable transparency”, “smart kitchen table with flexible cooktop, wireless power system and wireless data network”, “smart wall with intelligent and interactive system”, “smart furniture with programmable context and sensor network”, “smart floor”, etc.^[9]

3. Case Study (Sulaimani – Kurdistan Region of Iraq) Designing of Hypothetical Prototypes (Smart and Contemporary)

For the Research we have considered a case study of people of Sulaimani- Kurdistan Region of Iraq in general. This section explains the methodology for designing hypothetical models for the future Smart House and present Contemporary House in Kurdistan, Iraq. Prototypes were devised based on the target group of people who are young (Age 18-35) and at the stage of their life where they are capable of investing and thinking of buying their own house and are also more open and accepting of new technology.

3.1 Standards and Guidelines

For the prototype design the Urban Housing Standards, Issued by Republic of Iraq, Ministry of Construction and Housing, October 2010 ^[10] – based on studies carried out by Polservice

Company to prepare Housing Plan in Iraq were referred.

It can be observed that the S2 category of Small house which is a one or two bedroom apartments is the most suitable according to our target group of buyers. It was considered that the area of the Prototype should be within the maximum limit of the standards i.e. 75 m². The standards and indicators in the study used by State Commission of Housing are adjustable towards the increase up to 20%, in order to cope with the developments and current requirements. Two types of Hypothetical model were designed the first one is a Contemporary Home (75 m²) and second is a Smart Home (75m²) for a small family with one child.

3.2. Temporal /Spatial schedule of activities (Daily scheduling activities)

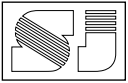
All the devices and spaces inside the Smart Home support people carrying out their everyday activities, tasks and rituals in an easy, natural and intelligent way. These technological changes will affect the way of living at home and will influence the spatial needs and preferences of those living there. Following Activities have been identified from an experimental research conducted by Heidari Jozam on Smart home design: spatial preference modeling ^[11]

3.3. Components of the Smart Hypothetical Prototype

Following table details the components which have been considered during the design of Hypothetical Prototype for future Smart home.

3.4. Tools for Design

- **Multi-use Plan:** Change the shape and size of internal space ^[17]
- **Using Flexibility in Furniture Design:** Possibilities of furniture arrangement,



transforming, an additional to use and free formations ^[17].

- **Adapt:** Designing building to adjust to different functions, users, and climates ^[17].
- **Dividing:** Building in a series of intervention levels creating a framework for flexibility ^[18]
- **Transform:** Means the capacity of building to change shape, space, form or appearance by the physical alteration of their structure, skin or internal surfaces. ^[1]
- **Moving:** Means converting the room into an inside /outside space that engages with the external environment in a different and more immediate way. ^[1]
- **Interact:** Buildings that respond to users requirements in automatic or intuitive ways. ^[1]
- **Multi-functionality:** Possibility of space to be used in different ways and for a set of known functions. ^[1]
- **Trans-functionality:** Creation of new undetermined and unpredictable functions according to the free users experience and consumption of the space. ^[18]
- **Mobility:** Built-in possibilities to move, rearrange, take away, or add elements. ^[18]
- **Divisibility:** Possibility of dividing the building into different functional units. ^[18]
- **Elasticity:** Possibility of a building to be extended (or retracted), horizontally or vertically ^[18]

3.5. Hypothetical Prototypes

Using the Principles discussed in section 3.1, 3.2, 3.3 and 3.4 two models were designed; the Prototype 1 is a Smart home (75 m²) and the Prototype 2 is a Contemporary home about (75 m²). Number of users in the first model is normally designed for 3 persons and can be increased for 6 persons; this model can be also accommodating 15 persons in spatial occasions (like party time). While the second model is normally designed for 3 persons and can be increased for 6 persons, but cannot accommodate occasions like party time. The aim of designing

hypothetical model is to evaluate if smart design can improve flexibility in practical way, for this reason we created 8 possible layouts which are efficient for the case study.

4. Testing for Spatial Flexibility in Smart and Contemporary Hypothetical Prototype

In this section, testing will be conducted for the Smart Apartment Prototypes and the Contemporary Apartment Prototype and will be followed by a comparative analysis of the results obtained. The testing tools are as below:

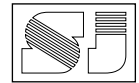
- Graphical scale to test capacity for changing space in terms of size, shape, and rearrangement of layout
- Feasibility Matrix to test Activity-Space interchangeability (tolerance)

4.1. Graphical scale to test capacity for changing space in terms of size, shape, and rearrangement of layout

a) Smart Home Hypothetical Prototype

From designing smart hypothetical model, we noticed that the capacity for changing in size, shape, linkage and layout became easier, faster and give us more possibilities of organizing spaces in Smart Homes. According to standards, contemporary apartment with 75 m² floor areas can accommodate 3 persons, while in smart design can accommodate minimum 3 persons, medium 5 persons and 15 persons in special occasions (like party time).

1. **Versatile space** in our hypothetical prototype layout could satisfy functions requiring in similar shapes with changing size, also it could change its shape to contain different functions.
2. **Linkage:** Space can accommodate different functions by changing the linkage of a series of spaces. There are different ways to link inner spaces:
 - **Creating semi-private location:** By using smart folding partition and smart moveable partition.



- **Creating public and semipublic:** By Smart furniture, space folding partition, smart moveable portions.

In different eight layouts we noticed that spatial organization can be changed in following main areas, which can be mostly influenced by new technologies in a Smart Home.

- **Smart kitchen:** While contemporary kitchen still is a distinct area in most homes, in the house of future the kitchen is predicted to be integrated with the living space to support multitasking with no physical boundaries that can support activities such as entertainment, social communication, virtual activities, job-related activities and family gatherings etc .
- **Smart Living and Workspace:** Smart living rooms most affected by Smart Walls, Smart Partitions and Smart Furniture will support different activities in future dwellings including watching TV, children gaming, Tele educating, working from home/ Tele working, Tele communicating and surfing on internet. These new interactive aspects influence the location of the Smart Walls, the arrangement of the furniture around it and the entire space. Such new layouts will be fundamentally different from the convention living room layouts
- **Personal zones and wellness zones:** Instead of conceiving a house as a series of rooms dedicated to single functions, it is more useful to think of it as a collection of multifunctional places in which the various daily activities of household can occur. Thus, when activities shift from the bedroom and take place in other spaces, bedrooms seem not to be required anymore in their current style and sleeping zones as private zones will likely emerge instead.

b) Contemporary Home Hypothetical Prototype

Below are possible Layouts of the Contemporary Apartments Prototype for e.g. in the Contemporary Prototype 1: A permanent blockwork partition can be constructed to divide the Master Bedroom into a Master and a child bedroom.

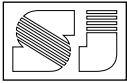
c) Results from comparative testing for Testing Level of Flexibility by Re-arrangement of Layout:

It is observed that Smart Homes offer multiple options for Re-arranging the Layout in a very efficient and quick manner. With the use of smart technology a Living Room can easily be converted from a Family living zone to Work Office to Guest Bedroom or an open space for a large gathering. The change in Layout is quick and reversible as well.

Contemporary Apartments show only long term flexibility which would result into permanent change in Layout. Hence we can say that Smart Homes are flexible in terms of various re-arrangement of layouts to suit the user requirement present and in future. That means the concept of adaptation more efficient than the permanent change in structure and that improve the effective of adaptation method.

4.2. Feasibility Matrix to test Activity-Space interchangeability (tolerance) a) Smart Hypothetical Prototype

Figure 4 displays the different activity spaces/locations considered. For the feasibility Matrix the activities from Table 3 were tested against each space i.e. whether the listed activity can be supported by that particular space by observation method. For e.g. relaxing is possible in the Public space/location S1 and S2 denoted by a tick (✓) and a white cell in the matrix. If an activity is not supported by a particular workstation, the cell is highlighted in grey. Hence for relaxing space/location S3, S4, S5 have



been highlighted Grey. Below is the figure denoting feasibility Matrix:

Results from Comparative Testing for Level of Flexibility according to Activity Space Interchangeability (Save Space)

Results obtained from Activity Space Feasibility Matrix testing are denoted for the Smart and Contemporary Home Prototypes in the figure 8. It denotes the comparative average %ages of Interchangeability in Space and Activity for the Smart Home Hypothetical Prototype and Contemporary Home Hypothetical Prototype (75 m²). It is observed that the:

- 1- Percentage of Interchangeability in Smart home in Space is 43% while in contemporary space is only 12%. This means that the flexibility of performing an activity in multiple locations is much higher in a Smart home than a Contemporary Home.
- 2- Percentage of Interchangeability in Contemporary home in Activity is 36% while in a contemporary home is only 12%. Hence the flexibility to perform multiple activities at one location in a Smart home is much more than that in a contemporary Home

5. Conclusions

The main advantage of ambient intelligent technology in the Smart Home is improving the level of flexibility in the ways of organizing spaces and doing activities. With our research, we tried to design hypothetical model suited to the lifestyle of people of Iraq. From the Testing we can observe that we have tested positive for all the Research Hypothesis in which we suppose that smart home design improve spatial flexibility by:

Hypothesis: Increasing Re-arrange ability of Layouts

Result

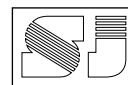
- 1- With the use of Smart technology it is possible to have a lot of adaptability and flexibility in Layout options for the Apartments.
- 2- Spatial Flexibility decreases by addition of fixed space as in contemporary apartments compared to the Versatile Space as in smart apartments.
- 3- Using fixed partition with the movable partition decreases opportunity of re-arranging ability in layout.
- 4- This flexibility is lacking in case of Contemporary Apartments as the flexibility of changing Layouts is in form of permanent changes like building or demolition of blockwork.

Hypothesis: Improving interchangeability between activity and space (Save Space)

Result

From the results of testing for Activity Space Matrix testing we can conclude that the smart apartments display higher flexibility in space as the amount of interchangeability in Smart Apartments is higher than the interchangeability in Contemporary Apartments. Hence with the use of Smart Technology we can achieve:

- Higher flexibility of doing activities in multiple locations interchangeably and
 - Higher Flexibility to do multiple activities at one activity station interchangeably
2. We can improve Activity Space Interchangeability by
 - Using Smart flexible and fixed devices decreases the opportunity of modifying the Layout easily.
 - Activities - if the number of flexible locations is maximized and fixed locations

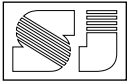


are minimized, it gives us the opportunity to do more activities.

3. More interchangeability is accrued in Smart Apartment Model 1 for flexible activities than Contemporary Apartment Model 2 because capacity of each location in Model 1 is more as smart devices are more efficiently utilized in Model 1 due to versatile space.

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فالمشكلة البحثية هي الافتقار لوجود مؤشرات واضحة وشمولية يمكن خلالها وصف تأثير تكنولوجيا المنازل الذكية على تطور كفاءة الفضاء الداخلي مقارنة بالبيوت الأعتيادية فاستخدم الباحث معادلات رياضية ورسومية لأختبار النماذج المصممة من قبل الباحث وتحليل تأثير استخدام التكنولوجيا الذكية على المرونة الفضائية في المنازل الأعتيادية والذكية في مدينة السليمانية في إقليم كردستان العراق.

فالهدف الأساسي من البحث توضيح تأثير التكنولوجيا الذكية في تطوير كفاءة الفضاء الداخلي للبيوت الذكية مقارنة بالبيوت المعاصرة وتقييم مستوى المرونة الفضائية بينهما حيث استخدم الباحث منهجية التحليل النوعي لأختبار النماذج الأولية التجريبية التي صممها الباحث في التحقيق في أثر استخدام التكنولوجيا الذكية على المرونة الفضائية في المنزل المعاصر و المنزل ذكي المستقبلي في السليمانية (لأقليم كردستان العراق). فقادتنا منهجية البحث التجريبية لدراسة العينة الي تنظيم البحث على مستويين.

- المستوى النظري لتشكيل الهيكل المفاهيمي
- المستوى العملي الذي أختارنا فيه نموذجين ذكي ومعاصر.

فقد أوضحت النتائج ان المنازل ذكية المستقبلية توفر مرونة فضائية مطورة مقارنة بالمنازل المعاصرة من خلال الأستخدام الأمثل للمساحة لمجموعة الوظائف المتعددة من خلال استخدام الأجهزة الذكية.

الكلمات المفتاحية: المرونة الفضائية، التكنولوجيا الذكية، المنازل المعاصرة، المنازل الذكية.

دراسة مقارنة في المرونة الفضائية بين المنازل المعاصرة والمنازل الذكية المستقبلية في العراق

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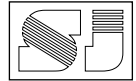
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المستخلص

أدت التطورات التكنولوجية على مدى العقد الماضي إلى تغير في احتياجات الناس و تغيير في نمط حياتهم الذي انعكس بدوره في العملية التصميمية و البيئة الحضرية ومن هنا أصبح من الضروري إنشاء مساكن قابلة للتكيف و اعتماد الأنظمة المفتوحة لتحقيق علاقات أفضل بين مكونات الفضاء الواحد. فقد أصبحت قابلية التكيف في البيوت الأعتيادية مع متطلبات حاجات الفرد الحالية غير كفاة فالتصنيف الوظيفي للفضاء هو المفهوم المستخدم في العملية التصميمية كتقسيم المسكن إلى غرف النوم، معيشة، حمامات... بحيث يتلائم المستخدم مع هذه البيئة الثابتة الغير قابلة للتكيف مع متطلبات الحياة الحديثة.

ومن هنا أصبح التكيف مع التطورات التكنولوجية أحد ضروريات أستدامة العمارة واداء وظيفتها بكفاءة عالية ومن أهمها كفاءة الفضاء الداخلي و خاصة بما يتعلق بموضوع المرونة، ويقصد بالمرونة قابلية الفضاء الداخلي على التكيف والأستجابة المباشرة و السريعة لعوامل التغير الوظيفي بالاضافة الى قابلية الرجوع إلى حالة الأستقرار الأولي.

**Table 1: General activities inside home** ^[11]

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			

Table 2: Figure denoting Smart Home Hypothetical Prototype Components – (By researcher)

No.	Component	Reference	Photos
1	Smart kitchen table	Project name Whirlpool interactive cook top [12]	
2	Smart Wall	Project name Touchscreen [13]	
3	Smart floor	Project name Lumo Play [14]	
4	Smart furniture	Project name Marvel Tech Group Touch Screen furniture [15]	
5	Smart partition and smart boundaries	Project name IKEA movable walls [16]	

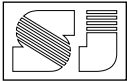


Table 3: Activity Space Feasibility matrix obtained by observation methods from the Smart Home Hypothetical Prototype (By researcher)

Activity Description	Public Zone			Private Zone		Inter-changeable Spaces	%Interchangeability
	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 4: Activity Space Feasibility matrix obtained by observation methods from the Contemporary Home Hypothetical Prototype 75 m2 (By researcher)

Activity Description	Public Zone					Private Zone		Inter-changeable Spaces	% Interchangeability
	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%

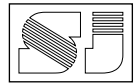


Fig. 1: Re-arrangeability in Layout for Contemporary Home Hypothetical Prototype (By Researcher)

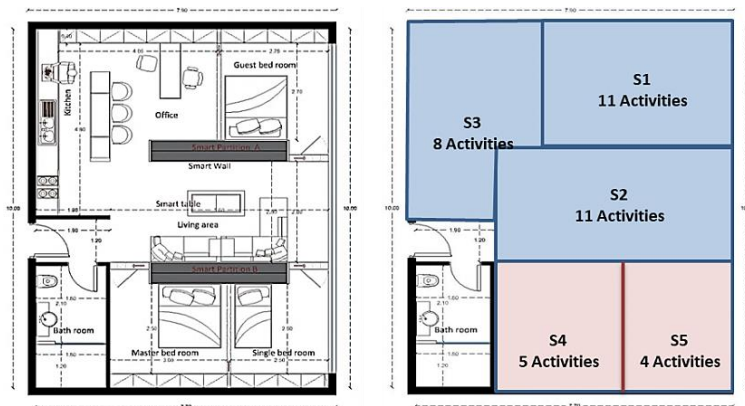


Fig. 2: Space/ Location definition for Smart Home Hypothetical Prototype (By Researcher)

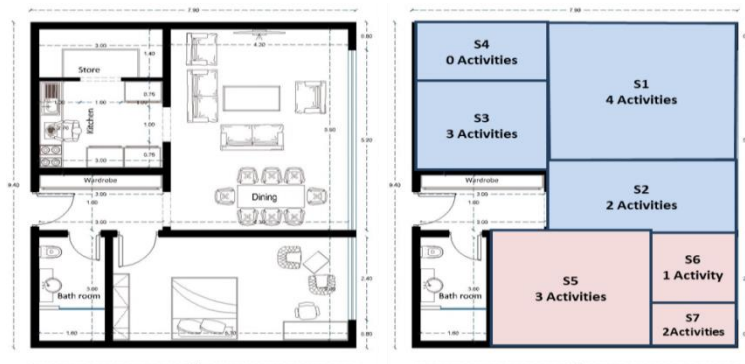


Fig. 3: Space/ Location definition for Contemporary Home Hypothetical Prototype (By Researcher)

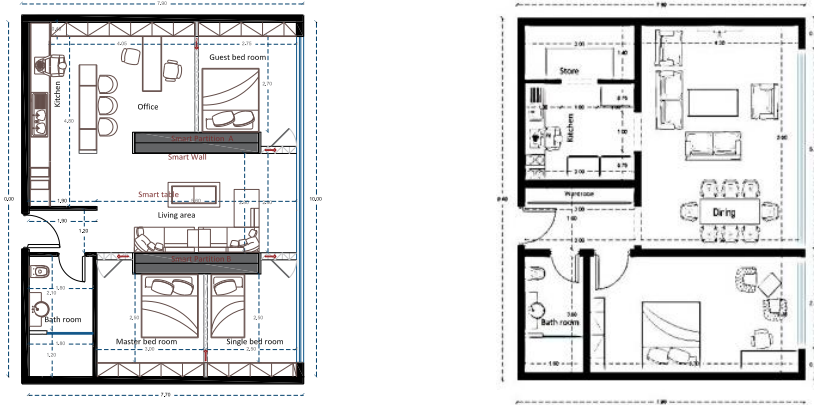
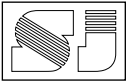


Fig. 4: (a) Figure denoting Smart Home Virtual Prototype Plan by researcher (b) Figure denoting Contemporary Home Virtual Prototype Plan (By researcher)

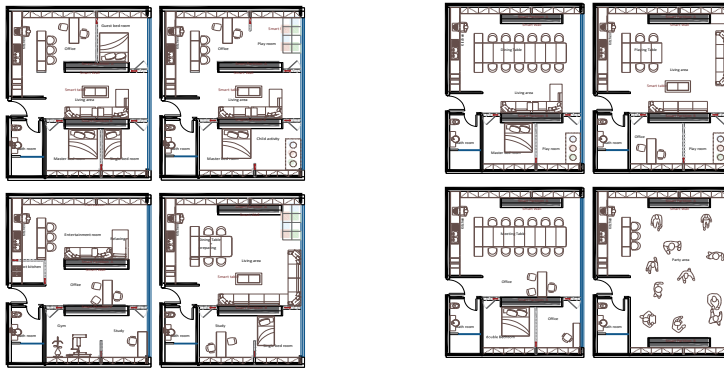


Fig. 5: Re-arrange able Layouts for Smart Home Hypothetical Prototype obtained by Manual Re-arrangement (By Researcher)

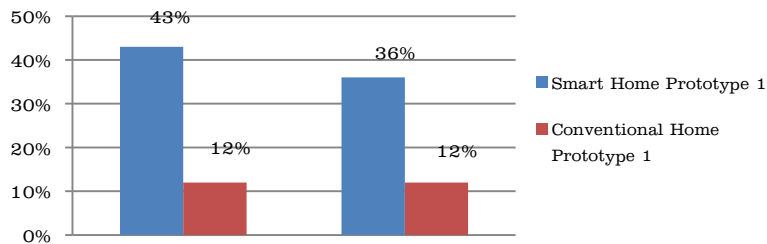


Fig. 6: Displaying interchangeability comparison between Smart and Contemporary Prototype 1 (By Researcher)