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The types of spatial adaptability based on user preferences of low-income apartments in erbil city

Husein Ali Husein* and Arazu Askandar Hamad

Department of Architectural Engineering, College of Engineering, University of Salahaddin, Erbil, Iraq.

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ABSTRACT

Spatial adaptability is the ability of floor plans to adapt to families' changing needs and requirements over time. Apartment floor plans that are not designed according to the user's preferences cannot meet his or her changing needs over time. So, an adaptable apartment floor plan is considered a desirable alternative that can provide various solutions to households' changing spatial needs in the present and the future. Future low-income apartment designs will be more effective if users select the most appropriate types of floor plan adaptability for their needs and culture. The aim of this study is to identify user preferences for the types of adaptability of floor plans and assess the adaptability capacity of low-income apartment floor plans based on those preferences. Based on the research criteria, six low-income multi-family residential buildings in Erbil City were chosen as case studies. The questionnaire was conducted through face-to-face interviews with 363 participants. The study used mixed methodologies, including a quantitative questionnaire survey and a qualitative case study analysis method, to answer the research questions. This study concluded that users did not prefer all the types of spatial adaptability; they preferred the ones that most suited their needs, lifestyles, and preferences. Low-income apartment floor plans didn't support user preferences, and residents of low-income apartments in Erbil City could not adapt their apartment floor plans according to their preferences. According to the findings of this study, there should be a greater emphasis on the future design of low-income apartment floor plans in order to meet the changing space needs and requirements of families. This study can help architects and policymakers improve housing quality in Erbil City by considering user preferences for space adaptation when designing low-income apartment floor plans in the future.

1. Introdaction

Theories and concepts relating to adaptability suggest that buildings are made up of several layers, including "location, structure, skin, services, space plan, and stuff." A space plan's adaptability is determined by its capacity to change in response to various spatial configurations, whether on an hourly, daily, or weekly basis or over the course of various seasons or even decades [1].

This makes it possible for residents to alter their living space in accordance with their needs and allows a variety of ways to occupy a residence [2]. Using adaptable space layouts, users are given the freedom to arrange or use the space anyway, depending on their activities and preferences [3]. Estaji [1] argues that an "ideal house" refers to a building that satisfies all human needs. The largest issue, though, is that the environment, user requirements, and preferences change quickly over time. As a result, buildings should

* *Corresponding author.*
E-mail address: husein.ali@su.edu.krd (Husein Ali Husein)

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have adaptable space layouts that can be reconfigured in a variety of ways to accommodate various living styles, requirements, and functions [2]. Housing that is spatially adaptable can foster diverse and inclusive communities in which people can live at their own place for the rest of their lives (e.g., illness, family expansion or contraction, aging, pandemic lockdown, digitalization of work and telecommuting, and so on) [3]. Spatial adaptability can be condensed into three fundamental strategies: flexibility, generality, and elasticity [4-7].

“Flexibility” has always been an important aspect in the design of housing and residential buildings [8]. Flexibility in architectural design refers to a building's ability to rearrange, remove, or add features and systems as user needs change [9]. These changing requirements can be personal, such as a growing family, practical, such as an elderly family member, or technological, such as updating outdated services [10]. It allows residents to modify their floor plans and occupy them in a variety of ways without being restricted by predetermined room designations [11]. Moreover, flexibility enables one to alter the number, size, and configuration of rooms within the defined layout of an existing apartment [7]. In the context of housing, “generlity” primarily refers to the ability of activities to be switched between different rooms [12]. Manum [6] defines it as "the ability of a fixed situation to accommodate a variety of requirements or preferences. In theory, every house has the potential to be used in a number of different ways. A bedroom, for example, can also be used as a hobby or study room [12]. In a general layout, the rooms are not assigned specific functions; instead, they can be used for a variety of purposes without the need to physically alter the space[7]. For adaptable housing, this is an important strategy [13]. Because it enables the spaces that have been used efficiently in the short- and long-term [14]. The last spatial adaptability strategy, which is "elasticity" in architectural design, refers to a building's capacity to be divided into various functional units or expanded either horizontally or vertically [9]. In a broad sense, it refers to a home's ability to change its size in response to a user's needs over the course of a lifetime [3]. An elastic layout allows the apartment's space to enlarge and shrink in size [7]. This study allows users to identify which types of spatial adaptability are suitable for them and examines the adaptability capacity of low-income apartment floor plans to accommodate their preferences. For this purpose, face-to-face interviews, a questionnaire, and an analysis sheet were adopted as methodologies in this study.

2. Literature review

There is extensive research relating to the adaptability of floor plans. Recently, Femenias and Geromel [3] evaluated two features, such as generality and flexibility, in order to find out what factors enhance the adaptability of floor plans for end users. The findings revealed that modern floor plans include features that do not support general use, such as small bed rooms and more pass-through rooms, while floor plan fragmentation and oversized living rooms enhance the flexibility of floor plans. Alsaati et al. [15] identified the flexibility criteria to meet the changing future needs and requirements of residents. The research was carried out by analyzing existing apartment floor plans using an analysis sheet and space syntax, as well as conducting questionnaire surveys with architecture experts. According to architectural experts, the most important flexibility criteria are building structure, space organization, plan geometry, service position, initial flexibility, number of façade planes, flexible furniture and sliding moving-folding wall partitions, slack space, dwelling joining, number and disposition of the entrance, dwelling dividing, and shared (switched) rooms. The analysis of floor plans revealed that flexibility criteria were not well applied in the design of low-income apartments, and some of them were ignored by designers. Another study looked at how the degree of flexibility in interior spaces is affected by the structure of the building and the amount of available space. The author categorized various types of flexibility based on their ability to change the size and arrangement of interior spaces. The study emphasized the importance of flexible building structures and free plans (free of structural elements) in designing housing spaces that can be easily modified to meet the changing needs and requirements of residents in the future [16]. Li et al. [17] explored the idea of open design in low-income housing, which aimed to make living spaces more adaptable to meet the changing needs and requirements of residents in the future. Based on their findings, the authors proposed several interior layouts within a specific open plan layout that can accommodate a variety of living patterns and demographic conditions. According to the study, an open-plan approach helps residents to provide a variety of internal layouts and can be used in the design of low-income housing floor plans in the future. Das et al. [18] compared the spatial organization of traditional and contemporary houses. The study focused on the spatial qualities that affect housing adaptability, such as openness, privacy, flexibility, generality, depth of space, and typicality of rooms. Various qualitative and quantitative measures such as plan analysis, activity charts, and space syntax were used. The study concluded that traditional houses were more adaptable than modern houses. The findings show that room typicality, openness, and flexibility have all decreased significantly in modern homes. Surprisingly, the average depth of space and degree of privacy had increased. Minami [19] demonstrated the importance of movable partition walls in achieving floor plan adaptability. The study concentrated on how people changed floor plans to accommodate their evolving needs and requirements and transformed their living spaces over time by moving partition walls and remodelling rooms. He conducted a questionnaire study, recording the actual alterations made to the apartment units and questioning residents about how and why they renovated their apartment floor plans. The survey found that, in most cases, the room arrangement was changed to make the private room or living room larger and to provide enough space for their children as they started school or to use the children's rooms for other purposes after the children left home. Further, Yunitsyna [20] proposed the concept of "universal space" in housing design, which is adaptable and flexible to individual and family living needs and preferences. The research proposed a set of volumetric and spatial parameters that can be used as design guidelines for designing residential floor plans. The most important aspects in determining the universality of rooms were the size of the room, the width of the room, and access to the room. By incorporating the universal design criteria, we can build more affordable, sustainable homes that can meet a variety of residents' needs.

Based on previous related studies, researchers identified the types and attributes of spatial adaptability according to their predictions, investigations, and expectations that users might need in order to meet their needs. Previous related studies did not mention user preferences to identify the types of spatial adaptability that are most compatible with their needs and preferences. Identifying the types of spatial adaptability according to user preferences can be determined as a research gap in this study. Low-income apartment floor plans should be designed to meet the needs and preferences of end-users, who have a greater understanding of their lifestyle, daily routines, and spatial requirements.

3. Theoretical frame work

Houses are modified to varying degrees by their users during the course of their lives, whether the designer designed them or not [21]. Researchers described the adaptations that users made to their homes to meet their needs.

This study tries to identify the most common types of spatial adaptability and design features that facilitate these adaptations as follows:

a. Flexibility

Flexibility lets you change the number, size, and configuration of rooms without changing the apartment's overall size [7]. Many families changed the room layout, added more bedrooms, and enlarged the private room as their children grew up and left the home to accommodate their changing lifestyles [19]. For the majority of residents, having more bed rooms in a given space is more important than the apartment's organizational and dimensional quality [22]. Based on a survey, residents of low-income apartments made some common modifications to the apartment floor plans in order to meet their needs and preferences, such as dividing a large bedroom and living room to create an additional bedroom through partition walls and curtains and also changing the connection between rooms [23]. According to Pulhan and Orcunoglu [24], residents of mass housing in the city of Girne (North Cyprus) made various floor plan adaptations, such as demolishing the entire wall to provide visual continuity between the living room and kitchen, the living room and entrance hall, and the living room and staircase. In addition, combining the kitchen and living room by residents to create a semi-public area makes the space adaptable, allowing for more activities and expanding the available space [25]. In conclusion, based on the theoretical framework, this study suggests that residents prefer to increase the number of bedrooms by dividing the master bedroom or the living room. It is possible to solve the problem of adding more sleeping space at the expense of reducing the size of an individual room or by dividing the large room into two independent rooms [22], [23]. So the size of the master bedroom and living room has an impact on increasing the number of bedrooms. In addition, this study suggests that residents prefer combining the living room with the kitchen in order to provide multi-functional space and visual continuity between them. Spatial organization has an impact on this type of adaptation. This can be achieved by locating the living room and kitchen adjacent to each other and locating a non-bearing wall between them [24].

b. Generality

Generality primarily refers to the interchangeability of activities between different rooms [12]. Manum [6] identifies it as having the capacity to fulfill a variety of needs or desires in a fixed situation [6]. In theory, every dwelling has the capacity to be used in various ways; a room defined as a bedroom, for instance, can be used equally well as a study or hobby room. Things get more interesting, however, if a dwelling can accommodate different living patterns. A home that can be occupied, without modification, by either a family with two children or three or four singles can be described as highly polyvalent [12]. As shown in [23], when residents inhabit an apartment, they don't use the spaces in the same way as they were designed. For example, they interchange the activity between rooms; for example, they change the bedroom for the living room and vice versa, or they change the room function to any other activity, such as changing the dining room and kitchen to a bedroom. Further, Pulhan and Orcunoglu [24] investigated and found that residents had converted one of the three bedrooms to a study room due to functional requirements. In conclusion, based on the theoretical framework, this study suggests that residents prefer to change the activity between rooms, for example, changing the living room to a bedroom, changing the bedroom to a guest room or a study room, or vice versa. Size, shape, and spatial organization of rooms are physical factors that affect the generality of the room [3]. Seo and Kim [26] consider that having a central hall promotes generality because activities can take place in any of the rooms. In his example, he divided the core and established a central hall with a circular arrangement of rooms. So, the central hall type can be achieved by a centrally located technical core and entryway along two opposing walls [27]. aIn a flat of the central hall type, each room is characterized by multiplex connections and functional neutrality toward the central hall. This enables you to switch between functions in day and night modes [26, 27]. The living room and bedroom, which are all connected by a common hallway and are approximately the same size, allow for generality in use [6]. Having rooms of equal size means that the living room is slightly smaller than the average and the bedroom is slightly larger than the average, allowing them to be occupied by a variety of different user groups [28].

c. Elasticity

Elasticity in architectural design refers to the ability to divide a building into separate functional units or expand it horizontally or vertically [9]. Flexible layout refers to the layout in which the size of the apartment space can be expanded or reduced [7]. The authors of this article [29] investigated the size modifications made by residents of low-income flat units to meet their needs and preferences. Resizing flats, which included knocking down walls to combine smaller units into larger ones or dividing larger units into smaller ones, was one of the most common changes. The modifications were usually motivated by financial factors, such as the need to rent out a portion of it or accommodate multiple generations of the same family. Also, Warouw et al. [30] found that occupants of resident-owned apartments engaged in two distinct types of expansion: small-scale horizontal expansion through the removal of boundary walls and large-scale expansion through the installation of open-plan designs on ground-floor units. While top-floor units added attic space by enclosing ceilings, erecting floors, and constructing small stairs, upstairs units added balcony space by erecting walls and laying floors. Furthermore, Hamza [31] illustrates three examples that were modified by residents. In the first example, a teenage boy's room was added to a house, attached to the exterior wall, and with a separate entrance, giving him privacy and independence. The home in the second example was divided into two independent dwellings so that one could be rented out while the owners continued to live in the original part. In the third example, the owner separated the living room to provide a self-contained unit for teenage boys and provided separate door access while continuing to permit him to use the home's public toilet.

In conclusion, based on the theoretical framework, this study suggests that residents of low-income apartments prefer to increase and decrease the size of their apartments. Increasing the size of apartment units can be achieved by joining adjacent units by constructing a non-loading wall between the units [32]. Merging the common space between adjacent units is another way to expand the size of a flat based on an agreement between adjacent users [32]. For decreasing the size of an apartment unit, a large residential dwelling can deal with the issue of the family's shrinking size by having the ability to be divided into two independent units or to separate part of it [15]. A separate part of an apartment can be achieved by separating a room within the apartment that is conveniently located near the kitchen, bathroom, and entryway. This room could be used by a teenager to provide privacy, or it could be rented out, for example [7]. Further dividing the dwelling unit into two independent units becomes simpler and more varied, with more precise and compact shapes, without major layout changes or brakes [27]. The centeral entrance position provides the best option for flexibility as well [27]. It is possible to divide an apartment into two distinct units with very basic tools, like an additional entrance [33]. An important factor to take into account in this type of spatial adaptability is where the service spaces are

located. The location of technical installations is one of the main fixed features of residential space [28]. When the service installations (kitchen, bathroom, and toilet) and the main entrance are all grouped in a row, it offers the maximum unit flexibility and allows residents to easily divide the unit into two independent units or merge the adjacent units to form a large unit, helping to rearrange the interior spaces in an efficient way. The technical core located between two flats offers a minimum of flexibility and prevents a flexible redistribution of interior spaces [27]. In summary, this study extracted some common types of spatial adaptability to be included in a questionnaire and extracted design elements to be included in an analysis sheet that help residents make such an adaptation (see Table 1).

Table 1. Key measures in the questionnaire and analysis sheet

Strategies of spatial adaptability	Measurement factors in the questionnaire	Measurement factors in the analysis sheet
Flexibility	Increase the number of bedrooms by dividing the master bedroom.	-Oversized master bedroom -Number of openings
	Increase the number of bedrooms by dividing the living room.	-Oversized living room -Number of openings
	Combine the living room with the kitchen.	-Spatial organization (living room and kitchen located adjacent to each other)
Generality	Change the activity between rooms, for example, by changing the living room to a bedroom, changing the bedroom to a guest room or a study room, or vice versa.	-Approximately equal habitable room sizes (master bedroom and living room size) -Central hall-type (divided technical core and entryway and positioned along two opposing walls)
Elasticity	Increasing the size of the apartment by merging the common space between the two units	-The presence of common space between adjacent units
	Increasing the size of an apartment by merging adjacent units	-Locating one non-bearing wall between the two units -Service installations and entrance are grouped in a row
	Decreasing the size of an apartment by separating a room	-Located a room near the entrance and service shaft -Possibility of providing an additional entrance
	Decreasing the size of the apartment by dividing the unit into two independent units	-Compact floor plan layout -Central entrance -Service installations and entrance are grouped in a row

4. Research objective

This paper attempts to obtain convincing answers to the following questions:

1. Are the existing low-income apartment floor areas and spaces adequate for the current residents' needs?
2. What are the types of spatial adaptability that residents of low-income apartments prefer?
3. Can residents adapt the low-income apartment floor plans to meet their preferences?

5. Research methodology

For the objectives and purposes of the study, two types of qualitative and quantitative data collection are required. First, the quantitative method was used as a measurement tool in this study, which included a questionnaire survey. The questionnaire survey in this study was designed with clear statements, a simple structure, and an appropriate number of questions. The author used 374 printed instruments and recorded the data on paper. Face-to-face interviews with residents were used to complete the questionnaire form, and the author carefully illustrated each question to reduce response bias. At the end, 363 questionnaires were filled out. The questionnaire form includes two types of questions: Likert scales and Yes/No questions with an explanation for the (no) response. Stratified random sampling was employed to select the number of participants in low-income apartments in Erbil city (see Table 2). Second, after identifying user preferences for different types of spatial adaptability, the study used an analysis sheet to examine the adaptability of low-income apartment floor plans to accommodate those preferences.

Table 2. Number of participants in the low-income cases study

Case study	Number of units	Stratified random sampling	Number of participants
Hana city	1008	(1008/2628)×336	129
444-Aapartments	444	(444/2628)× 336	57
Mamostayan city	192	(192/2628)× 336	24
Shahan city	672	(672/2628)× 336	86
Zhyan city	192	(496/2628)× 336	63
Lana city	120	(120/2628)× 336	15
Total	2628		374

The data collected in this study were quantitative and qualitative, so each type was analyzed separately. Quantitative data were analyzed using IBM SPSS 24 (Statistical Package for the Social Sciences) software. Three approaches were used to analyze the quantitative data: descriptive statistics, One-Sample T Test and One-Way ANOVA. In this study, descriptive statistics are employed to provide an overview of the respondents socio-demographic characteristics and their responses to yes-or-no questions. The One-Sample T Test was used in this study to assess user preferences regarding the types of spatial adaptability. The null hypothesis for a 1-sample t-test is $H0: \mu = \mu 0$.

If the p-value is larger than the significance level (usually.05), it means that $\mu = \mu 0$ (specified value =3) and not reject H0. Meanwhile if the p-value is less than the significance level (usually.05), it means that $\mu \neq \mu 0$ (specified value=3) you can reject the null hypothesis and draw the conclusion based on mean of respondents. Further, One-Way ANOVA is used in order to test the effect of socio-demographic characteristics and respondents of low-income cases study on the outcomes of a questionnaire about spatial adaptability. The Microsoft Office Excel 2013 program was used to analyze the qualitative data that was collected from analyzing low-income apartment floor plans. In this program, a value of 1 is assigned to the criteria that were achieved, and a value of 0 is assigned to the criteria that were not achieved, which were then collected and converted into numerical and ratio (quantitative) results.

a. Case studies

This article focused on low-income apartments because Silas [34], argues that the housing that is provided to low-income people most requires adaptability in space design. According to the study survey, Erbil City has eleven two-bedroom low-income apartments. Following discussions with expert consultants and statistical data analysis, in order to generalize the result, more than 50% of the study samples should be selected. As a result, six low-income apartments were chosen for this study based on their shared characteristics, such as the number of bedrooms, area, and type of spatial organization. All the selected cases study have two bedrooms. The floor area of low-income apartments in Erbil City varies greatly. The cases study that were constructed by the government, such as Hana City and 444

Apartments, have a smaller floor area than the other cases study that were built by investments. This study tried to select six cases study with floor areas that are approximately near each otherThe other case studies that were not chosen had floor areas larger than 128 square meters. All the selected cases study had a closed spatial organization with separate rooms for each function. For more information, see Table 3.

Table 3. Information about the selected case studies

Case study	Number of bedroom	Number of block	Number of floor	Number of flat/floor	Number of unit	Area	Year	Income group
Hana city	2	84	3	4	1008	98	2004	Low-income
444-apartments	2	37	3	4	444	98	2001	Low-income
Mamostayan city type A	2	6	8	4	192	106	2013	Low-income
Shahan city	2	28	6	4	672	128	2010	Low-income
Zhyan city	2	12	8	2	192	117	2014	Low-income
Lana city	2	4	10	4	160	108	2016	Low-income

6. Analysis and presentation of data

This section shows the analysis and presentation of data collected via comparison of low-income apartment floor plans with Iraqi housing standards, a questionnaire survey, and an analysis sheet for six low-income apartments in Erbil city.

a. Comparision of low-income apartment floor plans with Iraqi housing standards

Table 4 shows the indoor useful floor area of each apartment and its spaces and displays the difference in square meters, to determine whether they meet the Iraqi housing standards in their existing condition or not. It is important that activities be built in accordance with these standard dimensions; otherwise, having a comfortable apartment that meets all basic needs would be difficult. The average area is as follows: indoor useful floor area, 88.32 square meters; master bedroom, 16.96 square meters; children's bedroom, 14.39 square meters; living room, 24.9 square meters; kitchen, 11.33 square meters; bathroom and toilet room, 6.53 square meters; storage, 2.92 square meters; circulation space, 14.58 square meters. The habitable rooms (master bedroom, children's bedroom, and living room) were built nearly above the minimum standard in most cases, whereas the average kitchen area was built below the standards in most cases, and storage was not provided in 66.7 percent of design samples. The basic problem here is that the average indoor useful floor area in low-income apartments is below the minimum standard. Meanwhile, the bathroom, toilet, and circulation space areas are over the minimum standards. Due to a lack of indoor useful floor area and excessively large services and circulation spaces, the kitchen and storage do not have the required amount of space, and storage is not built in the majority of samples.

Table 4. Comparison of indoor useful floor and space areas with Iraqi housing standards

Indoor useful floor spaces	Area (Iraqi Housing Standard)	Cases study-two bedroom					
		Hana city	UN habitat apartment	Mamostayan city	Shahan city	Zhyan cityt	Lana city
Indoor useful floor area	93-99	92.94	71.3	84.86	103.7	92.24	84.86
master bedroom	15	15.3	14.36	17.28	22.36	17.5	15
children bedroom	12	14	12.8	15.76	15.2	14.8	13.76
Multi-purpose living room	24	25.74	24	15.76	29.89	32.6	21.46
Kitchen	12	9.9	7.56	12.23	15.4	10.92	12
Bathroom & toilet room	5	8.6	5.58	5.97	5.52	6.6	8.74
Storage	6	3.6					2.24
circulation space	12	15.8	12.9	17.86	19.45	9.82	11.66

Table 5. Socio-demographic Characteristics

Socio-demographic Characteristics		Count	Table N %
Gender	Male	187	51.5%
	Female	176	48.5%
Age	18-30	47	12.9%
	31-40	115	31.7%
	41-50	125	34.4%
	Over 50	76	20.9%
Time of work	Full time	70	19.3%
	Part time	76	20.9%
	Free job	89	24.5%
	Doesn't work	128	35.3%
Family Size	1 person	12	3.3%
	1-3 person	43	11.8%
	3-5 person	145	39.9%
	5-7 person	127	35.0%
	7-9 person	36	9.9%
Increase in family members after settling in this apartment	Not increased	180	49.6%
	1 person	84	23.1%
	2 persons	69	19.0%
	More than two	30	8.3%
Number of Years that Occupied in this House	Less than one year	22	6.1%
	1-3 years	80	22.0%
	4-7 years	141	38.8%
	More than 7 years	120	33.1%

6.1.1 Socio-Demographic Characteristics of Respondents

Results from the analysis of the socio-demographic characteristics of respondents **(see Table 5)** show that the largest number of respondents is male, with an average of 51.5%, while 48.5% of respondents are female. The majority of respondents (34.4%) are between the ages of 41 and 50. After that, ages 31–40 provide the second largest number of respondents, with an average of 31.7%; ages over 50 and between 18 and 30 provide the lowest number of respondents, with an average of 20.9% and 12.9%, respectively. In terms of working hours, 24.5% of respondents have a free job in which their working hours are not clear, while part-time and full-time have nearly the same average, which is 19.3% and 20.9% of respondents, respectively. Furthermore, those who do not work have the highest percentage of respondents, with an average of 35.3%. This result came from female respondents; 176 respondents were female. Most females from low-income families don't work and spend most of their time at home. The survey also shows the average number of family members per flat and that the majority of flats are occupied by families of 3-5 and 5-7 people, while families of 7-9 people account for 9.9% of respondents, and one-person families account for the least number of respondents. The majority of residents occupied their flats for 4–7 years, with an average occupancy rate of 38.8%, while more than 7 years, 1–3 years, and less than one year provided 33.1%, 22%, and 6.1% of the respondents, respectively. Nearly half of the respondents' numbers did not increase after occupation, with more than two people providing the lowest degree of respondent increment. Most families saw a one-person (23.1%) or two-person (19%) increase.

6.1.2 Adequacy of apartment floor plans

This section of the questionnaire provides information about the current household situation and the design of low-income apartment floor plans in order to determine whether the current low-income apartment floor plans provide adequate space and areas for residents.

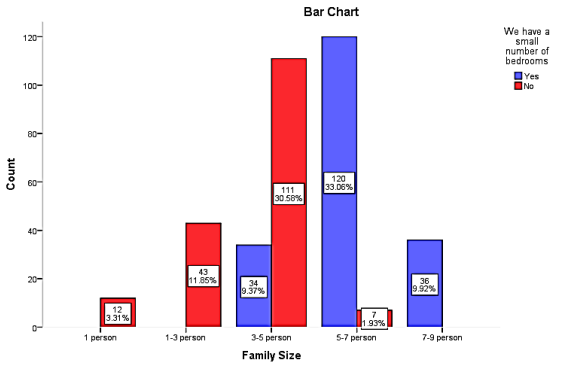


Figure 1. Relationship between family size and number of bedrooms.

As seen in the bar graph, there is a correlation between the number of bedrooms available and the size of the family; as the size of the family increases, the shortage in the number of bedrooms increases (see Fig. 1). In the absence of bedrooms, they have placed their small children's beds in their rooms, or their parents use the living room as a bedroom at night. Furthermore, the study discovered that, with the exception of Mamostayan City and Shahan City, respondents in Hana City, 444 Apartments, Zyan City, and Lana City reported that the kitchen area was not adequate for their needs. The kitchen area in the design samples of Hana City, 444-Apartment, and Zyan City is below the minimum standard requirement and cannot meet the needs of the residents. In Lana City, however, the area is consistent with the minimum standard, but its residents complain that the area does not provide enough space for their kitchen furniture because it contains three doors. At last, the living room area in all the design samples meets the needs of families except in Mamostayan City, which is far below the minimum standards.

Table 5. Adequacy of low-income apartment floor plans in Erbil City

Responsiveness to family needs		City											
		Hana City		Hbitat City		Mamostayan City		Shahan City		Zhyan City		Lana City	
		Count	Table N %	Count	Table N %	Count	Table N %	Count	Table N %	Count	Table N %	Count	Table N %
Does your apartment meet your family's needs?	Yes	37	10.2%	18	5.0%	10	2.8%	45	12.4%	27	7.4%	4	1.1%
	No	90	24.8%	38	10.5%	14	3.9%	40	11.0%	29	8.0%	11	3.0%
The parent's bedroom is small	Yes	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	No	127	35.0%	56	15.4%	24	6.6%	85	23.4%	56	15.4%	15	4.1%
The children's bedroom is small	Yes	0	0.0%	32	8.8%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	No	127	35.0%	24	6.6%	24	6.6%	85	23.4%	56	15.4%	15	4.1%
We have a small number of bedrooms	Yes	77	21.2%	34	9.4%	10	2.8%	39	10.7%	23	6.3%	7	1.9%
	No	50	13.8%	22	6.1%	14	3.9%	46	12.7%	33	9.1%	8	2.2%
Our kitchen is small.	Yes	87	24.0%	35	9.6%	0	0.0%	0	0.0%	27	7.4%	10	2.8%
	No	40	11.0%	21	5.8%	24	6.6%	85	23.4%	29	8.0%	5	1.4%
The living room(hall) is small	Yes	0	0.0%	0	0.0%	14	3.9%	0	0.0%	0	0.0%	0	0.0%
	No	127	35.0%	56	15.4%	10	2.8%	85	23.4%	56	15.4%	15	4.1%

6.1.2 User preferences for the types of spatial adaptabiliy

a. Flexibility

Long-term occupancy of the same apartment will be achieved by meeting the different needs of the users. The one-sample t-test (see Table 7) indicated that increasing the number of bedrooms by splitting the master bedroom into two bedrooms resulted in (Mean=4.36, P<0.05), which indicates that the majority of respondents would prefer to have a large master bedroom in order to divide to increase the number of bedrooms in apartment floor plans in order to accommodate their needs in the future. Furthermore, the result of increasing the number of bedrooms by dividing a large living room was (Mean=2.66, P<0.05); this means that despite the fact that on average, more than half of the respondents saw that the number of bedrooms did not correspond to family needs in all of the design samples, low-income families do not want to build an additional bedroom within the living room because of privacy; they do not want to mix the living room with the bedroom zone, and most low-income families would like to have a separate bedroom zone. Further, the result for merging the living room with the kitchen to provide an open plan was (Mean=2.64, P<0.05). Most families in low-income apartments prefer a closed plan in which the living room is not open to the kitchen, and they don't want to merge these spaces in the future. Most of their restrictions were about issues of privacy and smell.

b. Generality

Residents of low-income apartments prefer to change the activities between rooms, which is highly significant (mean (Mean=3.82, P<0.05) and they believe that it will help to provide more freedom in holding the activity in each room according to their preferences (see Table 7).

c. Elasticity

Residents prefer to increase the size of the apartment either by merging common spaces or by merging adjacent apartment units (Mean=4.31, P<0.05 and Mean=3.62, P<0.05 respectively) (see Table 7). The respondents' mean revealed that the majority of respondents would prefer to have a common space because it would provide a solution for the bedroom deficit and be less expensive than merging adjacent units. As opposed to this, respondents did not prefer to reduce the size of the apartment by seperating a room close to the entrance to be used as an office or studio apartment for teenagers who want to live alone or rent it out (Mean=2.13, P<0.05). However, respondents with a (Mean=3.96, P<0.05) preferred dividing the apartment into two independent small units because they stated that it is a good option for families who want their sons to be beside them when they get married.

6.2 Floor plan analysis

Based on the theoretical framework, an analysis sheet was prepared that contained possible values that facilitate these adaptations. The analysis sheet is divided into three main strategies of spatial adaptability: flexibility, generality, and elasticity.

6.2.1 Flexibility analysis

According to the questionnaire outcomes, increasing the number of bedrooms by dividing the master bedroom was one of the most preferable types of floor plan adaptability, according to residents. So, in the analysis sheet, this study seeks to examine the possibility of increasing the number of bedrooms by dividing the master bedroom. For this purpose, this study analysed the master bedroom sizes and number of openings (see Table 9, Section A). According to the Iraqi Housing Standards, the minimum area for the master bedroom should be 15 square meter and the minimum area for the children's bedroom should be 12 square meter (see Table 4). Despite that, a room in low-cost housing that is below the minimum standard was considered suitable and didn't reduce resident satisfaction [35]. Only Shahan City can support additional bedrooms in this study by dividing the master bedroom into two small, dependent children's bedrooms (11.18 square meters each) and using the children's bedroom as the master bedroom (15.2 square meters). In 83.3 percent of low-cost apartment floor plans, there is no possibility of increasing the number of bedrooms by dividing a master bedroom.

Table 6. User preferences for the types of spatial adaptability

Strategies of adaptability	Possible value	Mean	t	P-value	User preferences
Flexibility	I prefer to increase the number of bedrooms by dividing the master bedroom.	4.36	21.560	.000	✓
	I prefer to increase the number of bedrooms by dividing the living room.	2.66	-4.458-	.000	×
	I prefer to combine the living room with the kitchen.	2.64	-3.938-	.000	×
Generality	I prefer to change the activity between rooms,such as from the living room to the bedroom or vice versa, or from the bedroom to a guest room or a study room or vice versa.	3.82	11.414	.000	✓
Elasticity	I prefer to increase the size of an apartment by merging common spaces between adjacent units.	4.31	6.528	.000	✓
	I prefer to increase the size of an apartment by merging adjacent units.	3.62	21.875	.000	✓
	I prefer to decrease the size of the apartment by separating a room near the entrance.	2.13	8.338	.000	×
	I prefer to decrease the size of the apartment by dividing it into two independent units.	3.96	-11.555-	.000	✓

The major constraint for this alteration is the size of the master bedrooms. The average master bedroom area is 16.7 square metres and this area is not sufficient to be divided into two small bedrooms. In addition, the number of windows is not considered; there is only one window that will restrict dividing the master bedroom into two small independent bedrooms in the future.

6.2.2 Generality analysis

According to the questionnaire outcomes (see table 7), residents preferred to change the activities between rooms, such as from the living room to the bedroom or vice versa, or from the bedroom to a guest room or a study room or vice versa. There are two design features that enhance changing activities between rooms, and they should be met in the floor plans at the same time, such as approximately equitable habitable room sizes and central hall-type spatial organisation (the service core should be divided and placed with an entrance along two opposite walls) (see Table 1). For this purpose, this study analysed the sizes of habitable rooms (master bedroom, children's bedroom,

and living room) (see Table 8) and the spatial organisation of low-income apartment floor plans (see Table 9, Section B). Table 8 shows the room size analysis and displays the difference in square meters. The average size of the master bedroom is 16.97 square meters, the children's bedroom is 14.41 square meters, and the living room is 24.91 square meters. The survey discovered a significant difference between the size of private sleeping rooms and public living rooms. All study samples, with the exception of Mamostayan City, have bedrooms that are smaller than living rooms, restricting the changing of activities between rooms. In Mamostayan City, the size of the children's bedroom and living room are equal. According to the spatial organisation analysis, the central hall type was not exist in any of the study samples; none of them placed the service core and entrance at the centre of two opposite walls. Despite the fact that Mamostayan City has rooms of equal size, it is unable to change activities between rooms because the service core is positioned on one side of the apartment and does not provide central hall-type spatial organisation.

Table 7. Room size analysis

Category of rooms	Room name	Two-bedroom apartments						Mean
		Hana city	UN habitat	Mamostayan city	Shahan city	Zhyan city	Lana city	
Habitable rooms	Master bedroom	15.3	14.36	17.3	22.36	17.5	15	16.97
	children bedroom	14	12.8	15.8	15.2	14.9	13.76	14.41
	Living room	25.74	24	15.8	29.9	32.6	21.46	24.97

6.3.3 Elasticity analysis

Modifying the size of apartment floor plans meets the varying needs of families for space, and families can stay in their homes for extended periods of time. According to the questionnaire outcomes **(see table 7)**, residents preferred to increase the size of apartment floor plans by merging common space between adjacent units and by merging two adjacent units. Also, residents preferred to divide the apartment units into two small independent units.

Increasing the size of apartment floor plans: There are two factors that allow residents to increase the size of apartment floor plans: common spaces between adjacent units and locating two units adjacent to each other with a non-bearing wall between them while considering the location of service installations (service installations and entrances should be grouped in a row) (see Table 1). According to floor plan analysis (Table 9, Section C1), common space between adjacent units did not exist in all the study samples. Also, the study concluded that, with the exception of Zhyan City, a bearing wall between adjacent units did not exist. By joining adjacent units, it is possible to increase the size of an apartment floor plan by 83.3 percent. Zhyan City has only two apartments on one floor, and they are not placed next to each other. Further more, in all low-income apartment floor plans, service installations with entrances were not grouped in a row. There are dispersed service locations in 66.7 percent of the design samples, including Hana City, Mamostayan City, Zhyan City, and Lana City, and some of these services are situated between adjacent apartments, which reduces the flexibility of interior spaces after combining apartments.

Decreasing the size of apartment floor plans: Participants only preferred decreasing the size of an apartment by dividing it into two independent units (see Table 7). Compact layout, a central entrance, and the location of service installations are factors that help residents divide the apartment into two independent units (see Table 1). According to the floor plan analysis (see Table 9, Section C2), 33.3 percent of study samples have a nearly compact form, such as 444-Apartment and Zhyan City, and 66.7 percent have irregular floor plan layouts, such as Hana City, Mamostayan City, Shahan City, and Lana City. Furthermore, 50 percent of samples, such as Hana City, Shahan City, and Lana City, have peripheral entrances, while the other design samples have entrances that are nearly central. In the majority of apartment floor plans, the entrance is placed in extremely constrained locations where there is no space for an additional entrance for the new apartment. The location of services is also another restriction for this division. Technical services are dispersed in 66.7 percent of study samples and grouped in 33.3 percent. It is difficult to easily provide bathrooms, toilets, and kitchens for both apartments due to dispersed technical services. In conclusion, in all the design samples, it isn't possible to divide the apartment floor plans into two independent units because of the apartment floor plan layout, entrance location, and service location.

7. Discussion of findings

The previous section's outcomes and data that were obtained from the questionnaires of 363 low-income study participants as well as the analysis of the floor plans of six low-income apartment floor plans in Erbil City will indicate whether or not they have answered research questions.

7.1 The first research question

Are the existing low-income apartment floor areas and spaces adequate for the current residents' needs?

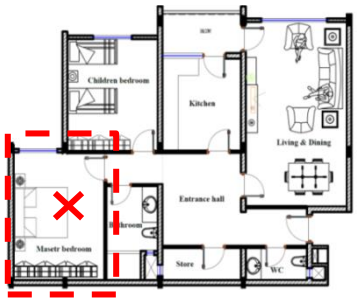
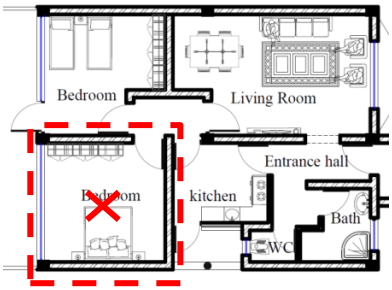
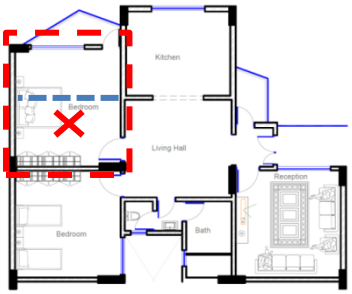
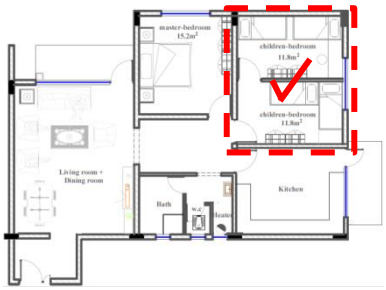
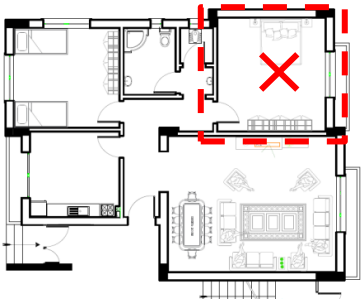
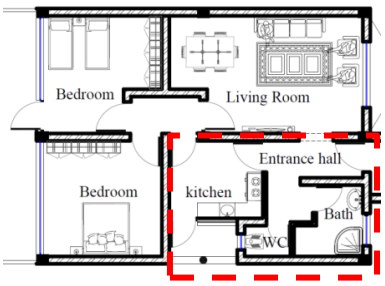
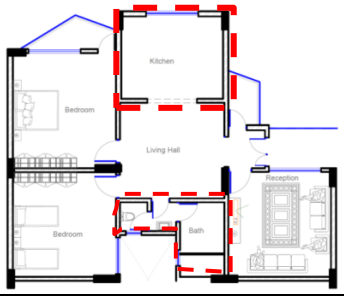
In this study, low-income apartment floor plans in Erbil City were compared with Iraqi housing standards, and a questionnaire was provided to determine how well the current apartment spaces and areas can accommodate current family needs, taking into consideration floor plan area and space comparisons with minimum standards and socio-demographic characteristics. The majority of respondents, or 61.2% on average, stated that their apartment's spaces and area weren't adequate for their needs. The following factors contributed to this lack of adequacy for family needs: 8.8% stated that the children's bedroom area is small; 52.3% stated that there is a shortage of bedrooms; and 43.8% and 3.9% stated that the kitchen and living room areas are small. The shortage in the number of bedrooms significantly contributed to the high occupancy rate (number of people per apartment), which was 44.9 percent of apartment units occupied by families with more than 5 people and families of different structures. Some of the 3–5 families had children of different genders that necessitated additional bedrooms. Similarly, a large number of respondents stated that the kitchen area didn't meet their needs because, in half of the study samples, it was built below the minimum standards due to oversized circulation areas and unstanderdized indoor useful floor area. Most residents stated that the children's bedroom and the living room were adequate for family needs.

7.2 The second research question

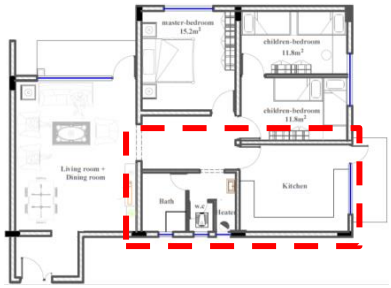
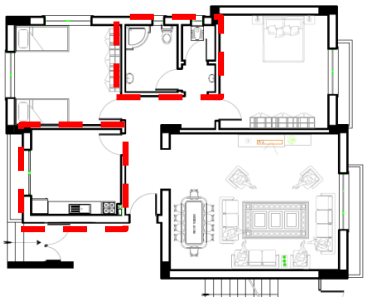
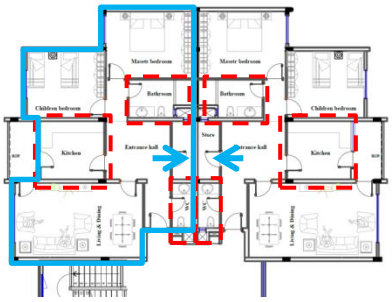
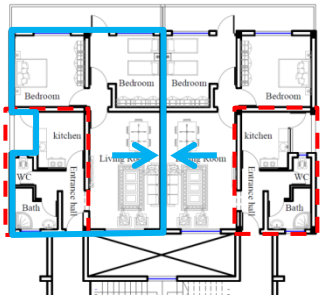
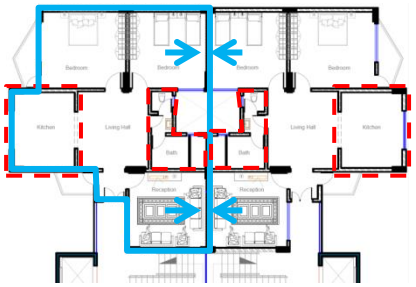
What are the types of spatial adaptability that residents of low-income apartments prefer?

Based on the outcomes of Table 7, residents of low-income apartments preferred to increase the number of bedrooms only by dividing the master bedroom into two small bedrooms as the number of family members increased. Another type of spatial adaptability that residents preferred was changing the activity between rooms,such as from the living room to the bedroom or vice versa, or from the bedroom to a guest room or a study room or vice versa. Additionally, it was preferred to increase the size of apartment floor plans either by merging common spaces between adjacent units or merging adjacent units, but primarily by merging common spaces between adjacent units. Conversely, it was preferred to decrease the size of flats only by dividing the apartment unit into two independent units.

Table 9. Floor plan analysis of two-bedroom low-income apartments in Erbil City

Section A: Flexibility analysis Criteria - Dividing the master bedroom into two bedrooms -Number of openings		
1- (Hana City) - Area (98 square meter)	2- (444- apartment) - Area (98 square meter)	3- (Mamostayan City) - Area (106 square meter)
		
-Master bedroom size is built nearly to the minimum standard (15.3 m2). -There is only one opening. -Dividing the master bedroom is not possible.	-Master-bedroom size built below the minimum standard (14.36 m2) -There is only one opening. -Dividing the master bedroom is not possible.	-Master bedroom size built nearly over the minimum standard (17.3 m2) -There is only one opening. -Dividing the master bedroom is not possible
4- (Sahan City)-Area (128 square meter)	5- (Zhyan City) - Area (118 square meter)	6- (Lana City)- Area (108 square meter)
		
-Master bedroom size is over the minimum standard (22.36 m2) -There is only one opening. -Dividing the master bedroom is possible	-Master bedroom size built nearly over the minimum standard (17.5m2) -There is only one opening. -Dividing the master bedroom is not possible.	-Master bedroom size built perfectly to the minimum standard (15 m2) -There is only one opening. -Dividing the master bedroom is not possible.
Section B: Generality analysis Criteria - A central hall type (divided the service spaces and positioned with entrance centrally along two opposing walls)		
1- (Hana City) - Area (98 square meter)	2- (444- apartment) - Area (98 square meter)	3- (Mamostayan City) - Area (106 square meter)
		
-There is no central hall type -Service spaces and entrance are not located centrally along two opposing walls. -Dispersed service spaces, some located between two adjacent units.	-There is no central hall type -Service spaces and entrance are not located centrally along two opposing walls. -Service spaces grouped peripherally on one side of the walls.	-There is no central hall type -Service spaces and entrance are not located centrally along two opposing walls. -Dispersed service spaces, some located between two adjacent units.

Continue ……..

4- (Sahan City)-Area (128 square meter)	5- (Zhyan City) - Area (118 square meter)	6- (Lana City)- Area (108 square meter)
		
-There is no central hall type -Service spaces and entrance are not located centrally along two opposing walls. -Service spaces grouped peripherally on one side of the walls.	-There is no central hall type -Service spaces and entrance are not located centrally along two opposing walls. -Dispersed service spaces	-There is no central hall type -Service spaces and entrance are not located centrally along two opposing walls. -Dispersed service spaces, some located between two adjacent units
Section C: Elasticity analysis C1: Enlarging the size of the apartment Criteria -Common space between adjacent units -Two units adjacent to each other -A non-bearing wall between the units -Service spaces and entrance are grouped in a row		
C2: Decreasing the size of the apartment Criteria -Compact layout -Service spaces and entrance are grouped in a row -central entrance		
1- (Hana City) - Area (98 square meter)	2- (444- apartment) - Area (98 square meter)	3- (Mamostayan City) - Area (106 square meter)
		
-The service spaces with the main entrance are not grouped in a row -Dispersed service spaces ; some technical service is positioned between two flats.	-The service spaces with the main entrance are not grouped in a row -The service spaces with the main entrance are grouped in a column	-The service spaces with the main entrance are not grouped in a row -Dispersed service spaces, some service spaces positioned between two flats.
C1: Increasing the size of the apartment -A non-bearing wall between the units. -It is possible to merge adjacent units by removing a store. -There is no common space between adjacent flats.	C1: Increasing the size of the apartment -Non-bearing wall between the units. -It is possible to merge adjacent units. -There is no common space between adjacent flats.	C1: Increasing the size of the apartment -Non-bearing wall between the units -It is possible to merge adjacent units. -There is no common space between adjacent flats.
C2: Decreasing the size of the apartment -Irregular layout -One peripheral entrance. -It isn't possible to divide the apartment into to independent units	C2: Decreasing the size of the apartment -Nearly compact layout -The entrance is nearly in the center. -It isn't possible to divide the apartment into two independent units	C2: Decreasing the size of the apartment -Irregular layout -The entrance is nearly in the center. -It isn't possible to divide the apartment into two independent units because of the entrance location, service location, and flat form.

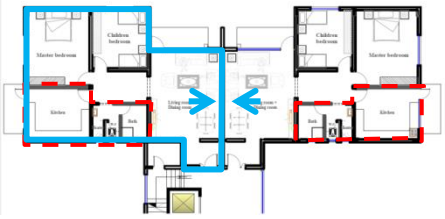
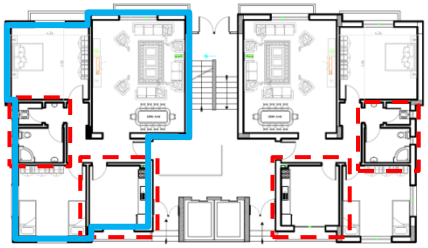
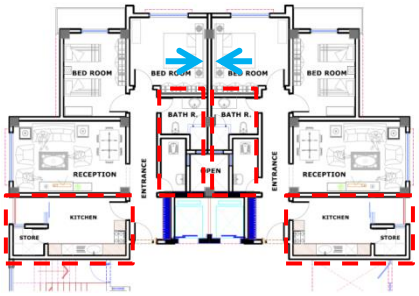
7.3 The third research question

Can residents adapt the low-income apartment floor plans meet their preferences?

The study concluded that residents of low-income apartments in Erbil city preferred to increase the number of bedrooms by dividing master bedrooms. However, based on the master bedroom size analysis, the study revealed that the master bedroom area of low-income apartments in Erbil City is not large enough to be divided in order to increase the number of bedrooms. Residents of low-income apartments preferred to change the activity between rooms,such as from the living room to the bedroom or vice versa, or from the bedroom to a guest room or a study room or vice versa.

Residents of low-income apartments in Erbil City cannot change the activities between rooms because neither approximately equitable room sizes nor central hall-type spatial organisation existed in the analysis of low-income apartment floor plans in Erbil City. If the spatial configuration is not of the central hall type, the depth of the plan increases and does not provide equitable access to service spaces and entrances.

Continue ……

4- (Sahan City)-Area (128 square meter)	5- (Zhyan City) - Area (118 square meter)	6- (Lana City)- Area (108 square meter)
		
-The service spaces with the main entrance are not grouped in a row -Service spaces are grouped peripherally.	-The service spaces with the main entrance is not grouped in a row -Dispersed service spaces	-The service spaces with the main entrance are not grouped in a row -Dispersed service spaces and some of them located between the two units
C1: Increasing the size of the apartment -Non-bearing wall between the units -It is possible to merge adjacent units. -There is no common space between adjacent flats.	C1: Increasing the size of the apartment -There is no unit adjacent to another. -It is not possible to merge the units. -There is no common space between adjacent flats.	C1: Increasing the size of the apartment -Non-bearing wall between the units -It is possible to merge adjacent units. -There is no common space between adjacent flats.
C2: Decreasing the size of the apartment -Irregular layout -One peripheral entrance. -It isn't possible to divide the apartment into two independent units.	C2: Decreasing the size of the apartment -There is no common space between adjacent flats. -Nearly compact layout -The entrance is nearly in the center. -It isn't possible to divide the apartment into two independent units	C2: Decreasing the size of the apartment -Irregular layout -One peripheral entrance. -It isn't possible to divide the apartment` into two independent units

Residents of low-income apartments in Erbil City preferred to increase the size of apartment floor plans either by merging common space between adjacent units or merging two adjacent units to form a larger one. According to apartment building floor plan analysis, they can increase the size of an apartment only by merging adjacent units.

Furthermore, residents of low-income apartments in Erbil City preferred to decrease the size of apartment floor plans only by dividing the dwelling unit into two independent units. Due to the irregular floor plan layout and the lack of sufficient space for providing additional entrances, the location of entrance, and the location of service installations, residents of low-income apartments in Erbil City cannot divide the dwelling unit into two independent units.

8. Conclusion

After examining the outcomes of the questionnaire survey and floor plan analysis of low-income apartments in Erbil City, this study came to the following conclusions:

1. According to the outcomes of the questionnaire and comparistion of low-income apartment floor plans in Erbil City with Iraqi housing standards the study concluded that the existing low-income apartment floor areas and spaces did not adequately meet the needs and requirements of their residents due to unstandardized apartment floor areas and spaces, family size, and family structure. Most residents of low-income apartments required additional bedrooms, while the indoor useful floor area of low-income apartments in Erbil city was constructed below the minimum standards, which affected some activities that were not built in accordance with these standards, and storage was not built in most of the study samples. Besides the unstandardized floor area, the layout of a space and the number of openings in the layout also had a significant impact on providing sufficient spaces to meet family needs and requirements. More consideration must be given to the floor plans' flexibility in order to accommodate an extra bedroom, as well as to their design and layout, in order to guarantee that they satisfy inhabitants' preferences for furniture arrangement.
2. According to the outcomes of the questionnaire survey about 8 types of spatial adaptability, the study concluded that residents of low-income apartments in Erbil City preferred only 5 types of spatial adaptability that aligned with their needs, lifestyles, and preferences, such as increasing the number of bedrooms by dividing the master bedroom, changing the activities between rooms, increasing the size of the apartment floor plan by merging common space between adjacent units, increasing the size of the apartment floor plan by merging adjacent units, and dividing the apartment units into two small independent units. The study also showed that residents of low-income apartments in Erbil City paid more attention to the privacy issue, as they prioritised privacy over providing an additional bedroom within the living room or providing an open plan by combining the living room and the kitchen.
3. According to the outcomes of the floor plan analysis of low-income apartments in Erbil City, the study concluded that low-income apartment floor plans in Erbil City didn't support user preferences. The current residents of low-income apartments in Erbil City were not able to increase the number of bed rooms; they were not able to change the activities between rooms; and they were also not able to divide the dwelling unit into two independent units. The only spatial adaptation that they could make to their floor plans was increasing the size of apartment floor plans by merging adjacent units in an inflexible way. This means that after merging the units, due to the irregular layout form, poor location of service installations, and poor location of the entrance, they were unable to rearrange their apartment interior spaces according to their needs and preferences.
4. Spatial adaptability strategies are important aspects of designing comfortable and functional living spaces that can adapt to the family's changing needs and requirements over time. Therefore, this study suggests that architects and policymakers in Erbil City should consider user preferences for space adaptation when designing low-income apartment floor plans. This will guarantee that the design of low-income

apartment floor plans in Erbil City aligns with the needs and preferences of residents.

9. Limitation of the study

This study focuses on low-income apartment floor plans in Erbil City because these apartments have a fixed size and are occupied by families with low incomes. As a result, they require more adaptable floor plans than single-family homes, which are easier to expand, extend, or demolish.

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

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