The Effect of Geometrical characteristics and Space layout on the Efficient Thermal Performance in Residential Apartments

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Abstract. Although many environmental studies contributed to understanding the thermal behaviour of residential buildings, they mostly focused on a set of design strategies that aim to reduce the consumed load by dealing with the building as a whole, without considering the characteristics of the parts and their internal distribution in the residential floor plan. Accordingly, the research aims (within the level of residential towers) to study the effect of the geometrical characteristics and the spatial layout of the apartment represented by the apartment layout system, its openness to the outside, and the geometrical characteristics of its spaces on the efficiency of its thermal performance and the extent of variation between its spaces. To achieve the goal, a thermal simulation was performed using the Ecotect2011 program on a selected sample of 12 apartments for local housing of various projects that cover with their characteristics the variations whose effects are required to be tested within the research objectives. The research came out with a set of conclusions that can give basic indicators to the designer in achieving higher efficiency of the thermal performance of a residential apartment and reducing the variance in the necessary air conditioning load between its spaces.

1. Introduction

Architectural design plays an essential role in achieving thermal comfort. This requires the climate to be one of the most important design criteria, leading to an energy-saving and environmentally friendly building [1]. The thermal performance expresses the extent to which the building design, in its shape and components, responds to the changing climatic conditions daily and seasonally [2]. It also indicates the total energy expenditure per unit required to heat or cool the interior space of the building to the minimum thermal comfort. [3]. Thermal comfort is the main driver of energy consumption in buildings. it is responsible for nearly half of the global energy spent in residential buildings. So, it plays a major role in determining the value of building energy demand. Building actors have to move towards achieving this through controlling design and building materials to offer the best possible thermal comfort and lowest energy cost while respecting the environment [4]. The proper conuration and forming of the building can reduce the energy consumption required to maintain comfortable indoor conditions and achieve what is call efficient thermal performance [5], which is known as the ideal relationship between the building...
design and its thermal performance, to reduce the energy consumed to offer the thermal comfort of the person in the building [6].

2. Related studies
Buildings can be designed to meet the residents’ needs for heat and with low levels of energy by adopting a design approach that integrates passive energy techniques into the building design process to reduce the consumed load [7]. Environmental studies suggested many design strategies that helped architects bring their buildings closer to comfort [8]. Al-Aqili, 2008 pointed the most important strategies as the geometry, building orientation, design of its envelope, determination of window-to-wall area, thermal transfer coefficient of envelope material, extent of their absorption, their emission falling rays, ceiling height, technology and the need for HVAC system [9]. (Talab, H, 2014) defined more passive design strategies like shading devices, double glazing, natural ventilation, green roofs, insulation materials, evaporative coolers, indirect radiation cooling, painting with light colors with high reflection [10]. Such studies and many others, in general, focused on dealing with the building as a whole, without looking at the internal parts and details that compose it and their effects.

Along with these studies, another research checked the role of the geometrical and topological characteristics of buildings plans on its thermal performance. (Gregor, 2009) classified the space layout as one of the design strategies affecting the thermal performance of the building [11]. Other studies indicated that the system of architectural space layout is greatly affects efficient environmental practices [12].

The study of (Musau, and Steemers, 2008) also examined the effect of the diversity of space layout in office buildings on determining the levels of energy consumption required to meet the needs of the user, and the hypothesis relied on the possibility of achieving significant energy savings through formulating and adopting space layout strategies, the study concluded that the advantage of open and semi-open schemes over closed ones in achieving energy savings [13]. (Lim, 2018) analysed the energy performance in residential buildings focusing on the possibility of dividing the floor area thermally into the air-conditioned part of the apartments as a whole, and the second non-air-conditioned part represented by the public service space of the elevators and stairs, the performance was determined according to the ratio of the non-air-conditioned area to the air-conditioned area [14].

![Figure1](image1.png)

Figure 1. Air conditioned and non-air-conditioned areas in residential floor plan [14]

The study of (Souza & Alsaadani, 2012) investigated the effect of office space layout on heating and cooling requirements, by modelling it with different thermal division strategies, and focusing on models that committed to changing space layouts only. The areas that form the core of the building were excluded from the comparisons and the results confirmed that the selected models witnessed a difference in the annual demand for heating using different zoning strategies [15]. (Taylor, P., & Yi, H., 2015) study dealt with research in the methodology of organizing the design of the space layout for office spaces, based on the thermally optimal zoning of an individual space or a group of interior spaces. The results showed differences in heating and cooling loads between the single and multi-zone models [16].

As a conclusion, these studies presented a number of indicators with the building, including:

1- The effect of the space layout, nature of the building on the efficiency of its thermal performance.
2- The possibility of looking at the building on each of its frequent floor as a group of areas with different degree of need for air conditioning loads.

All of these studies demonstrate the necessity for designers and architects to think about the environmental practices of elite while organizing building spaces in general, but this effect has not been fully confirmed. Numerous studies are needed to compare the effects of diversity with space layout and organizations in terms of energy indicators [12], and it is worth noting that the residential buildings had the less share of these studies. The research will focus on the role of the internal layout of the floor plan on the energy-saving efficiency by studying the effect of geometrical and topological characteristics of the apartment on the thermal performance of residential tower apartments in particular. To address the research problem, it is necessary first to introduce the characteristics of spaces and spatial layout within the private characteristics of the residential building and the spaces of the apartment to measure its role in affecting the thermal performance of the apartment.

3. Spaces of the residential building
In its simplest layout, the residential floor consists of two main parts, first is the general circulation and services of the floor as a whole, while the second is the residential apartments. Each apartment consists of a group of spaces that classified into two categories: the main living spaces and the secondary supportive spaces that represented by the service, storage, circulation and etc. These spaces are differed among themselves in terms of geometrical characteristics, such as dimensions, area, proportions, the number of faces exposed to the outside, and the way it is organized within the space layout formed by it.

3.1. Thermal division of the residential floor based on the type of activity:
When studying the thermal performance of apartments in the residential tower, it is necessary to refer to the most basic details that express the true size of the energy load required for air conditioning. Although the surface coefficient ratio / volume is able to explain the relationship between the building envelope and its size and can be used to evaluate the thermal performance in buildings [17], these two factors can be adjusted for their value through some of the fundamentals of space divisions in the residential building. ‘Figure1’ presented the first part of the residential floor divisions that classified it to:

- Public service spaces: It includes the main service activities of the residential building represented by elevators, stairs, and floor services.
- Apartments spaces: includes all apartments spaces on the residential floor [14].

This consideration leads to different calculations of the size covered by heat treatment after subtracting a portion of the service spaces from it ‘Figure 2’ shows an example of this division in a residential building that opens all its internal spaces directly to the outside.

![Figure 2](image)

Figure 2. A model for a residential apartment in which all spaces are external. -Researcher

3.2. Thermal division of the residential floor based on the signature of the spaces:
According to (Los Alamos, 2002) on thermal loads and the value of HVAC in buildings, the study distinguished between two types of spaces as shown in ‘Figure 3’.
Peripheral spaces: The spaces directly affected by the outside climatic conditions. The architectural features of the envelope will determine direct solar gain and thermal loads.

Internal spaces: The spaces affected by the loads of the occupants (electrical, lighting systems and equipment in the space [18]).

Another study (Wafia, 2008) represented the morphological structure of any building with three layers (Kernel (the center), the outer shell (envelope) and classes (intermediate layers) considering the kernel in the center away from external disturbances of the climate as the most thermally stable. The greater thermal turbulence will occur as moving towards the Perimeter, as shown in ‘Figure 4’ [19].

Figure 3. Division of plan spaces [18]

Figure 4. The division of the building into three layers [19]

As an extension of this trend, according to [18], [19] studies. ‘Figure 5’ presents a model of the most widespread form of the point system of residential building. Beyond the first distinguishing of the public service spaces, it is possible to transfer this important division, gradually to the apartment level itself by dividing its spaces to:

External spaces: which are in direct contact with the building's exterior envelope.

Internal spaces: which are without direct contact with the external building envelope and are concentrated in movement corridors, bathrooms and stores.

Figure 5. A model for a residential apartment with the three layers division. -Researcher

3.3. Thermal divisions of the apartment based on the geometrical characteristics of its spaces:

To clarify the thermal performance of the apartment and its details, it is necessary to distinguish between several divisions of apartment spaces based on a group of classifications and for different purposes, and these divisions can be presented as follows:

3.3.1. Functional division of the apartment spaces: A residential apartment consists of a group of spaces designated for a set of basic living and service activities and with different connections. The area of the basic activities in the apartment varies according to the type of space and the degree of luxury. Yet, it is possible to compare the area of the most important spaces (other than the bathroom spaces the relatively small storage space) in terms of the minimum areas determined by its values in the housing standards of economic housing design. Although these values differ from one country to another, they can give a picture for comparing the spatial differences between these activities.

The Iraqi standards for housing specified the basic activities area of the mid. area apartment (M1 & M2), which are the closest to the average size family in Iraq. According to what is shown in table 1.,
there are two ranges of the activities space area, the first is the minimum areas for the main and
secondary sleeping activities and the food preparation space, the second is larger area of the family
living in the apartment

| N   | Space type      | Apartment unit | N   | Space type      | Apartment unit |
|-----|-----------------|----------------|-----|-----------------|----------------|
| 1   | M. bedroom      | M1 15 M2 15    | 3   | Food preparation| M2 12 M1 12    |
| 2   | Secondary bedroom| M1 12 M2 12   | 4   | Living spaces   | M1 30          |

3.3.2. Division according to the exposure area to the outside (number of exposures):
The general rule for calculating the thermal effect of any building is based on the relationship of the
exposed surface area to its size. This relation is mainly affected by the area of the apartment or its
spaces that exposure to the outside. As illustrated in ‘Figure 6’ the allocating of apartment or any of its
spaces at the corner of the building, or the shifting movement in their envelope may raise the area of
the outer surface, and increase the exposed surface area to its size

3.3.3. Spaces division according to layout system types:
According to the topological characteristics, the studies distinguished the existence of more than one
system of functional relations between the components of the apartment activities [21],[22] named
three types of space layout systems for residential buildings:
1- The closed plan: where all the activities are distinguished by separate spaces.
2- The semi-open plan: which tends to have partial integration of certain rooms in common spaces.
3- The open plan: which shows a tendency to group more activities in one space.

The latter tends to achieve an absolute space that claims all in one, and its use is concentrated in
smaller apartments to achieve a higher feeling of comfort and eliminating the feeling of space
constraint. However, this system carries its problems in application with the largest apartments, which
may be within one of the first or second types. With the specificity set by the housing standards in Iraq
for the sleeping spaces, the discrepancy between the two types of housing can be limited to the
relationship between the food preparation space and the living space on one hand, and their openness
to the movement system in the apartment. As shown in ‘Figure 7’
This divergent relationship between living activities, food preparation, and movement between the two modes contributes to raise the living space area (by adding these accessories) compared to the fixed sleeping space area, which increases the degree of spatial disparity between them.

4. Research problem
The previous studies that focused on the effect of building spaces layout on its thermal preservation recommended that this effect has not been fully confirmed. This explain the need for more studies to compare the effects of diversity with space layout and organizations in terms of energy indicators and specially in residential buildings which present the highest sector of energy consumption. Among this path, the research put the problem as “The lack of clarity of the role played by the geometrical characteristics of the spaces and the spatial layout of the apartment as a whole in affecting the thermal performance of the residential tower and its spaces”.

5. Research objective
The research aims to Calculate the effect of the geometrical characteristics of spaces represented by the area and the number of their exposures to exterior, and the space layout of the apartment on the efficiency of thermal performance. This can be achieved through testing the three following topics:
1- The effect of the space layout system (closed or semi-open) on the thermal load per square meter of apartment area.
2- The effect of the variation of the apartment exposure to outside on the thermal load per square meter of the apartment.
3- The variation of thermal load between the spaces of the apartment, and the effect of different space layout systems of apartment on it.

6. Research hypothesis
To achieve the research goal and objectives, the following hypothesis were developed:
1- The semi-open system for apartments gives a better thermal preference than the closed system
2- The position of apartments in relation to its area of exposure to outside have an impact on the efficiency of its thermal performance.
3- The presence of an effect of the area of the apartment and its spaces on the efficiency of their thermal performance

7. Research methodology
To check the validity of hypothesis and achieving the objectives, and after selecting the case study samples, the research methodology was adopted, for conducting the case study on two basic aspects:
First: Conducting the thermal analysis on the chosen study sample using the simulation program (Ecotect 2011).
Second: Statistical analysis of the data extracted from the simulation process using the statistical program (Microsoft excel 2010).

8. Case study
To test the three objectives of the research and to reach realistic conclusions, the research elected a sample of apartments fulfilled the following conditions:
1- The apartments were of different types of space layout styles (semi-open system-close system).
2- The apartments were of different exposure to the outside by containing different models of apartments directed in one or more directions to exterior (corner or non-corner apartments).
3- The apartments were of different areas (within the limits of the average family size), which exclude small and very large apartments.
The research linked with studying the relationship between "exposed surface area" / volume (which is a working relationship and influence in any location in the world with variation in the effect of gaining or losing heat in the apartment), this provides the possibility to choose any sample that meets the previous conditions. However, dealing with the local environment justifies choosing a group of selected apartments from projects within the city of Mosul or from its neighborhoods (Duhok and
Erbil), which are located within a similar climatic region with the scarcity of models available for vertical housing projects in the city of Mosul. Table 2. shows the sample selected for apartments.

| Project Code | Project Name         | Sample No. | Image 1 | Image 2 | Image 3 | Image 4 |
|--------------|----------------------|------------|---------|---------|---------|---------|
| Z_57         | Parosh Erbil         | 1          | ![Image](image1.png) | ![Image](image2.png) | ![Image](image3.png) | ![Image](image4.png) |
| Z_58         | Lebanese Village Erbil| 2          | ![Image](image5.png) | ![Image](image6.png) |         |         |
| Z_59         | Four Towers Erbil    | 3          | ![Image](image7.png) | ![Image](image8.png) | ![Image](image9.png) |         |
| Z_60         | Diwan Mosul          | 4          | ![Image](image10.png) | ![Image](image11.png) | ![Image](image12.png) |         |

### Table 2. Details of Samples chosen for case study. / Researcher

Thermal simulation of the selected apartment models:
Thermal analysis was performed using the simulation program (Ecotect 2011), and the annual thermal load per square meter of area (Thermal load per m²) was measured for each apartment from the selected sample in three cases:
The first case: the apartment as a whole (Total-apartment) referred to as (Total-A)
The second case: spaces as separate parts (zone1, zone2, cts)
The third case: the total of the areas exposed to the outside and can be referred to (Out-zone), and as shown in 'Figure 8'.

For the purpose of focusing on the mentioned influencing factors, the thermal effect of each of:
1- Ceiling, floor height and balconies.
2- Solar radiation, openings (windows), shading and insulating materials.
3- Internal loads and gain from adjacent spaces and ventilation.

The thermal comfort limit was fixed between (22-28) °C [23], standardization of the outer wall material (block15cm, cement plaster10mm, plaster poard20mm) and the adoption of climatic data for the city of Mosul because the selected projects are located in the city of Mosul and its vicinity.
9. Results

The results can be presented in three topics that related to the objectives of the research:

Part 1: The effect of the apartment space layout system:

to calculate the effect of both the semi-open and closed plan system on the annual thermal load per square meter of apartment spaces, the selected sample was classified according to the type of plan, when comparing the results of the apartments (1-6) with a semi-open plan, and the apartments (7-12) with a closed plan, we find that the effect is relative, which appears through the calculation of: \((\text{area of out-zone}) / (\text{area of total-A})\)

Then calculate: \((\text{thermal load per } m^2 \text{ of total-A}) / (\text{thermal load per } m^2 \text{ of out-zone})\)

The following steps are included:

1- Calculating the total area of the out spaces (out-zone) and the area of the apartment as a whole (Total-A) and their averages, for each of the two apartment types. Then calculating (area of out-zone) / (area of total-A) for each apartment and the rate for each type as shown in ‘Figure 9’ and ‘Figure 10’

2- Calculating the thermal load values /m² of each apartment as a whole and of its external spaces of all the sample and their rate according to the two types as in ‘Figure 11’ and ‘Figure 12’

3- Calculating the thermal load /m² for the apartment as a whole / the thermal load /m² for the external spaces and the rate according to the two types as shown in ‘Figure 13’ and ‘Figure 14’

The previous shows that the semi-open layout and within any apartment spatial characteristics gives a higher ratio of (area of the external spaces/area of the apartment). It also gives a value closer to thermal load /m² of external spaces to thermal load /m² of the whole apartment and as shown in table 3.
Figure 11. Thermal load / m² for Total-A and Outzone & the rate, for semi-open plan apartments

Figure 12. Thermal load / m² for Total-A and Outzone & rate for the closed-plan apartments

Figure 13. Ratio of the thermal load/m² of Total-A/Out-Zone and rate of the semi-open plan apartments

Figure 14. Ratio of the thermal load/m² of Total-A/Out-Zone and rate of the closed plan apartments

Table 3. The effect of the space layout system. / Researcher

| space Layout system types | semi-open plan | Closed plan |
|---------------------------|----------------|-------------|
| Rate of (out-zone) m²/ (total –A) m² | 0.89 | 0.71 |
| Rate of thermal load of (total –A) m²/thermal load of (out-zone) m² | 0.89 | 0.71 |

Part 2: The effect of the apartment exposure area to the outside:

The sample classified in terms of the exposure area to the outside into corner and non-corner apartments, and according to the sample table 2, the apartments (3,5,6,7) are non-corner, while the rest are Corner apartments. Figure (15) and (16) show the thermal load /m² for each apartment and its rate, standard deviation for each of the two types. They presented that the rate of thermal load /m² in corner apartments is clearly higher than its value in non-corner apartments, and also that this value for any corner apartment (regardless its characters) is significantly higher than in any of non-corner apartments.

Table 4. shows a higher value of standard deviation in corner apartments than the non-corner which mean that this value recorded more stable values around rate than the corner apartment which may vary due to the integration of different effects of exposure with the inner characteristics of the apartment.
Table 4. Comparison between the thermal load/M² of the corner and non-corner apartments and the variance around the average

| Type of apartments | Non-corner apartments | Corner apartments |
|--------------------|-----------------------|-------------------|
| The rate load of m² for out zone space | 62559 | 100317 |
| Variation in value around the rate | 15% | 29% |

Figure 15. Thermal load/ m² and the average for non-corner apartments

Figure 16. Thermal load/ m² the average for corner apartments

Part 3: The variation of the thermal load between the apartment spaces:
The variation of the annual thermal load /m² of the different apartment spaces is a reflection of the difference in the geometrical characteristics in the relationship with the building's outer envelope. In order to calculate the aspects of this effect, the study first measure the difference between the corner and non-corner apartments in the value of the variation in the thermal load between their spaces. Within this classification, the thermal load rate / m² {(the rate of thermal load of all external spaces of the apartment (M H)} was calculated. Also, the variance ratio (VH) was calculated for each apartment as:

\[(VH) = \frac{\text{The difference between (MH) and the thermal load/m² of the most extreme area from the average (MH)}}{\text{(MH)}} \times 100\%

The value of (VH) in non-corner apartments ranged between (5-127%) and rate of (40.9%), while in corner apartments it ranged between (6-105%) and average of 46.9%.

Figure 17. Ratio of variance in thermal load / m² for space of non-corner apartments

Figure 18. Ratio of variance in thermal load / m² for space of corner apartments

Although the results indicate that the rate of (VH) in corner apartments is higher than its value in non-corner apartments, they show a wide range of its value in the two samples. By dividing the corner sample into two parts, the first includes apartments that contain small spaces in their corner part, and the second in which the larger or open living spaces occupy the corner part, the difference of results can be observed, as the (VH) in the first part ranged between (44.6-105%) with a rate of 59.8% while...
it ranged in the second part between (6-10.4%) and a rate of 8.2%. The signature of small spaces in the corner of a residential apartment, which includes the larger area of the relationship with the outer envelope of the building, clearly raises the heat load of these spaces and their contrast with the rest of the apartment spaces, unlike the second part, which limits the effect of the contact area outside with the expansion of the corner space.

On the other hand, the results indicated that such a variance can appear strongly even in non-corner apartments, which is evident in “Figure 17”, which indicates that some design solutions to increase the openness of the apartment to the outside or treat the provision of lighting to some of its spaces may increase the heat load for some spaces, the variation in the connection between the spaces leads to very high limits, as shown by the sample in apartment Model No (7).

10. Conclusions
The most important findings of the research can be referred to as follows:

1- The space layout has a clear effect on the apartment thermal performance, the open and semi-open types increases the apartment internal space that accommodates the thermal transfer between it and the specified surface area, which lead it to have better thermal performance than that of the closed style.

2- The change of the apartment’s relationship with the outside, according to the exposure area of corner or non-corner types gives a clear general impact on the thermal performance of the apartment, regardless of its detailed variables.

3- The process of dividing the apartment into spaces according to its exposure to the outer space (within the constant total exposure area of the apartment) provides great effects on the variations of the thermal load between them. This can be addressed either by controlling the size of the openness of different spaces to the outside that may increase when trying to have more availability of lighting and open the spaces to the outside. Or by controlling the space distribution in corner apartments

11. Recommendations
Discussing the results presented by the study illustrates the possibility of reaching additional specific conclusions through the expansion of this study and within larger samples focusing in detail on the variables affecting the thermal performance and additional features of the sample such as the area of the apartment, and which can give additional indicators for the design of ecological housing provided by larger samples of models with more compatible variants.

Reference
[1] Muhaisen, A. S. (2012). Effect of Building Form on the Thermal Performance of Residential Complexes in the Mediterranean Climate of the Gaza Strip by Supervisor.
[2] Muhammad, Rania Ezzeddin Abdel-Rahman. (2016) “Improving thermal performance in school buildings by using Sustainable Green Schools Concept - Case Study (Basic Schools in Khartoum)” Master Thesis submitted to Sudan University of Science and Technology, College of Graduate Studies, College of Architecture and Planning, February
[3] gold standard for the Global Goals, (2017) “Thermal performance improvements in low-income dwelling structures ”
[4] Bencheikh, D., & Bederina, M. (2020). Assessing the duality of thermal performance and energy efficiency of residential buildings in hot arid climate of Laghouat, Algeria. International Journal of Energy and Environmental Engineering, 11(1), 143–162.
[5] Abed, H. M. H. (2012). Effect of Building Form on the Thermal Performance of Residential Complexes in the Mediterranean Climate of the Gaza Strip by Supervisor
[6] Al-Sudani, Jamal Abdel Wahid. (2009) “Energy and the Complementarity of the Environmental Design Performance of the Building Envelope”
[7] Zahiri, S. (2016). "The effect of Passive Design strategies on Thermal Performance of Female secondary school Buildings during Warm season in a hot and Dry climate ", 1–15.

[8] Al-Rashed, Nawras Rashid, (1996) “Adopting the principle of equivalence of general thermal energies to predict the ideal geometrical formation of the building envelope”. Master Thesis submitted to the Department of Architecture, University of Technology, Iraq.

[9] Al-Aqili, Wael Awwad, Dr. Ibrahim Jawad Al Youssef. (2008) “Reducing the cooling load by applying the smart building envelope system”, a research published in the journal

[10] Taleb, H. M. (2014). "Using passive cooling strategies to improve thermal performance and reduce energy consumption of residential buildings in U.A.E. buildings. Frontiers of Architectural Research". 3(2), 154–165.

[11] City_of_Vancouver. (2009). "Passive Design Toolkit". 1–42.

[12] Dobbelsteen, A. Van Den. (2020). "Effects of Architectural Space Layouts on Energy Performance": A Review

[13] Musau, F., & Steemers, K. (2008). "Space planning and energy efficiency in office buildings: The role of spatial and temporal diversity. Architectural Science Review", 51(2), 133–145.

[14] Lim, H. S., & Kim, G. (2018). “Analysis of Energy Performance on Envelope Ratio Exposed to the Outdoor”. Advances in Civil Engineering.

[15] Souza, C. B. De, & Alsaadani, S. (2012). "Thermal zoning in speculative office buildings: discussing the connections between space layout and inside temperature control", 417–424.

[16] Taylor, P., & Yi, H. (2015). "User-driven automation for optimal thermal-zone layout during space programming phases", 37–41.

[17] Yang, W., Zhou, S. Q., Lin, Y. L., & Li, C. Q. (2018). “A Study on the Effect of Building Shape on Thermal Load". 27–32

[18] Los Alamos national lab, (2002) 'Lanl Sustainable design guide ".

[19] Wafin, Marzouki, (2008) “The outer envelope and the internal space organization, the effect on thermal efficiency, the condition of hot and dry climates”, a letter submitted to Mohamed Khaider University of Biskra / Faculty of Science and Technology / Department of Architecture, Algeria.

[20] Iraqi Ministry of Construction and Housing, Public Housing Authority, (2010): "Urban Housing Standards"

[21] Michalek., J., (2002) “Interactive layout design optimization”. MS thesis, University of Michigan.

[22] Alfirevic, D., Alfirevic, S., & Alfirevic, S. S. (2016). "Open-plan in Housing Architecture: Origin, Development and Design Approaches for Spatial Integration 

[23] Ali and Shaheen, Turki Hassan and Bahjat Rashad (2012) “Climatic considerations in the planning and architecture of the traditional Arab city, the ancient city of Mosul as a model” published research paper Al-Rafidain Engineering Journal, Issue 21.