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Architectural Systems Integration in Traditional Houses of the Mosul City of Iraq

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Abstract

Traditional houses in old Mosul city have much potential in the aspect of systems integration. These architectural systems are envelope, structure, interior, and mechanical. Each architectural object of the traditional house serves as a part of more than one system in both visual and performative integrations. The study analyses architectural elements (spatial and physical) of the traditional house and examines their integration level according to their ability to contribute to the building systems. This type of analysis will be possible by creating a 3D model of a traditional house and splitting each system by the architectural elements representing it in its 3D model. After that, intersecting the 3D models will produce the different systems' shared volumes and mark the integration percentage. The research aims to examine the suggested method of using 3D models intersection of the various building systems. Hence, that will be vital for any future attempt to employ traditional elements in modern design and consider the integration results instead of shallow usage of these elements. The research concluded the contribution ratio of each architectural element to each building system. Also, it set a precise technique to measure that contribution.

Disciplinary: Architecture (Building Systems).

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1 Introduction

Traditional houses in Mosul city have been built a long time before residents deployed modern technology and depended on their power sources. Thus, its building techniques were very sustainable, as they relied on natural materials, and old structural approaches and responded to the local environment. Moreover, adopting its architectural elements in more than one building system can maximize their efficiency and create a state of integration among these systems. The

researcher has to clarify these pivotal points: the building systems are determined firstly. After that, the research defines the traditional house in Mosul, classifying its architectural elements.

1.1 Architectural Building Systems of the Traditional House in Mosul City

Buildings are a combination of four basic systems (Rush 1986):

The structure system allows the building to stand. It may form by bearing walls, columns, frames, slabs, shells, and others.

The envelope system's vital purpose is to protect the building from penetration of the outside circumstances naturally or by unnatural causes. Another essential issue of the envelope system is that it is the visible part of the building, which makes it carries the external aesthetic value.

The mechanical system supplies the building with all the necessary services for its occupants. This system includes many categories; power supply, heat transfer control, water supply, fire safety, security and monitoring systems, and waste disposal.

The interior system is whatever is seen from inside the building by its habitats. It includes building internal parts, as well as furniture and other decorative elements. Also, it can conclude intangible objects like spatial (opened, semi-covered, and covered) volumes.

Figure 1 illustrates The combination of building systems.

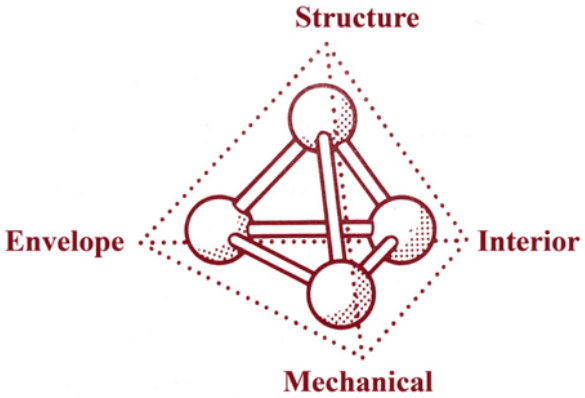


Figure 1: Building System Combination (Redrawing by the Authors, adopted from Rush (1986)).

As graphic documents, photos, and drawings showed, building systems formed the traditional house of Mosul as they can appear in it as follows:

These elements form the structure: thick bearing walls (40cm – more than 1m thick in some cases) containing limestone as primary material with plaster in between. Columns are carved from local marble, as well as the arches attached to them. Local builders facilitated two principal techniques to form ceilings and roofs; the first and older methods were adopted for domed and curved types.

Façade walls, as well as external roofs, represent the outside elements of the traditional house. The façade does not show complex architectural elements. They contain the same inside

walls materials with a minimum number of openings (Main entrance and necessary windows, in addition to balconies in some cases). External roofs are covered by limestone and finished with plaster.

Building services used traditional techniques to adapt to the environment. Some elements of mechanical systems are parts of other main architectural physical elements, as in the natural isolation system of thick walls and voids between ceilings and roofs. Other components are spatial elements that can provide shading or air movement. Finally, some architectural elements serve ventilation and air-conditioning purposes, such as Malqaf (A vertical void that acts as a wind catcher with the cooling system), or Shanshool (A projected window or balcony enclosed with carved wood located in the upper levels of the external façade).

After passing the main entrance gate toward the inside, interior elements showed to the house user. Spatial objects like the open court, Ewan (intermediate void), or arched galleries are forming the fundamental parts of the interior system, along with closed spaces for rooms, Rah-rah (semi-basement), and basement. Also, other decorative elements are complementary parts of the house interior, as they represent an aesthetic.

1.2 Understanding Traditional Houses in Mosul

In the middle of the 20th century, massive transformations occurred in the building methods, techniques, and building materials in Mosul city. These changes derived from the introduction of electricity usage. This dependence on the new energy source leads to separate the different building systems from each other in terms of their integration (Alomari& Al-Qemaqchi 2020). For example, new concrete structures need insulation additions, modern appliances installed to provide thermal comfort, and many other elements attached to create an efficient interior experience and contemporary façade design.

This disintegrative state among building systems leads to consuming more energy, new spaces, and low economic efficiency. According to the relationship between its components and building systems, this research attempts to search back for the best integration methods in the traditional house. Its data are beneficial in any future attempts to create sustainable architecture.

On the other hand, previous studies investigated the traditional house in Mosul city regarding its components, spatial arrangement, and sustainability. However, the necessity urged for a better understanding of the traditional house analysis according to its integrative state. This integration is what makes the traditional house much more efficient than the modern one.

2 Literature Review

The research analyzed four famous traditional houses as samples to discover the architectural elements of the traditional house in Mosul city. The reason behind taking all specimens from these houses is the variety of architectural elements. Otherwise, smaller constructions might not have many architectural characteristics, leading to taking many more samples without receiving the aim.

2.1 Traditional House in Mosul City

The term "Traditional house" in Mosul city refers to the houses located inside the old city of Mosul. Residents rebuilt their dwellings many times throughout history, from the first establishment of Mosul until nowadays. Still, they kept the same methods and techniques of construction, building materials, and architectural elements (Taha & Abdulqader, 2019).

2.2 Architectural Elements of the Traditional House in Mosul City

The research depends on these four traditional houses to extract the traditional architectural elements (Thannon 1982):

Al-Jalili House: Built in the year 1748 A. D., This house is one of the largest residences in Mosul city with more than 1161 square meters of a plot area, includes 36 rooms, 6 Ewans, 45 gallery pieces, 5 Rah-rahs, two stables, three courtyards, and a large kitchen zone.

Totonchi House: This house is even more significant than the previous, built in the year 1815 A. D. on a plot area of 2602 square meters. This house consists of three zones; The outer part is used basically as a guest house, the internal part, which is named Haram contains most of the house parts, and the large kitchen zone. However, most parts have been lost or added to new attached buildings (Figure 4).

Abdoni House: This house is smaller than the first house, with about 650 square meters, although it is still relatively large. It was built in the year 1740 A. D. and lost about 200 square meters of its area for a neighbor's house.

Zyadah House: The house area is about 533 square meters; its building process finished in 1870 A. D.

For organizing purposes, architectural elements are categorized into physical and spatial elements, as follows (Thannon 1982), (Thanoon 2007), (Mustafa et al., 2010):

2.2.1 Physical Architectural Elements

These items are the materialistic objects that form the physical shape of the building. For the traditional house of Mosul city (Sabah 2006), these are:

Walls. The essential structural elements of the house. Their structure contains local natural materials, thickened to bear the building load, and provides effective isolation for inner spaces. Some walls are penetrated with the openings of doors and windows, while others contain recesses that match window shapes and order.

- Columns. They are vertical elements of the house structure, made by local marble and carved with various ornaments. Columns in the traditional house of Mosul have three main parts: base, body, and crown. They come in different shapes (circular, square, or octagon cross-section), scale (1.5m-4m of height), and proportion (thick to thin), according to their location and the weight they carry.

- Arches. The function of these elements is to distribute weight and transfer it to columns. Local

marble forms their main curved parts, decorated with plant-shaped ornaments, and the voids between an arch and other elements are stuffed with limestone and finished with plaster.

- The well. One of the essential elements of the traditional house. Its location is on the side of the courtyard usually. The apparent part of the well is carved and decorated with ornaments.

- The stairs. This element is pivotal for vertical communications. The void underneath the stairs formed a service storage space. Therefore, the space containing the stairs can be considered as a spatial element too.

- Qantara. This astonishing element represents a connection between two houses, belongs to one of them, and crosses over the outside ally. It consists of a room above the arched passage.

- Shanshool. The projected expansion of windows or balconies. The leading purpose of this element is to improve house ventilation. Moreover, it is used to fix the irregular room shape by extending its corner(s) toward the outside and enhancing the aesthetic value of the outside façade.

- Malqaf. A vertical tube void inside a wall that allows airflow between the roof and the room(s) located under its position.

Figure 2. illustrates examples of the physical architectural elements of the traditional house in Mosul city

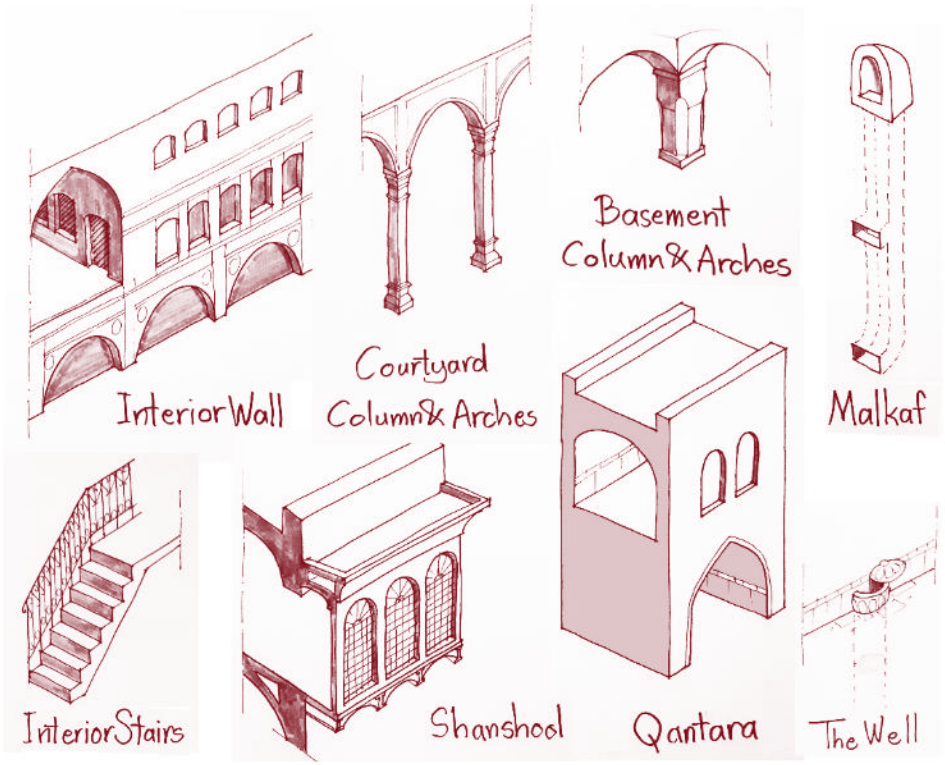


Figure 2: Examples of the physical architectural elements of the traditional house in Mosul city (Sketch by author).

2.2.2 Spatial Architectural Elements

The traditional house in Mosul has many spatial elements since its orientation is toward the inside. This feature formed the original theme of old buildings. This type of organization consists of these elements (Al-Jameel & Al-Tuhafi 2014; Aulakh & Chahal 2018):

- The entrance. It contains the main house gate, outside door, and arched passage from outside to the inner house spaces. The main gateway can have a regular size, as in Abdoni and Zyadah houses, or large relatively like the entrance of Al-Jalili house.

- The courtyard. It is the main spatial element in the traditional house, with a pivotal position as it is located in its center and surrounded by other components. The courtyard space connects the house facilities and the outside environment because it opens directly to the sky. Accordingly, it forms a source of natural lighting and ventilation for the house. Also, it is vital on the spatial level as it acts as the main foyer to other spatial elements (Mustafa & Sanusi 2010).

- The Ewan. One of the most distinguishable elements of Mosul's traditional architecture. This semi-opened space faces the courtyard directly and distributes the rooms to its side elevations through doors and windows. Ewan's height reaches the upper levels of the house. Its ceiling is arched or tapered, and its ground is higher by at least 40 centimeters above the courtyard ground level.

- The arched galleries. This element is a longitudinal semi-opened passage. It separates the courtyard from the facing rooms. An arched gallery is a combination of columns carrying arches opened to the courtyard side, room wall, and openings on the other side. Its ceiling is closed by small tapered domes and supporting arches. The Ewan plays an important environmental role as it provides cover from rainwater and shading from the summer's sun rays.

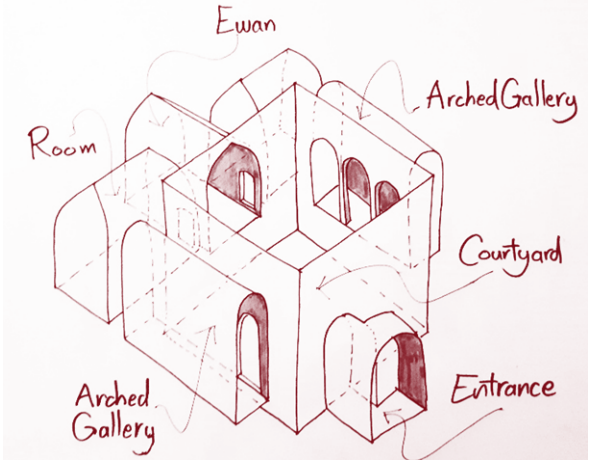


Figure 3: Examples of the spatial architectural elements of the traditional house in Mosul city.

- Other spatial elements. The movement in the traditional house starts with its entrance and ends with different types of rooms, Rah-rah, and the basement. House users conduct their main activities inside these spaces. They have at least one opening toward the courtyard or other semi-opened volumes. The shape of the ceilings is tapered or domed.

Figure 3. shows the spatial architectural elements of the traditional house in Mosul city.

2.3 The Role of the Architectural Elements of the Traditional House in Mosul City in Its Building Systems

The paper examines each element by discussing its possible role in architectural systems. This process will clarify the building elements' integration level and combine the whole integration state of the traditional house in Mosul city. Also, the researcher categorizes the elements as physical and spatial architectural elements. Their architectural systems contributions are

2.3.1 The Role of Physical Architectural Elements

- **Walls.**

Structural system: They take most of the house components load and transfer it to the ground footing.

Envelope system: The external wall represents the house façade. It separates the house inside from outside space, provides privacy, and isolates the street's environmental effects. Also, it carries external parts and openings of the house.

Mechanical system: They provide adequate thermal isolation according to their building material and thickness.

Interior system: They form the main borders of spatial elements, and add aesthetic value to interior spaces through the decorative parts and ornaments attached to them.

- **Columns**

Structural system: They contribute to carrying weight in some of the house components and transfer it to the ground or underneath walls.

Interior system: They form some spatial elements borders, thus adding aesthetic value to interior spaces through the ornamental carving.

- **Arches**

Structural system: Inside the house, they concentrate and transfer the load over them to the columns. In some cases, they carry the payload of projected elements on the façade.

Envelope system: Some projected expansion of the upper floor(s) are leaning on the arches. Thus, they represent part of the façade composition.

Interior system: Arches are part of some interior spatial elements. Also, plant shape ornaments are usually attached to them as an aesthetic additive decoration.

- **The well**

Mechanical system: The well is the only installation related to the water supply system.

Interior system: It represents an aesthetic element according to its decorative appearance.

• **The stairs**

Envelope system: Stairs that are attached to the external wall change the skyline of the façade in most cases.

Mechanical system: Voids under stairs are part of the storage system.

Interior system: They are the only mean of vertical communication in the traditional architecture in Mosul city.

• **Qantara**

Structural system: This expansion between two external walls supports both of the attached walls. Additionally, its lower part is a tapered or arched passage.

Envelope system: Qantara is an external part that contributes to creating a unique urban image of old Mosul city.

Mechanical system: Ventilation in this element is so efficient as it has windows on both sides, allowing the best airflow through it.

Interior system: It creates an additional room for one of the side houses.

• **Shanshool**

Structural system: As it replaces a part of the thick heavy wall, it reduces the structural part's load since its components are so lighter than the wall.

Envelope system: It forms an apparent part of the external façade.

Mechanical system: This is one of the traditional techniques for achieving adequate ventilation and air-conditioning.

Interior system: In most cases, Shanshool is a projected part of the interior space of the upper room, aimed to refine the upper level(s) shape.

• **Malqaf**

Structural system: Malqaf is a part of a wall.

Mechanical system: This element works as an air duct for the natural ventilation and air-conditioning process.

2.3.2 The Role of Spatial Architectural Elements

• **The entrance**

Envelope system: It starts with the outside gate, a pivotal part of the external façade.

Interior system: The courtyard is the core of this system, as it is the center of the movement inside the house, almost all spaces lead toward it, and most of the decorative elements are apparent from it.

• **The courtyard.**

Mechanical system: This element is the vital source of natural lighting and ventilation for the interior spaces.

Interior system: The courtyard is the core of this system, as it is the center of the movement inside the house, almost all spaces are oriented toward it, and most of the decorative elements are apparent from it.

• **The Ewan.**

Structural system: The ceiling shape of the Ewan forms voids that reduce the load as they form a space or contain lighter materials.

Mechanical system: Ewan plays an environmental role as a transitional space between the courtyard and inner rooms. Furthermore, its shading ability makes it a summer seating place.

Interior system: Its transitional role affects the movement between interior spaces, and the aesthetic impression is one of its apparent properties.

• **The arched galleries.**

Structural system: Arched galleries play a pivotal role in carrying upper projected balconies and roofs toward the inner space of the courtyard.

Mechanical system: By preventing rainwater from falling directly down to the rooms and shading the summer's sun, these galleries are very efficient for environmental purposes.

Interior system: They are passages to move horizontally from space to others, especially on the upper floor(s). They are, moreover, decorated with many ornamented elements.

• **Other spatial elements.**

Structural system: The ceiling shapes of the inner spaces represent the traditional method of the roofing process, as the domes and arches carry the roof by the same building materials without using any reinforcement.

Envelope System: The parts attached to the outside wall had their projected elements and openings on the external façade toward the ally.

Mechanical system: The shapes of their ceilings create voids between them and the external layer of the roof. These voids contribute to the isolating system.

Interior system: These spaces are the final movement destination in the traditional house. Further, their walls contain recesses that act as fixed cabinets.

Table 1 summarizes the role of each architectural element in the traditional house systems in Mosul city by ticking the cell that matches their contribution(s).

3 Method

The research adopts a two-step method to explore integration in the architectural system of traditional houses in Mosul city. The first step relies on the narrative analysis of the architectural elements and how they can participate in multiple or one systems (The researcher administrated this discussion previously in the literature review).

The next stage is to build a three-dimensional model of Al-Totonchi House (Figure 4) and calculate its total volume by cubic meters. Each system is represented by the architectural elements included in it and builds its three-dimensional model. The result will be four different models. Thus, the architectural systems in the building ((S)Structure, (E)Envelope, (I)Interior, and (M)Mechanical) have their diagram and volume measurements. Then, the researcher intersects the volume of each system with all other systems (only two systems' volume at a time: S+E, S+I, S+M, E+I, E+M, and I+M), by calculating the space that the two systems occupy at once to achieve the first level of integration. The next level of integration results from three systems intersection (S+E+I, S+E+M, S+I+M, and E+I+M). The final degree of systems integration is formed from applying the previous method to all systems (S+E+I+M) simultaneously. The researcher calculates the volume of each step and converts it into a ratio by dividing it by the whole house volume.

Figure 4 shows the documented projections of Totonchi House.

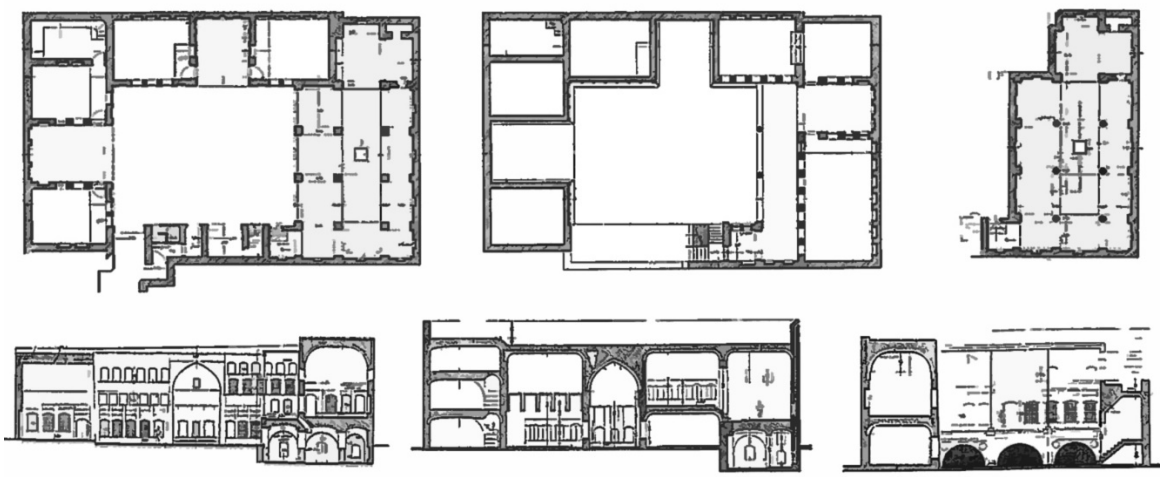


Figure 4: Totonchi House projections (Redrawing by author, adopted from Thannon 1982).

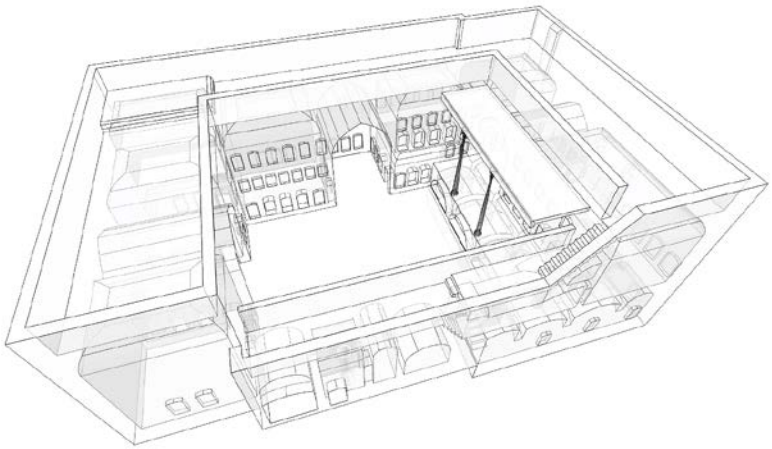


Figure 5: Totonchi House, a three-dimensional model. Total volume = 1946 m^3.

The researchers built a three-dimensional model according to the architectural documentaries of Totonchi House projections. Figure 5 shows a 3D model of Totonchi House.

4 Result and Discussion

4.1 Theoretical Results and Discussion

The paper examined each architectural element by discussing its possible role in architectural systems. This process clarifies the integration level for the parts and the whole integration state of the traditional house in Mosul city. Table 1 summarizes the contribution of the house's components in architectural systems.

Table 1: The role of the architectural element in building systems.

Architectural Element	Structural System	Envelope System	Mechanical System	Interior System
Walls	●	●	●	●
Columns	●			●
Arches	●	●		●
Well			●	●
Stairs		●	●	●
Qantara	●	●	●	●
Shanshool	●	●	●	●
Malqaf	●		●	
Entrance		●		●
Courtyard			●	●
Ewan	●		●	●
Arched Galleries	●		●	●
Other Spatial Elements	●	●	●	●

Most of the architectural elements (12 out of 13) contribute to the interior system of the traditional house in Mosul city (Except Malqaf). Next is the mechanical one, which employs ten elements. After that comes the structural part, which includes nine architectural elements. Only seven elements have a role in the envelope system. Walls, Qantara, Shanshool, and other spatial elements are individually contributing to all the building systems.

4.2 Implementational Results and Discussion

The physical objects can build a mass within the three-dimensional model, while the spatial components will be subtractive spaces from the total volume. For example, the volume of Totonchi House equals 1946.45 cubic meters.

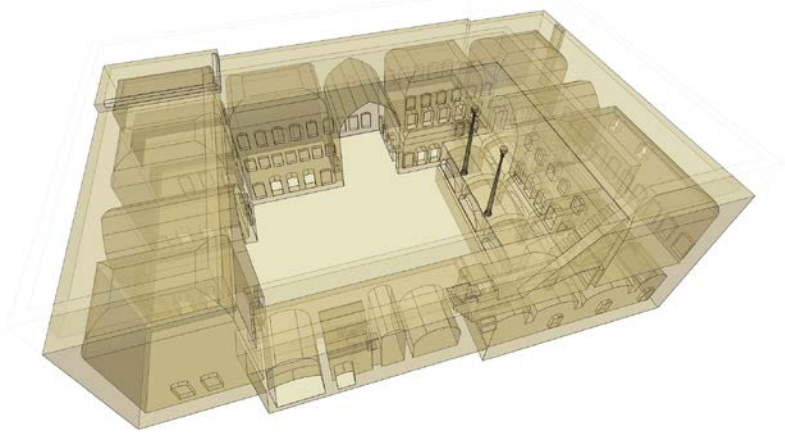


Figure 6: Model of the structure system in Totonchi House. Volume = 1760 m^3.

The structure system, represented by most of the house mass, reaches 1760 cubic meters, as shown in Figure 6. The envelope system includes exterior walls, roofs, and the walls of the courtyard inside the house. These surfaces separate interior rooms from the external environment. This system comes second in rooming the house mass as it reaches a volume of 1689 cubic meters.

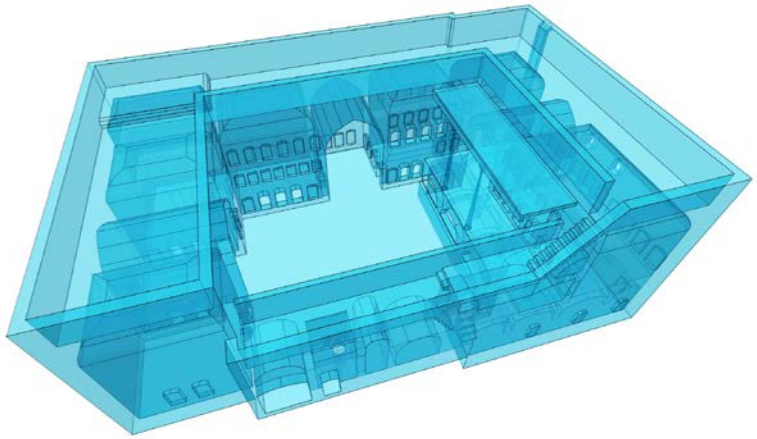


Figure 7: Model of the Envelope system in Totonchi House. Volume = 1689 m^3.

The Interior system comes next in volume order with a volume of 1299 cubic meters from the total mass of the Totonchi house, as Figure 8 shows. Regarding its few physical elements, the mechanical system only has a volume of 137 cubic meters only (Figure 9).

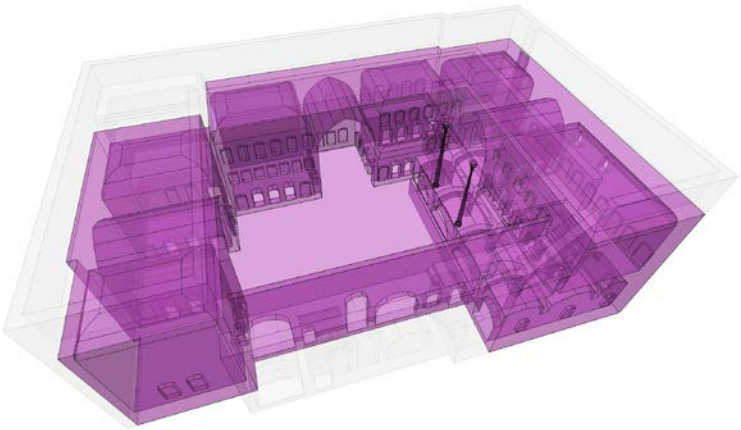


Figure 8: Model of the interior system in Totonchi House. Volume = 1299 m^3.

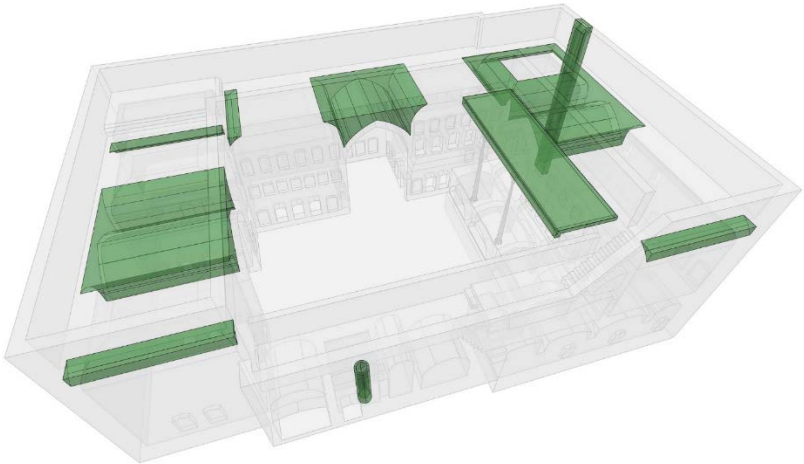


Figure 9: Model of the mechanical system in Totonchi House. Volume = 137 m^3.

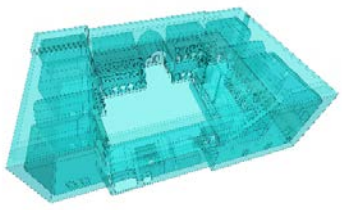
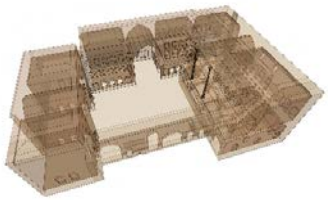
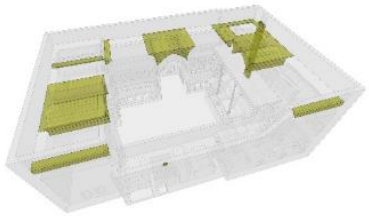
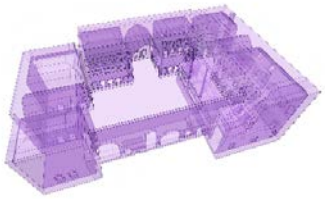
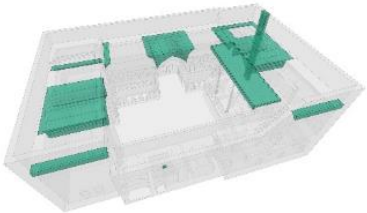
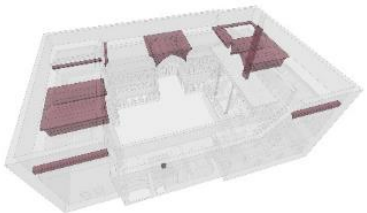
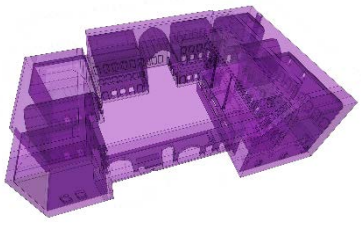
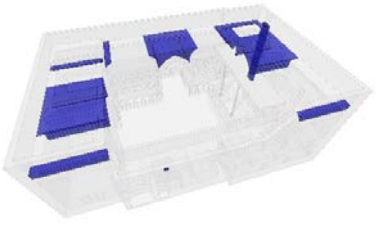
Table 2: Diagram of calculating the architectural systems integration.

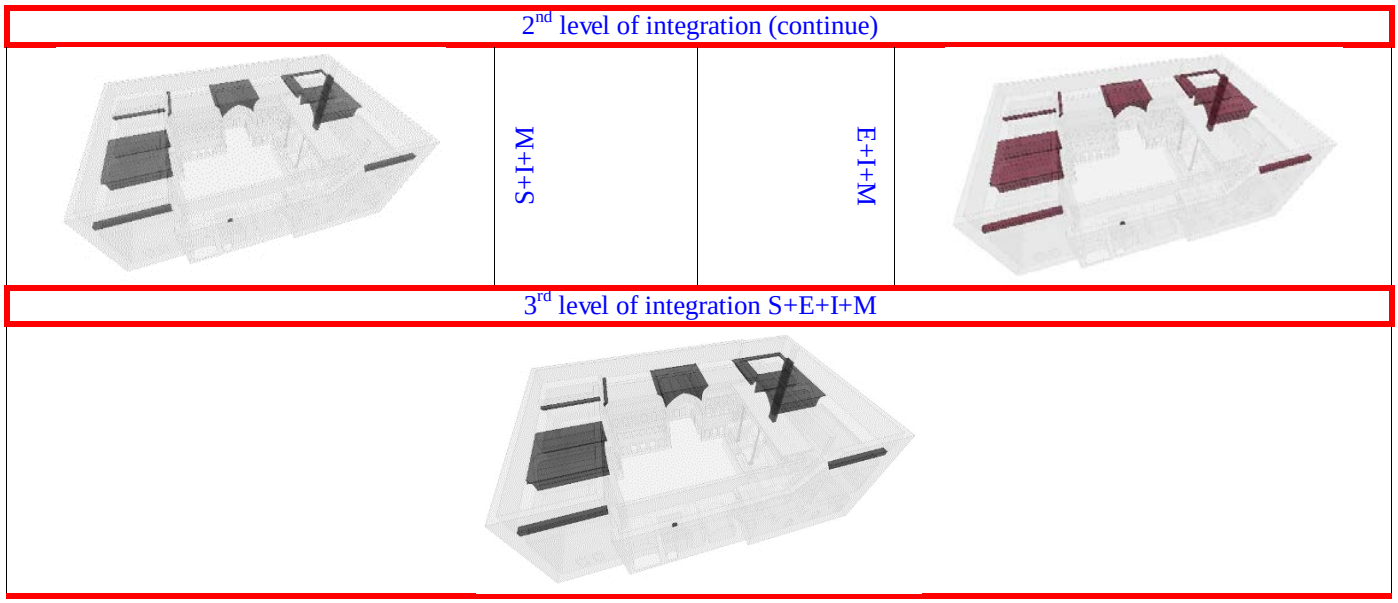
Name	Volume (m^3)	Ratio (%)
The whole mass	1946.45	100
Structure System (S)	1760.79	90.46
Envelope System (E)	1688.93	86.74
Interior System (I)	1299.63	66.76
Mechanical System (M)	137.41	7.06
1st level of integration (One system with another)		
S+E	1504.74	77.30
S+I	1284.48	65.99
S+M	103.89	5.33
E+I	1284.48	65.98
E+M	136.30	6.98
I+M	103.91	5.34
2nd level of integration (Three systems at a time)		
S+E+I	1086.91	55.85
S+E+M	125.13	6.43
S+I+M	103.89	5.33
E+I+M	103.89	5.33
3rd level of integration (All Systems Together)		
S+E+I+M	103.89	5.33

Table 2 clarifies the whole process of calculating the level of architectural systems integration. First, it mentions the total mass of the Totonchi house and its total volume; next, each architectural system and the integration levels gradually. Finally, the following procedure intersects these volumes with each other (Calculating what is mutual between the elements of two systems or more).

For more illustrated details, Table 3 contains the graphic translation of Table 2.

Table 3: 3D Graphic diagrams of systems integration.

1st level of integration		
		
S+E	S+I	S+M
		
E+I	E+M	I+M
2nd level of integration		
	S+E+I	S+E+M
		



These numbers give clear indications of the integration levels in the traditional house in Mosul city. In the 1st level, the most substantial relation of integration is between the structural system and the Envelope system.

On the other hand, the weakest integration plunges to 5.34% between the interior and mechanical systems. 2nd level of integration shows the best ratio of 55.85% among the structure, envelope, and interior systems. On the other hand, the less integration ratio is among envelope, interior, and mechanical systems, with only 5.33%. This ratio preserves itself in the final level, representing the fully integrated parts of the traditional house.

5 Conclusion

The research applies the concept of building systems integration on the heritage architecture, represented by the traditional house in Mosul city. This paper viewed the house elements in a new method, depending on the building systems and how they reach the integration state. This research focuses on the subject of building systems and their integration point of view.

Discussions and results reveal pivotal points about the integration among building systems of the traditional house in Mosul city. Traditional building techniques approved themselves as economical methods that achieved all possible benefits from every architectural element in the traditional house. That is achievable only by involving these elements in more than one system simultaneously. The traditional house and its architectural elements are designed to respond to environmental requirements without neglecting aesthetic values and structural basics.

Most attention was paid to the aesthetic value of the space they used, followed by thermal comfort. Next, the durability of the structures and the last and least attention went to outside appearances. The research predicts the hierarchy of importance and the ideals of local people.

This paper introduces a new precise method for providing, testing, and measuring the integration between architectural systems. That was possible by building a three-dimensional model of a building (the whole building), determining all elements to participate in each system type, representation in individual models, then intersecting volumes and calculating common

masses. The researcher accompanied all that analysis with graphics to illustrate and clarify the analytic procedure. Finally, the research focuses on the design potential of the architectural elements of the traditional house in Mosul city. These integrational principles can (and must) be adopted in any future designs to gain sustainability through integration.

6 Availability of Data and Material

Data can be made available by contacting the corresponding author.

7 Acknowledgment

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