

¹Rifqa A. Shukur,²Omar A. Sabah

Upgrading Building Services of Mosuli Heritage Houses



Abstract: - The old city of Mosul possesses a distinguished architectural identity developed through the ages. Updates and attempts to implement developed service systems in heritage houses has always been a challenge. Thus, heritage houses suffered deterioration, distortion, uprooted plantings, removed structure, changes in site, encroachments, ending with harmony deficiency between building services additions and the architectural characteristics. Insufficient integration between current building services and heritage houses represents a general problem. This research plans to meet inhabitant's needs, provide conceptual residence compatible for current needs, and preserve architectural identity. It is pivotal to establish guidelines and methods for integrating building services with the characteristics of Mosuli heritage houses and to set rules as an approach for future work. Research problem is "Deficiency and necessity of effective guidelines to incorporate modern building services with original building systems in heritage houses, to preserve architectural identity while providing inhabitants needs". Research aims building an integration methodology platform for upgrading building services with less impact on identity. Clear guidelines and methods for integrating and upgrading building services in Mosuli heritage houses were concluded through characteristics forming original services systems as a key to solve this issue and preserve architectural identity simultaneously.

Keywords: Building services, heritage houses, Mosul house features, upgrading services.

I. INTRODUCTION

Architecture in Mosul preserved originality expressing cultural interaction and responding to development through ages, which preserved the special architectural identity of the city that distinguishes it among other regional heritage cities [1]. The multiplicity of human needs and services introduced in the last century, their routes, materials, and required equipment's, affect built heritage and hold significances serving as tangible links to the past. Heritage houses in the old city of Mosul are characterized by multifunctional elements. Services were well integrated systems within heritage houses in Mosul [2]. It was noticed that lately implemented services are poorly integrated with building systems and negatively affect facades, interior, structure, service, site and the city's architectural identity.

This research addresses upgrading and modernising building services of Mosuli heritage houses, starting from the beginning of the twentieth century with the telephone [3], water supply and electricity connections [4,5], followed by television around middle of last century [6], ending with the internet [7] as discussed in the next sections. Researchers sensed the problem and restudied heritage house components and characteristics as indicators for importance and the need to protect heritage [8], as well as the Iraqi law to preserve valuable built heritage [9]. Yet, no provision of clear methodology or direct instructions have been given to integrate these necessary services for a house compatible to inhabitant's needs, which also preserve architectural identity.

The need for integrated upgrading became urgent after liberation operations during 2017-2018, when the old city was exposed to massive destruction, especially the housing sector [10]. Local, regional and international organizations started to rebuild the city, adopting local and mostly modern construction methods and materials. Solution plans for modern building services in construction to meet the need to provide adequate housing for human needs, relied mainly on initial basic solutions [8]. The dilemma of preserving the city's architectural identity remained a challenge, dependent-on individual instructions as guidelines not available in a form that is appropriate for direct application. Attempts have emerged to avoid the problem in the form of predominantly descriptive or documentary studies to deduct complementary characteristics of the heritage methods and reuse them. A background of Mosul's heritage and houses accompanied with criteria, systems and services' state before and after the upgrading to include modern services are presented for being essential to the topic of this study.

^{1,2}Architectural Engineering Department, Collage of Engineering, University of Mosul, Iraq
[1]* rifqa.21enp35@student.uomosul.edu.iq,[2] Omar.Sabah@uomosul.edu.iq

A. MOSUL HERITAGE HOUSES

The term refers to houses within the old city of Mosul. These residential dwellings were rebuilt many times historically until recently using well-preserved methods and construction techniques, architectural elements and materials.

Old city of Mosul: It is important to mention that the old city of Mosul is one of the most valuable cities in northern part of Iraq, established in 1080 BC as a small dominion on the westside (right bank) of Tigris River, opposite to the ancient city of Nineveh on the left bank, renowned for its rich history, diverse architecture, and cultural heritage, containing numerous historical landmarks [10]. Mosul situates a strategic location, known for its knowledge, exchange, and commerce and distinguished domestic architecture [10,11].



Fig. 1. a) Iraq plan; b) Mosul city currently; c) The Old city [12]

Architectural characteristics and components of the heritage house in the old city of Mosul: Built heritage is characterized by historical, symbolic, architectural, aesthetic, cultural, and societal values [10,11] a concept extended in accordance to Venetian Charter for Architectural Preservation of 1964. Characteristics reflect local building traditions, materials, and techniques, designed to suit local climate, lifestyle, and cultural practices [2,8,10]. Many scholars studied house components. References [8], [2], and [13] listed the courtyard, Ewan, the rooms, basement, corridors, entrance, kitchen, food-stuff cupboard, stairs, the roof, arched galleries, the well, bearing walls, columns, frames and arches, roofs, shells, furniture, decorative elements, Qantara, building internal-parts, Malkaf, Shanshool, Rah-rah in addition to materials, ornaments, wall treatments, windows and openings. The primary structure and finishing materials of the traditional house, are mostly natural, brought from nearby areas. In Mosul, limestone was the main building material, in addition to alabaster in some parts of the house, plaster mortar is the primary filling material [8]. Facades often feature intricate geometric patterns and decorative elements, including ornate carvings, stucco work, and marble ‘Mosuli Farsh’, showcasing the skilled craftsmanship of the region. Timber, stone, and palm fronds reflect the availability of local resources and the region's architectural heritage [14]. In general, the courtyard layout serves as a central open space and the living areas are arranged around it, providing natural light, ventilation, and privacy for the residents. Shanshool is a distinctive feature, wooden or metallic lattice screens or balconies are often found on the upper levels of the houses, providing privacy, allowing air circulation and views of the surroundings [14]. Flat roofs are often used as additional living spaces or outdoor gathering areas, often covered with waterproof materials such as tar or clay to prevent water penetration while internal spaces are designed to accommodate the needs of extended families, and rooms for specific functions as dining and sleeping [15].

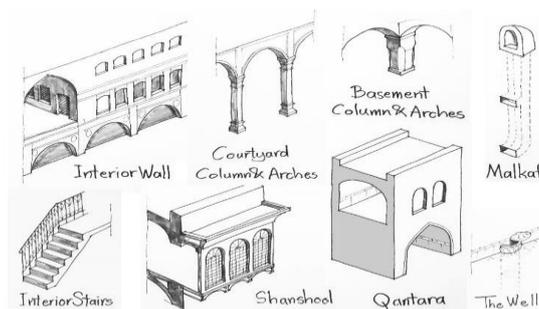


Fig. 2. Characteristics and components in Mosuli heritage house

Assessing heritage assets: This includes two main criteria; significance and documentation as referred to in [16] and [17]. The former includes age and historical significance, building materials and craftsmanship, cultural and social importance, contextual value, unique architectural features, authenticity and integrity, cultural continuity in addition to rarity and representativeness. While the latter includes documentation and historical records that support in evaluating the house's heritage value and abilities [16,17]. Evaluating a heritage house encompasses various factors specific to the region's cultural, historical, and architectural context which is related to the study subject and considered in the practical framework.

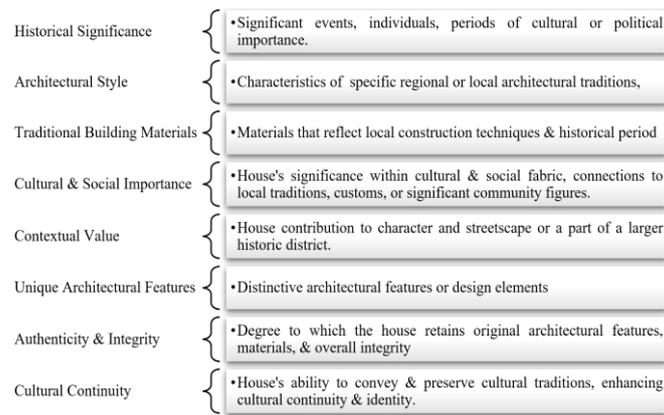


Fig. 3. Heritage house evaluation factors [17] (Listed by author)

Heritage value and identity of Mosul: Architectural characteristics contribute to unique identity and cultural value. Rich heritage value and identity are deeply rooted in Mosul's historical, cultural, and architectural significance, embedded in the long history as a centre of trade, knowledge, and civilization [10]. Various factors shape Mosul's identity, including strategic location, diverse ethnic and religious communities, and architectural heritage [10,11]. The city has witnessed the rise and fall of numerous empires and has been influenced by different cultures throughout history [10]. Architectural heritage of Mosul is particularly noteworthy [11,17], envisaged in various historic buildings like mosques, churches, palaces, and heritage houses that reflect a blend of architectural styles. The cultural and social fabric of Mosul is an integral part of its identity, projected through traditional crafts, music, and cuisine [10,11]. Preserving and revitalizing the heritage value and identity of Mosul is crucial for its post-conflict recovery and the well-being of the residents. Efforts are being made to restore damaged heritage sites, document cultural practices, and promote cultural tourism, contributing to the revival of Mosul's heritage and identity as a vibrant and historically significant city [10,13]. Potentials of reusing the built heritage are high, and the need for implementing services after examining value, capabilities, criteria, and house characteristics are important to preserve identity. Mosul's valuable historical centre [18] urges the researcher to ensure that reuse objectives are aligned with the specific requirements of the area, identity, and building function. Reference [13] argued that the image of heritage cities and the interaction between exterior and interior, coincide with visitors' ability to recognise places as a mental image is formed, which plays an important role in preserving the image of heritage places. An original place's image should be preserved [18]. This emphasizes integration importance rather than using imported materials, elements, and mechanisms which confuse the recipient and affect the architectural identity and value. This reflects the current issue during heritage buildings reconstruction and modern services installation.

B. Building services:

The services that might be needed by building occupants and supplied through mechanical system according to Rush [19], or service system due to Backman [20] as both researchers pointed to the role of integration between service system and other building systems. Decisions to implement or upgrade modern building services usually result from concerns for occupant needs, health and wellbeing. Sometimes from an economical aspect to turn heritage buildings into sellable entities or for upgrading purposes and even usage change. Mostly, user comfort is given greater importance than the heritage house unfortunately, which assures the need for guidelines to serve modern life and preserve identity. Upgrading the original services and adding extra services need to be integrated with the building systems as they were in the original state. This is not a linear process but a creative one [19]. Householders must know that final result will balance multiple needs, no perfect-services exist. The architectural design is affected by the great technological development of service system elements [21]. Reference [22] presented guidelines to incorporate modern services into preservation projects using available features, construction facts and original systems in historic buildings. It monitored conditions of heritage buildings after the modern services and the effects on exterior, interior, structure and mechanical systems in Kansas City, Missouri. Reference [2] assured that Mosuli heritage houses originally served occupant comfort through traditional methods. House elements served the service system in addition to other systems pointing to high levels of integration in Mosuli heritage houses, but did not address modern services in heritage houses.

Kinds of modern building services in general: A myriad of building services are available due to development and technology. Researchers have classified building services on levels; Portman [23] focused on categorization. Shaheen [21] listed service sorts as heating, ventilation, air condition system (HVAC), gas system, water and plumbing, electrical and lighting system, communication and information system, elevator and escalator, fire

protection system and security system. Five kinds were included under domestic building services guide [24]; Space heating, domestic hot water, mechanical ventilation, comfort cooling, and internal and external lighting. *For this study*, multiple services were found through exploratory visits to the old city of Mosul (Fig. 4). Modern building-services currently found in the heritage houses of Mosul city are: 1- space heating and heat transfer control, 2- ventilation and air movement, 3- comfort cooling (air-conditioning and shading), 4- communication and information service systems, 5- lighting (internal and external, 6- power, 7- drainage and plumbing, 8- water supply, 9- domestic hot water, 10- security, 11- safety, and 12- special systems. Those services are used by this research author to present building services in the Mosuli heritage houses during two phases, formerly and currently.

Next Fig. includes a part of the exploratory visits:

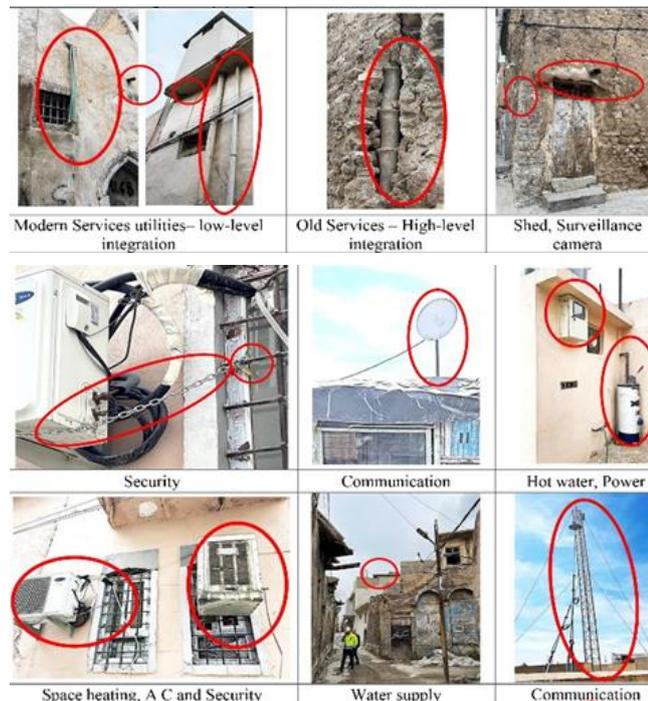


Fig. 4. Exploratory visit photos and highlighted observations.

1) *Former building services in Mosuli heritage houses:*

space heating and heat transfer control: In the past, heating was gained from furniture and decorative elements (for example Manqal - charcoal grill), and any similarly developed devices in wealthy people's residences. The open court attracts sun rays [26], and the Ewan to a lesser extent due to partial covering. Heat transfer was controlled via thick bearing walls (could be 40-100 cm), having a void in between ceiling (slabs) and building's internal-parts [7], covering the court with kinds of cloth or plants in summer time, in addition to facilities such as rah-rah, Ewan, and basement, keeping food in food-stuff cupboard and al-Ashkhim [27].

Ventilation and air movement: Ventilation was acquired through effective elements like open court, the stairs, Ewan, openings and entrance door or using traditional manual fan made from date palm leaves, Malqaf, Shanshool, Qantara and Tarma (similar to arched gallery but made of light materials, high and supports air movement) [2,27].

Comfort cooling (air-conditioning and shading). Using spatial elements as Rah-rah and the basement during hot season [2,27], climber plants and trees or wetting dry weeds and thorny plants then waiting for air movement to receive cold air or even wet the court shed and using northern Ewan. Malqaf, Qantara, basement, Shanshool, and arched galleries were used for shading [27],

Electrical \ power or fuel: Coal, oil, kerosene or petroleum were important as fuel derivatives for heating, cooking, lighting and other purposes [25].

Lighting (Internal, external, artificial and natural): Built-in lanterns places and removeable wooden lanterns were used for lighting, in addition to oil and kerosene lamps. Natural lighting depended on openings and the court [26].

Communication and information: This concept was not as it is in modernity, as people would use special rooms and Shanshool as observation places and also a small tube in a hole in the wall to chat [25].

Domestic hot water, water supply, drainage and plumbing: Hot water for cooking was obtained by heating it on Mankal or similar devices, but for shower (which was rarely then mandatory in the house) was done by putting coal in a hitch in the walls under the bathroom floor beside the water tank to get hot water and floor in same time later was by kerosene derivatives. For water supply, the Saqqa (a water delivery man) was responsible for transporting water from Tigris River to the city for drinking and cooking [28]. The well in the house provides water [27], for washing, cleaning and watering plants and for livestock [25]. Drainage and plumbing flowed outside for light water and to a ditch for heavy water for future emptying [25].

Safety and security: Thick bearing walls [2] and minimum openings to the outside with firm doors were used for this purpose [25].

2) Modern building services in Mosul heritage house:

Water: According to [4] and [5], drinking water was dependent on Saqqa until the British occupation, and their project to “supply the town with water.” It was decided to start water liquefaction in Mosul, and the project was opened in the year 1927, pipes were extended in streets and public roads, then they were connected to houses and public places. After 1932 houses were connected to a water network.

Electricity: According to reference [5], electricity was planned to be available in the year 1921 through diesel generators. Lamps were used to illuminate the alleys. In July 1933 the municipality distributed a leaflet announcing readiness to provide people with electric power day and night. Electricity was simple in the early-to-mid fifties of the last century by establishing large and modern generating stations, therefore its delivery to housing units was accompanied with details and changes at the level of building systems that affected integration of the architectural space.

Services: Services like communication, landline telephone in Mosul city appeared around 1938 [3], television transmission arrived in Mosul in the late sixties of the last century [6]. The internet entered Iraq in 1998 for official use, as university of Mosul, then for made for public use since 2000 [7].

As a result of various services availability and according to time phases of last century, an impact on architecture and changes occurred. Upgrades differed in the terms of integration degree between building systems and services on different aspects that is affecting architectural identity, which is related to this study subject.

3) Building systems:

A building system refers to the coordinated set of elements aimed at achieving clearly defined performance specifications [20]. This group of items may be combinations of devices, assemblies, material configurations, controls, and other electronic, mechanical, and structural strategies used to address a specific subjective. Referring to [19], building systems are a combination of four distinct systems: a) Structure for building support and stability, enabling it to stand and composed of elements, b) Envelope to provide protection from external elements, whether natural or man-made contributing to the building's aesthetic value, c) Mechanical system encompasses various services required by the occupants, ensures comfort, safety, and functionality of internal environment, and d) Interior which refers to everything that is visible and experienced inside of the building. According to Bachman [20] building systems are five as he added the site system. Detecting building systems in Mosul heritage houses components reveals the core systems, envelope, structure, mechanical / service, interior and site system, as each have basic elements integrated with each other, each element can play a role in two or more systems [29, 20].

Table I. Elements integration forming building systems.

House Elements	Integration with Systems
Columns	Structure + Interior
Frames & Arches	Structure+ Interior+ Envelope
Ceiling (Slabs, Domes)	Structure+ Interior+ Envelope
Shells	Structure + Interior
Furniture & decorative elements	Interior + Services
Qantara	Structure+ Interior + Services+ Envelope
Internal parts (opened, semi-covered, & covered volumes)	Interior

Malqaf (Wind catcher)	Services+ Envelope
Shanshool	Structure+ Interior + Services+ Envelope
Open court	Services+ Envelope
Ewan	Structure+ Interior + Services
Arched galleries	Structure+ Interior + Services
Rooms \ chambers	Interior
Rah-rah	Services+ Envelope
Basement	Services+ Envelope
The well	Services+ Envelope
The stairs	Interior + Services+ Envelope
Entrance	Interior + Envelope
Food stuff cupboard & Ashkhim	Structure+ Interior
Kitchen	Interior

Two elements are integrated into four systems, while five cover three systems, ten are involved with two systems and three elements represents one system. Some of the information have been mentioned by Al-Omary and Sabah [2] while others are completed by the researchers.

C. Integration:

Integration in architecture refers to the process of harmoniously incorporating various elements, components, or systems into the overall design or structure of a building [30]. It involves the seamless blending and unification of different aspects, such as architectural features, materials, technologies, functions, and environmental considerations, to create a cohesive and balanced whole [19]. Reference [29], based on Rush [19] cleared integration types by focusing on the integration between mechanical system and building systems. Architectural integration can be an approach that explore elements and equipment relation with passive systems of the building to instruct its image, spaces and performance toward efficiency maximization, comfortable living and architectural identity conservation.

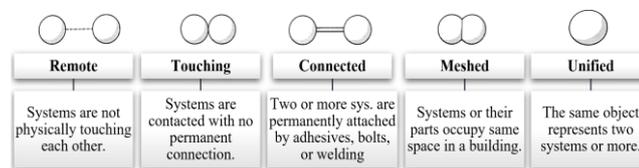


Fig. 5. Integration types illustration

D. Guidelines and legislations:

Absence of definition for a universal conservation format is considered a positive notion according to [30] since it allows flexible methodologies to take place. Out of the interest in world heritage protection and its importance, countries have issued several charters and agreements in this regard at local and international levels. Reconstruction after destruction affirms national identity, therefore conservation conventions are varied. Researchers have briefly presented the closest seven among post-conflict reconstruction conventions [31,32,33,34,35,36,37]. Local official legislations related to study subject are mentioned in “The Iraqi Law of Antiquities and Heritage” [38]. Antiquity definition is mentioned in article (4, Seventh). The crime of vandalism was mentioned without providing a definition for the crime of vandalism, explicitly in Articles (22, 35, 39 and 43). Rather, it merely provided pictures of this crime. Movable and immovable assets whose age is less than (200) years old are considered heritage. Among (37) articles, heritage maintenance was mentioned in (Chapter 1 articles 2 and 3, chapter 2 article 5). The researchers translated, extracted and summarized the most related to study subject in Table II.

Table II Iraqi law legislations, the most related to study subject

Article	Remarks
Maintaining heritage from deterioration, damage decay	Ch.1, Article 2, 3 rd
Expansion and development according to the era	Ch. 2, Article 10, 1 st

requirements, without harming or distorting them	
Maintenance and restoration under Antiquities supervision	Ch. 2, Article 11, 1 st
Demolition, restoration, renovation or modification of any of aforementioned facilities shall not be carried out except after Antiquities Authority written approval	Ch. 2, Article 11, 4 th
Uprooting plantings, removing structures, or performing any work that results in changing features of archaeological site.	Ch. 2, Article 15, 4 th
Evacuating the rented heritage building for the purpose of maintenance and restoration	Ch. 4, Article 25.
Not permissible to encroachment on heritage buildings and neighbourhoods	Ch. 4, Article 28. A
Not permissible to demolish, rebuild, restore, or changing documented buildings use, except with Antiquities Authority approval, and a permit from the participating party ensures harmony with characteristics and general standards.	Ch. 4, Article 28. C

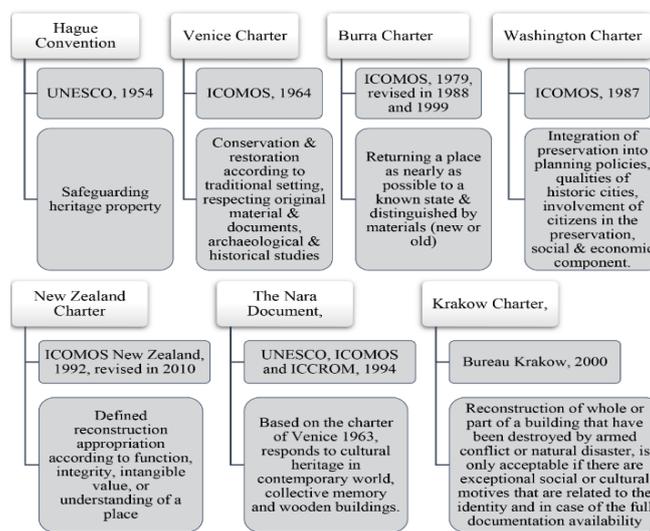


Fig. 6. Related to the post- conflict reconstruction conventions

From the need to explore the articles’ impact on Mosul heritage houses and architectural identity, the researchers performed observation visits to the old city of Mosul and located problems that affect the heritage context, caused by modern building services. Problems arise from the need to balance visual, spatial and functional requirements of modern building services in the reconstruction of Mosul's heritage and to increase house compatibility. Most related observations were classified, documented, and presented in Table III. The exploratory visit pointed to various problems and effects; some related to pipes that distort external appearance. Pipes or extensions deliver water to heritage houses, penetrate walls and rise to reach water tanks at the top. Pipes may also be for sewage and raindrops. Upgrade led to lack of integration between added equipment and the surrounding environment, in addition to the loss in part of houses’ mass and value. Extensions caused damage, water leakage and holes in walls and ceilings. Electrical power cables, their sticking on and dangling from the walls and alleys are located. Heating and air-conditioning equipment that are attached to the walls change features and cause distortion.

Table III Exploratory visit summary

#	Building-Service	Availability	Impact - Variables
1	Space heating	<input checked="" type="checkbox"/>	Damage, deterioration and decay
2	Heat transfer control	<input checked="" type="checkbox"/>	
3	Air-conditioning	<input checked="" type="checkbox"/>	
4	Shading	<input checked="" type="checkbox"/>	

5	Communication	<input checked="" type="checkbox"/>	Distortion & harm
6	Information services	<input checked="" type="checkbox"/>	
7	Lighting	<input checked="" type="checkbox"/>	Uprooting plants
8	Power	<input checked="" type="checkbox"/>	
9	Drainage	<input checked="" type="checkbox"/>	Removing structure
10	Plumbing	<input checked="" type="checkbox"/>	
11	Water supply	<input checked="" type="checkbox"/>	Changing features
12	Domestic hot water	<input checked="" type="checkbox"/>	
13	Security	<input checked="" type="checkbox"/>	Encroachment
14	Safety	<input checked="" type="checkbox"/>	Harmony lacks
15	Special systems	<input type="checkbox"/>	N/A
Key 1- <input checked="" type="checkbox"/> : Service is available. 2- <input type="checkbox"/> : Not available. 3- N/A: Not Applicable			

II. RESEARCH PROBLEM

Conceptual foreground followed by exploratory visits and locating different effects on heritage context resulted from services implementation or upgrade beside counting services, reflecting legislation application and identifying the integration which led to the research problem. *There is a deficiency and necessity of effective guidelines to upgrade and implement building services into original building systems in heritage houses, to preserve architectural identity while providing inhabitants needs.*

III. PURPOSE AND OBJECTIVE

This research mainly aims to meet inhabitants' requirements, provide a concept of residence that is compatible for current needs and to preserve architectural identity.

Additional aims are: highlighting building services' integration in Mosul heritage houses, stating integration opportunities between modern building services and building systems in the heritage houses of Mosul, locating heritage house capabilities to upgrade and implicate modern building services without negatively affecting the architectural identity, and captioning the effects of incorrect implementation of building services.

IV. METHODOLOGY

This research uses a qualitative method to reach purposes and objectives choosing case studies. Multiple data collection techniques are used in addition to related literature and documents to collect data for houses' former state, and semi-structured interviews consisting of multiple sections and ten main questions for nine experts followed by observation for six case studies. This includes voice recordings and notes accompanied with filling observation checklists as fact sheets in addition to photographical documentary. Experts' answers within ten sheets were analysed and compared beside a comparison sheet for results from case studies and two additional detailed breakdown sheets. Households have provided valuable data about services in the particular heritage houses in addition to accessibility to the house which is a critical criterion. Case studies for Mosul heritage houses are located in the old city, nearby Al-Nabi Jarjis shrine and Al-Noori mosque. A 3-dimensional model showcases services in addition to an analysis sheet are used for each case supported by gathered data. Through this process there are comparisons between services before and after upgrade to locate possibilities for better integration and identity preservation.

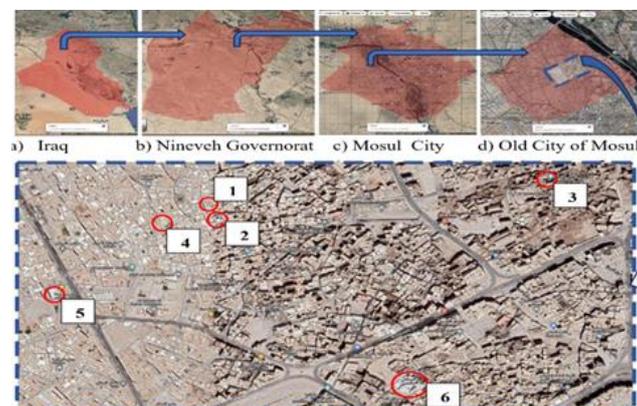


Fig. 7. Case studies location on Google earth plans

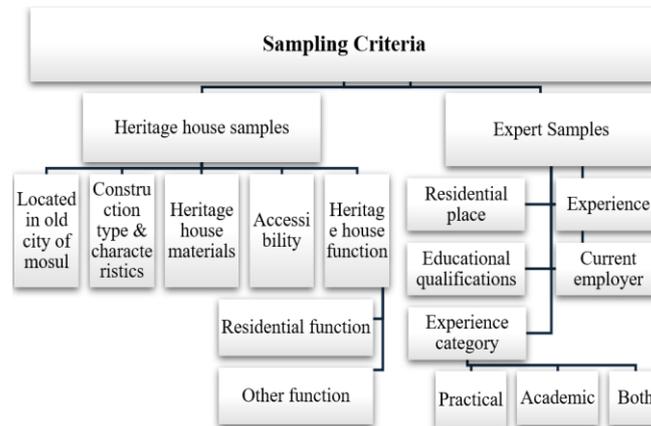


Fig. 8. Sampling criteria

Fact Sheet- Case No.: 2	Identifying name: 'Ghanim Haj Yaseen Heritage House'
<p>Site visit details: -First visit: Feb. 2023 -Location: 36°20'39.3"N 43°07'40.1"E -Entrance orientation: North & West - Approximate plot area: 165 m²</p> <p>Main floor plan:</p> 	
<p>Description: -Heritage house in the old city of Mosul from early 20th century. -Has two entrances for being corner house. Occupied by his owners since around seventy years ago. Mr. Abdul-wahhab Al- Saedy _<i>Commander of the Counter-Terrorism Service</i>_ and solders used it then was on media, also a solder carried the old woman _<i>owner</i>_ on his back during liberation, 2017 then came back to check on her went viral on social media. -Became locally known for that. -Original mechanical system includes: Original thick bearing walls <i>almost all of them</i>, filled-in wells, variable staircases, no Qantara, no Shanshool, no Malqaf, has Courtyard, has Ewan, no Arched gallery, Others as Voids, Akhshem, multi levels, communication tube, ropes and clothes shed.</p>	
<p>Photos & documentaries:</p> 	

Fig. 9. Observation checklist example, shows the second case

Presents a comparison between the six cases in the integration between building services and building systems.

Table V Field observation results for legislations application

Modern Building Services		Legislations					
		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
HVAC	Space heating & Heat transfer control		☑	☒	☑		☑
	Ventilation & Air movement			☑	☑		☑
	Comfort cooling (AC & Shading)			☒	☑		☑
Electrical	Power			☒			☑
	Lighting (Internal, external)			☒	☒		☒
	Communication & Information	☒	☒	☒		☒	☒
Plumbing	Domestic Hot Water			☒			☒
	Water Supply			☒	☒		☒
	Drainage & Plumbing.			☑			☑
Safety	Security		☒	☒	☒		☒
	Safety			☒	☒	☒	☒
Other	Special systems	☒	☒	☑	☒		
☑		Legislations applied					
☒		Service not available					
☒		Legislation applied except harmony					
		Service available, legislations were not applied					

The sign (☑) is placed due to complying to legislations, (☒) for unavailability of modern building service. The sign (☒) for complying to legislations but missing the harmony.

Table VI Field observation results for integration opportunities

Modern Building Services		Integration Opportunity					
		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
HVAC	Space heating & Heat transfer control	2	2	2	2	3	3
	Ventilation & Air movement	3	3	1	1	3	4
	Comfort cooling (AC & Shading)	5	5	☒	4	5	4
Electrical	Power	4	3	3	3	3	3
	Lighting (Internal, external)	3	5	4	3	3	4
	Communication & Information	3	4	☒	3	☒	☒
Plumbing	Domestic Hot Water	3	3	☒	2	2	☒
	Water Supply	3	2	2	2	2	5
	Drainage & Plumbing.	5	4	4	5	5	5
Safety	Security	2	1	3	☒	3	3
	Safety	2	2	☒	☒	2	☒
	Special systems	☒	☒	3	☒	5	3
Numbers (1-5)		Number of Integration Opportunities					
☒		Service is not available					

Sign (☒) is placed when service is unavailable. Numbers (1-5) refers to the number of integration opportunities.

Highlighted points related to the study subject are presented as follows:

1) Modern building-services and building systems:

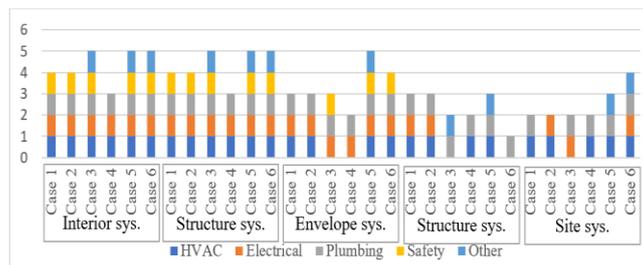


Fig. 11 Modern building services and affected building systems

Fig. 11 illustrates the availability of modern building-services in each of the six cases. Each has a different colour, coinciding with the concerned building system. HVAC, electrical and plumbing are shared services among all of the six cases as top three of five main services. Safety services come in second level in five of six cases. Other special systems rank lowest, available only in three of six cases. It is noted that this applies only when the actual service is available in the heritage house case.

For the systems, five building systems for each of Mosuli heritage houses case studies are affected by modern building-services differently, sometimes all of the five systems for certain service, and only one for another as in

the comparison between six cases. Out of five building systems, interior and structure occupy first place followed by envelope, service and site systems respectively.

2) *Legislations:*

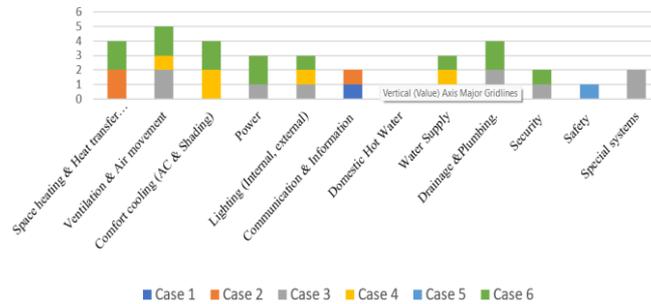


Fig. 12 Legislation compliance while integrating modern building-services to building systems

Fig. 12 clarifies case compliance with concerned legislations during integrating modern building services into building systems of the Mosul heritage house, in the face of being undetailed, yet available to preserve heritage identity and wellbeing. Mentioned legislations were not perfectly followed in all of the six cases, without covering all of the five services in best cases. It's applied to the top three services mentioned previously HVAC, electrical, and plumbing and to mention that also not for each of main service subdivisions. Case (6) has fulfilled HVAC, electrical, and plumbing, while case (3) HVAC, plumbing and other special system, then cases (4) and (2) ending with cases (1) and (5) with nothing.

3) *Integration opportunity:*

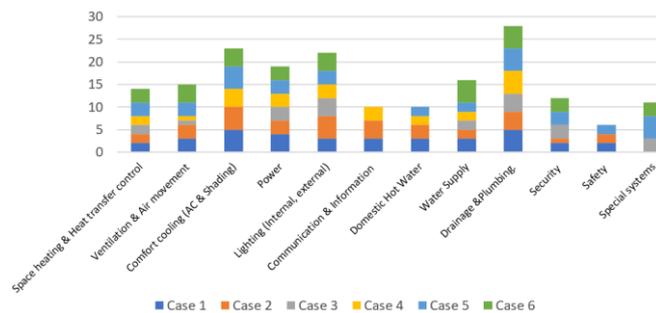


Fig. 13 Integration opportunities between modern building services and building systems

The opportunity for full integration between modern building services and building systems, increase compatibility of the heritage house and forms solutions for services upgrade process. Based on Fig. 13, plumbing is at the peak then HVAC is followed by electrical services. Safety and other special systems had least occurrence.

Figures 11, 12 and 13 revealed variation in modern building services among selected cases, accompanied with inequality in each service relation with every single system and integration and by referring to their compliance to related legislations in-touch with this study subject. Legislations comparison sheet and graph is the less fortunate among the three; building systems, legislations and integration opportunity. Various services were investigated, determined, and their relation to building systems was determined. Differences in gathered information from both experts and heritage house cases were reflected by filling sheet cells.

VI. CONCLUSIONS

The revealed data from results and discussions presented variation in integration and services' relation with building systems and compliance to legislations, giving interesting high grades to some unexpected cases. Conclusions are extracted from this study based on conceptual foreground and literature supported by practical application. This study concluded:

- In depth knowledge of heritage house characteristics forming building systems, increases chances to create more of integration opportunities and identity preservation beside a compatible house in return.
- The study clearly assured that it's a must to locate openings, shafts, badgers, and less value elements in the vertical and horizontal plane to be showed on a 3D model for the heritage house during planning for the upgrading and installation of modern building-services.

- The study encouraged to upgrade existing services or developing them for more sustainability and architectural identity preservation, beside keeping the mental image and memories of inhabitants of the very place.
- Many troubles occurred due to neglecting and cancelling the role of original heritage service systems totally or partially _humidity and mould in lower levels _basement\ Sirdab and Rah-rah_ as examples due to closing the Malqaf shaft as in case No. 4 of Mosul heritage house.
- Factors such as limited space, structural constraints, and the need to harmonize modern systems with traditional aesthetics and materials pose significant challenges. However, integration also presents opportunities to enhance energy efficiency, improve comfort levels, and ensure long-term sustainability of these houses. Proper maintenance and ongoing monitoring of systems is essential for longevity and functionality.
- A heritage building it is characterized by historical, symbolic, architectural, aesthetic, cultural, or societal values which needs to be determined and reused.

VII. DECLARATION OF COMPETING INTEREST

The authors declare no conflicts of interest.

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This study didn't receive any specific funds.

IX. DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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