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POSTWAR SUSTAINABLE HOUSING DESIGN STRATEGIES: THE CASE OF RECONSTRUCTION IN MOSUL, IRAQ

Hala Ali Abdulrazaq

Supervisor: Doctor Manuel de Arriaga Brito Correia Guedes
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Thesis approved in public session to obtain the PhD Degree in Architecture
Jury final classification: Pass with Distinction

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Jury

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Abstract

Iraq has suffered a series of wars during the last four decades. The last conflict against the Islamic State from 2014 to 2017 caused severe destruction to buildings in seven provinces. The damage to the housing sector in Mosul (Nineveh's city centre) has the greatest share. The cities are still covered by tons of rubble.

Several international humanitarian organizations are providing urgent assistance to help local people to rebuild their homes. However, an unguided rebuilding strategy is proving to be inefficient, causing more damage to the built environment, and there is no comprehensive plan to protect historic buildings with high heritage value.

This research is focused on post-war architectural design strategies that may guide and support the different ongoing reconstruction projects in Mosul. The research outcomes emphasize the historical value of the architectural patrimony in Mosul and provide solutions for a sustainable reconstruction through the use of rubble. Results are based on evidence collected from understanding the local architecture, including building typologies and construction materials. Field surveys were carried out in the Old City and war zone areas: these included damage assessment, interaction with the local authorities and international organizations involved in the rebuilding process, and study on the potential for reuse and recycling of rubble in the design process.

This allowed the research to identify design guidelines that are: (1) integrated and inspired by the local architecture in the Old City; (2) sustainable and environmentally conscious, involving local materials and encouraging the reuse and recycle of rubble.

Keywords: houses in Mosul, Mosul post-war reconstruction, reuse with rubble, sustainable architecture, Mosul post-war architecture.

Resumo

O período de guerra que o Iraque viveu durante quatro décadas é responsável pelos danos observados na arquitectura daquele país. O último conflito contra o Estado Islâmico, entre 2014 e 2017, causou graves destruições em edifícios de sete províncias. Em Mosul (centro da cidade de Nineveh), observou-se que a maior parte dos danos ocorreu no sector habitacional. Em consequência, as cidades encontram-se cobertas por toneladas de escombros. Várias organizações humanitárias internacionais prestam ainda hoje assistência para ajudar a população local a reconstruir as suas casas.

Para além da não existência de um plano abrangente para proteger os edifícios históricos com um elevado valor patrimonial, observa-se que a estratégia não informada das acções de reconstrução é ineficiente, causando mais danos ao ambiente. A presente investigação tem como objectivo evidenciar o papel do projecto arquitectónico para o estabelecimento do controlo sobre as diferentes acções de reconstrução em curso em Mosul.

Os resultados da investigação sublinham que o valor histórico das casas e a reutilização da grande quantidade de entulho existente são os princípios fundamentais que devem guiar as intervenções arquitectónicas propostas. Estes resultados apoiaram-se numa metodologia de investigação que se baseou em evidências recolhidas a partir da compreensão da arquitectura local, materiais de construção e tipologias construtivas, em visitas de observação às cidades antigas e suas zona de guerra, na avaliação dos danos, na validação da reutilização e reciclagem de entulho no processo de projecto de reconstrução, e na interacção com as autoridades locais e organizações internacionais envolvidas.

As distintas leituras permitiram a identificação de uma estratégia de projecto: (1) integrada e inspirada na arquitectura local da Cidade Velha, (2) sustentável e ambientalmente consciente, que considera a aplicação de materiais locais e visa reduzir a quantidade de entulho gerado pelo conflito, encorajando a reutilização e reciclagem de entulho.

Palavras-chave: habitação em Mosul, reconstrução de Mosul no pós-guerra, reutilização de escombros, arquitectura sustentável, arquitectura de Mosul no pós-guerra.

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LIST OF ACRONYMS

Acronym	Description
IDP	Internally Displaced Persons
ISIS	Islamic State in Iraq and Syria
ISIL	Islamic State in Iraq and the Levant
NGO	Non-Governmental Organization
KRI	Kurdistan Region of Iraq
KRG	Kurdistan Regional Government
MoP	Ministry of Planning
IOM	International Organization for Migration
AFP	Agence France-Presse
AP	Associated Press
PWD	Public Work Department
UN	United Nations
UNEP	United Nations Environment Programme
UNHCR	United Nations High Commissioner for Refugees
UNESCO	United Nations Educational, Scientific and Cultural Organization
UN-Habitat	United Nations Human Settlements Programme
UNDP	United Nations Development Programme
ERW	Explosive Remnants of War
PDM	Post Distribution Monitoring
MODM	Ministry Of Displacement and Migration
NRC	Norwegian Refugee Council
OCHA	Office for the Coordination of Humanitarian Affairs
AoO	Area of Origin

NFI	Non-Food Items
CCCM	Camp Coordination and Camp Management
RCBP	Recycled-Content Building Products
US	Unites States
UK	United Kingdom
ICOMOS	International Council on Monuments and Sites

INTRODUCTION

Seven provinces in Iraq have been occupied by the Islamic State of Iraq and the Levant (ISIL) from June 2014 until July 2017. The group was deliberately attacking the heritage sites and destroying the local historical houses while they were invading the cities and during their occupation period. In October 2016, the Iraqi military started to liberate the cities through a battle backed by an international coalition force. Further destruction to the housing sector was caused by the airstrikes during the liberation battle. ISIL was a threat for the majority of the local people in Iraq. Most of the houses owned by religious groups, ethnic minorities and the local people who were associated with the Iraqi government were threatened by ISIL.

The devastation caused by ISIL and the airstrikes to liberate the cities led to a large internal displacement crisis in Iraq. The local people fled to the closest cities to seek safety that caused an urgent need for temporary housing solutions. The situation of the local people who stayed in the cities (stayers), the local people who fled the cities to another place in Iraq (Internally displaced Persons) and the people who are turning back to the cities (returnees) is worsening even years after the liberation of their cities. The main reasons for this situation are: the cities are still covered with tonnes of rubble; the houses of most of the local people need major interventions that they cannot afford; the current lack of strategy and coordination on individual reconstruction activities; the host cities are overcrowded as a result of the large displacement; and the camps are currently inadequate, as they were designed to host the IDPs for a short period of time. There is an urgency for an efficient coordination strategy on rebuilding activities, as they are being implemented without rules under the pressing emergency needs. The main actors for housing reconstruction are a few international humanitarian organizations and some individual local people. Coordination between the current actors and the local authorities, who should be responsible for the reconstruction projects, is almost non-existent.

Among the seven affected provinces, Nineveh suffers the greatest level of destruction. Mosul (Nineveh's main city) was occupied by ISIL for a longer period, as it was the first invaded city and the last one to be liberated. Since the liberation of Mosul in 2017, humanitarian actors have been providing emergency assistance with temporary housing units and, in a few cases, rehabilitating infrastructure and public facilities.

However, several actors, including Nineveh's Governorate and international actors have expressed their concern that reconstruction without a coordinated strategy is inefficient and may complicate the long-term development of the city. Indeed, the recovery and reconstruction of

architecture in Iraq would greatly benefit from a guiding framework to support architects with post-war design strategies. Hence, this research aims to define priorities and deliver a comprehensive framework for the post-war reconstruction design focusing on housing reconstruction. The housing sector is the most affected one in Iraq and Nineveh, sharing 44% of the total damage across the seven provinces.

This research focuses on the role of architectural interventions in post-war housing reconstruction in Iraq. It addresses a better understanding of the scale of architectural damage and defines post-war architectural design priorities. The research assumes that we need to involve the reuse and recycle of materials and elements from rubble in the rebuilding process in order to reduce the environmental impact and the cost of reconstruction.

The study intends to identify a comprehensive architectural design guidance for the post-war reconstruction through a methodological approach that addresses the local architecture and identifies the main sustainable design strategies to be used in the reconstruction. This includes the identification of the most relevant heritage sites, and the assessment of the potential use of rubble on the reconstruction process. Field surveys were carried out, involving case studies' selection; visits to the Old City, camps, war zone areas; damage assessment; evaluation of the potential reuse and recycling of rubble; interviews with decision makers; and interaction with the local authorities and international organizations involved in the rebuilding process. In addition, the research involves an analysis of the current reconstruction and recovery activities in Mosul, highlighting emerging needs for heritage recovery, and provides recommendations for the implementation of suggested actions.

The outcome of this methodological approach allows identifying key strategies for the post-war architectural design in the destructed areas that achieves the following goals: establish design recommendations that allow the continuity of the local architecture and save the heritage from further damage; the assessment of the damage scale and quantification and qualification of rubble will lead to suggest a design strategy that makes reuse and recycle happen in order to reduce the quantity of generated rubble and furthermore shifting the balance from recycling to reclamation and reuse to reduce the reprocessing involved and hence lead to energy and cost savings.

Research goals and questions

Between the urgent need for the reconstruction of the housing sector in one hand and the need for a sustainable design and heritage protection in the other hand, the research intends to develop

a rebuilding framework that seeks to achieve continuity and sustainability in the post-war housing architectural design approach. It is increasingly demanding for the post-war architects and the local people who lost their houses to consider reusing and recycling materials in the post-war reconstruction plan. This has been undertaken in a small scale In Mosul in two heritage buildings undertaken by UNESCO (Al Nuri Mosque and Al Tahera Church).

The research seeks to develop a guideline to incorporate repaired architectural elements and materials into a larger scale for the reconstruction of the Old City. There are a growing number of policies at the international level aimed to encourage the use of repaired and recycled materials. The waste industry has developed guidance to reduce the quantities of construction waste being sent to landfill. The recycling industry has generated useful guidance to stimulate the markets for construction materials made from recycled materials. However, that kind of guidance is not enough to guide the architects to incorporate repaired and recycled materials in the reconstruction in a large scale for houses with different damage levels and different heritage value and construction materials in Mosul.

The research considers the use of architectural elements and materials that can be repaired and reused in the same building or can be stored to be reused in a different building with the same heritage value. Reuse refers to the material that is being used for the same purpose as it was used in its previous life. The research also considers the use of recycled materials. When materials are recycled, their new life begins as a raw material for a manufacturing process and the primary concern is knowing the ingredients or chemical composition of the material.

In order to reveal a comprehensive framework for the post-war architectural design, the research intends to develop a design guidance that is (1) integrated and inspired by the local architecture in the Old City; (2) sustainable and environmentally conscious, which considers involving local materials and aims at reducing the quantity of the rubble generated from the conflict by encouraging the application of reuse and recycle of rubble (Table 1).

These two main goals are followed by:

1. Gather existing information to understand the architectural and material features of local housing in the city of Mosul in order to:
    a. Identify sustainable design practices and strategies to support post-war housing reconstruction,
    b. Make the process of characterisation of rubble easier.
2. Analysing the current actions and challenges placed on ground to rebuild and how they affect the post-war reconstruction framework

3. Analysing and evaluating the housing damage

4. Propose strategies to apply the practice of reuse and recycle of the rubble generated from the conflict.

The main research question is:

What are the main post-war sustainable architecture design priorities that should support the reconstruction approach?

Table 1. Research goals and questions

Goals	**Research secondary questions**
Identify main characteristics of the historical architectural design and building materials that can contribute to the post-war architectural design.	What are the architectural characteristics of local houses in Mosul? What building materials were used in each design element for traditional architecture? What are the sustainable design strategies used in the traditional house?
Address the state of post-war housing settlements, the current rebuilding activities and challenges, and how they affect the rebuilding later.	What are the temporary housing solutions taking place in Mosul for the people who need to rebuild their houses? What activities are taking place in Mosul by local people to rebuild their houses? How has the government been involved in the ongoing self-reconstruction? What rebuilding efforts are the international organizations providing in Mosul?
Assess the architectural damage scale in Mosul through rubble qualification, quantification and distribution of housing sector.	What is the damage scale of the historical houses in Mosul? How is the rubble treated currently in Mosul? What is the quantity of housing construction rubble in Mosul? Given the quantities of rubble, where is it located mostly in the city?
Investigate the ways that architectural design process can include reused and recycled	How to apply reuse and recycle practices in the architectural design process?

building materials and elements in the reconstruction process in Mosul.	
Develop a post-war architectural design guidance based on principles that focus on achieving the main goals of the research.	Taking into consideration the goals of the research and the findings of each of the previous questions: what are the main post-war architectural design priorities that should support the post-war reconstruction approach?

Methodological framework

To answer the main research question, the methodological approach addresses pre and post-war analysis of the housing sector. In order to achieve integrity with the local architecture in the post-war architectural design, the research studies traditional architecture of the houses in Iraq before the last war (ISIL war), identifies the main architectural design strategies used in local houses, and then identifies the possibilities to apply it in the post-war architectural design. After that, the research addresses the post-war destruction scale including housing challenges, current rebuilding activities, government and international organizations' involvement in the rebuilding process and assessment of the housing constructional destruction. Finally, the research finds out the possibilities for the application of reuse and recycle to the constructional rubble generated from the housing sector (Figure 1).

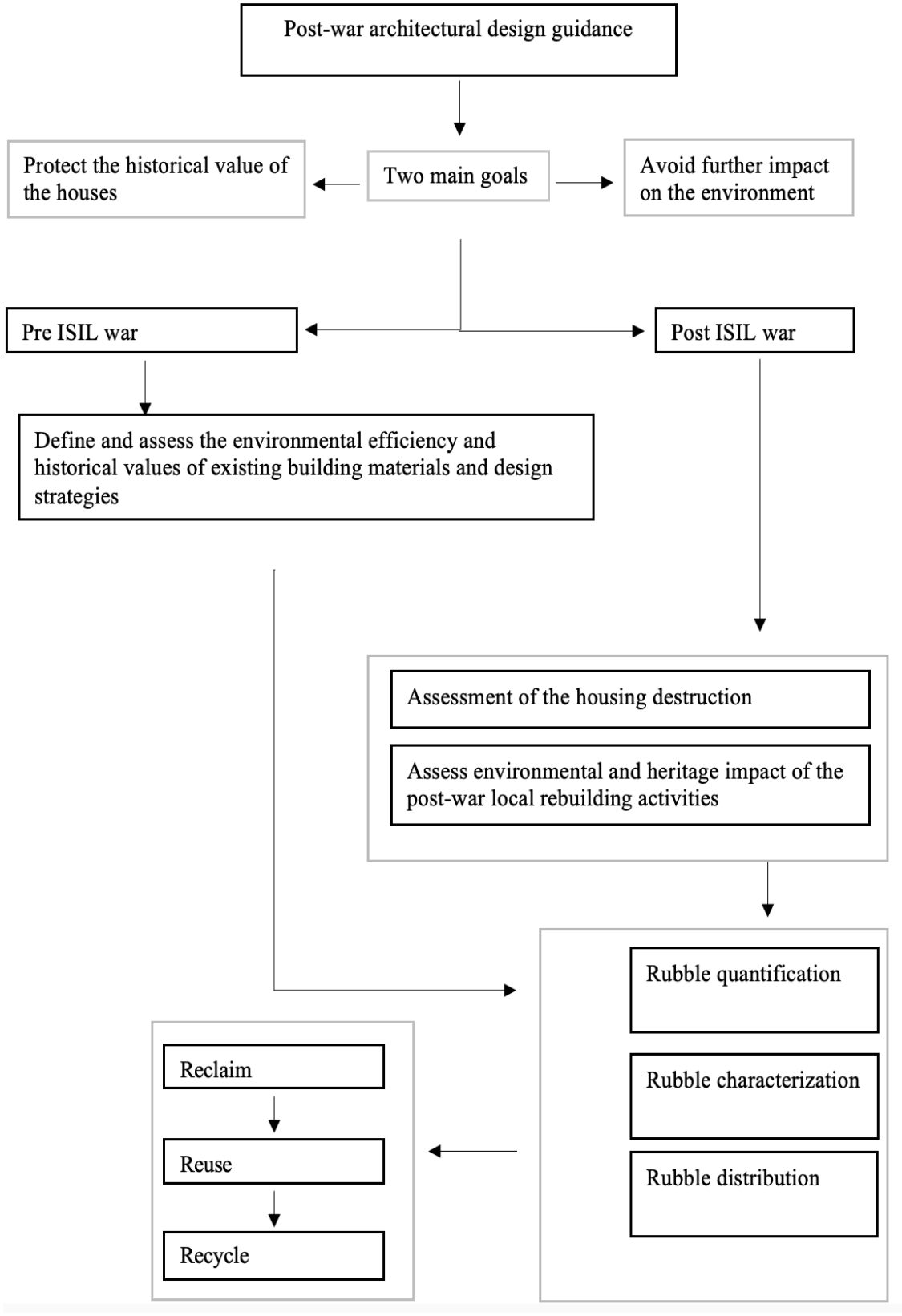

Figure 1. Main research steps (Source: author).

The research framework is divided into three parts (Table 2).

Table 2. Main research parts

	Brief	Scope	Indicators
Chapter 1 and 2	Study the local architecture in Mosul, Iraq and identify sustainable design strategies and building materials used.	Old City in Mosul	Openings, roof, properties of the walls and roof, bioclimatic strategies, building materials.
Chapter 3 and 4	Evaluation of the post-war housing settlements and local people urgent housing needs. Address the rebuilding process going on in Mosul and its influence on the environment and continuity of the cultural values.	Mosul Temporary housing solutions for the local people of Mosul	Post-war housing shortage, camps functionality, international organizations' involvement, government's involvement.
	Quantification and qualification of the rubble generated from the destruction and the distribution of the rubble.	Mosul	Rubble quantity, disposal locations, heritage buildings' protection, security, rubble management strategies, governmental plans and actions, international organizations' actions.
Chapter 5 and 6	Study the opportunities to reuse and recycle building materials and products that are included in the rubble generated after the conflict.	Mosul	Building materials, building elements/products, reusable materials and elements.

1.Traditional houses in Mosul are studied. The origins of the decorative elements found in rubble are identified. Then, the traditional house elements are analysed including courtyard, Iwan, openings, roof, building layouts, Shanasheel, Malqaf and building materials. The techniques, decorations and ornaments are also defined. The main goal of this part is to define the main design techniques that can benefit the post-war design and to help the characterization of rubble in part 3 of the research. The methodological approach and results are presented in chapter 1 and 2.

2. Post-war housing settlements are analysed to identify housing reconstruction challenges. The content of this part is developed under direct consultation, meetings and interviews with the local authorities, Mosul university, decision makers and international organizations in Mosul. The reports conducted by the UN agencies and local authorities are taken as the base data for the statistical analysis. Then, given the housing characteristics in the first part and the data collected during the observational visits and meetings conducted in the municipality of Mosul, the research develops a framework for housing rubble assessment in Mosul. In result the research aims to find out the quantity of constructional rubble generated from the housing sector, the distribution of rubble around the city and the rubble generated from heritage buildings. The results and methodological approach are presented in chapter 3 and 4.

3. The possibilities of the application of reuse and recycle practices in the post-war architectural design stage are addressed to help architects to incorporate reclaimed and recycled materials in houses design. In conclusion, the integrated analysis of the houses pre and post-war, given the historical background; the materials, products and design strategies needed to protect; post-war challenges; reusability of each one of them; recycling possibilities, all of that allows to establish the priorities for the post-war architectural design. The results and methodological approach are presented in chapter 5 and 6.

Methods

Different methods are used in each chapter of the research. The methods are presented extensively in each correspondent chapter. The main adopted tools are presented in Table 3.

The data are collected under consultations with the Engineering Consultancy Bureau, the university of Mosul, the Committee Responsible for the National Effort to Restore Services in Nineveh Governorate, ministry of housing and construction in Iraq and Mosul Self Rebuilding Facility. Some of the data and research on destruction of the housing sector, environmental challenges and rubble assessment have been developed based on the data given by the UN agencies including: UN-Habitat, UNDP, UNESCO and UNEP, along with the reports provided by the Municipality of Mosul.

Statistical analysis tools were used to treat primarily rubble quantification in Mosul city derived from an initial damage assessment based on satellite imagery from July 2017 carried out by UN Environment in collaboration with UN-Habitat, Disaster Waste Recovery and Urban Resilience Platform.

Structured interviews were collected in consultations with local authorities and the ministry of construction and housing to evaluate the involvement of the government in the current rebuilding activities. The interviews also focused on the actions taken by the local authorities to treat rubble, either in clearance, transfer, protect heritage sites' rubble and further rubble management actions. The interviews also aimed to find out if the decision makers in Mosul are approaching any plans to apply reuse and recycle to treat the rubble.

Observational visits were challenging due to the security issues and the ongoing conflicts by small groups of ISIL that were still hidden in the city. Finally, the researcher was allowed to enter Mosul after obtaining permission from the governor of Mosul Dr Muzahim Al Kyatt, in June 2019. The path of the visits was limited due to the forced security spots by the government.

In the end of the month, five constructive visits were accomplished following different paths in each visit (explained in detail in chapter 3).

Table 3. Research tools

Research questions	Methodological approach	Tools
What are the sustainable design strategies used in the traditional house?	Analyse the Old City in Mosul Study the characteristics of traditional house in Mosul	Data collection and investigation of local architecture Observational Visits, walkthrough visits
What are the architectural and constructive characteristics of traditional houses?	Analyse the local housing projects in Mosul	
What building materials were used in each design element	Investigate building materials used in traditional houses	
Post-war reconstruction challenges in Iraq		
What are the temporary housing solutions taking place for the local people?	Statistical analysis of the internal displaced people and their housing challenges	Collection of reports from international organizations Observational visits walkthrough visits Interviews with local people Interviews with decision makers in Mosul and local authorities
What activities are taking place in Mosul by local people to rebuild their houses?	Investigation of the current rebuilding approaches and the involvement of locals, government and the NGOs on ground	
How has the government been involved in the ongoing self-reconstruction?		
What rebuilding efforts are the international organizations providing in Mosul?		
Reuse and recycling from rubble		
What is the damage scale of the historical houses in Mosul?	Analyse and evaluate the destruction scale in Mosul	Collection of reports from international organizations Observational Visits, walkthrough visits Quantification of construction rubble of the housing sector Interviews with decision makers in Mosul and local authorities
How is the rubble treated currently in Mosul?	Investigate the rubble quality around the city	
What is the quantity of housing construction rubble in Mosul?	Statistical analysis of the rubble generated from the houses in Mosul according to reports collected from UN agencies	
Given the quantities of rubble, where is it located mostly in the city?	Apply the quantities of rubble from previous question and investigate its distribution in Mosul	
How to apply reuse and recycle practices in the architectural design process?	Evaluate the opportunities for the application of reuse and recycle in post-war architectural design process	Data collection and analysis of reuse and recycle practice Observational Visits, walkthrough visits

Case study

Mosul, the main city of Nineveh's province, is extensively analysed as the main case study in this research for several reasons: (1) the researcher obtained a permission to do observational visits in Mosul supported by the declaration provided by the supervisor, since it is not possible to have easy access to other areas of the war zone; (2) Mosul is Nineveh's biggest city and the second largest city in Iraq; (3) Mosul shares the biggest destruction of the seven affected cities in Iraq (Figure 2 and 3) and shares the biggest destruction of the housing sector in Iraq; (3) the Old City of Mosul is one of the best examples of the traditional architecture in Iraq; (4) the architectural heritage in the Old City of Mosul and Nimrud is in danger and furthermore the environmental impact of the war on Mosul is the biggest among the other cities affected in Iraq as it shares the biggest amount of rubble.

The travelling challenges between the cities due to the security issues and the continuous unstable situation in Iraq were the main reasons to choose the cities that host the Internally Displaced Persons (IDPs) from Mosul who are in camps, such as, Duhok, Erbil and areas around Mosul.

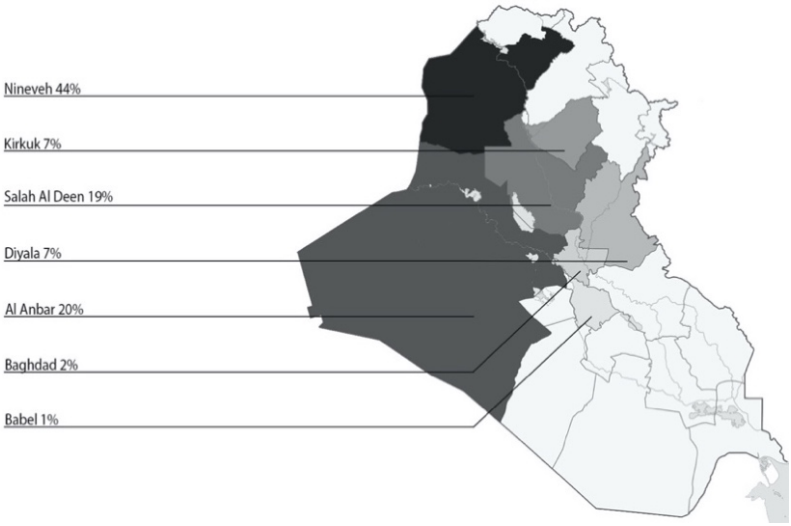

Figure 2. The seven provinces invaded by ISIL in Iraq (Source: author).

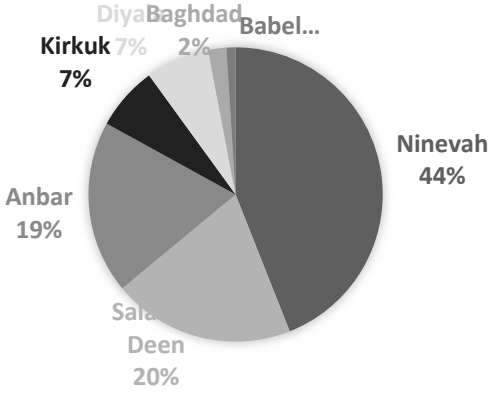

Figure 3. Share of housing damage in the seven affected provinces (Source: author).

The housing sector in Nineveh is displaying 44% of the total share of reported damage to housing assets is Iraq (Figures 4 and 5). The urban centres in Nineveh alone incurred 58% of the total damage to urban centres across the seven provinces.

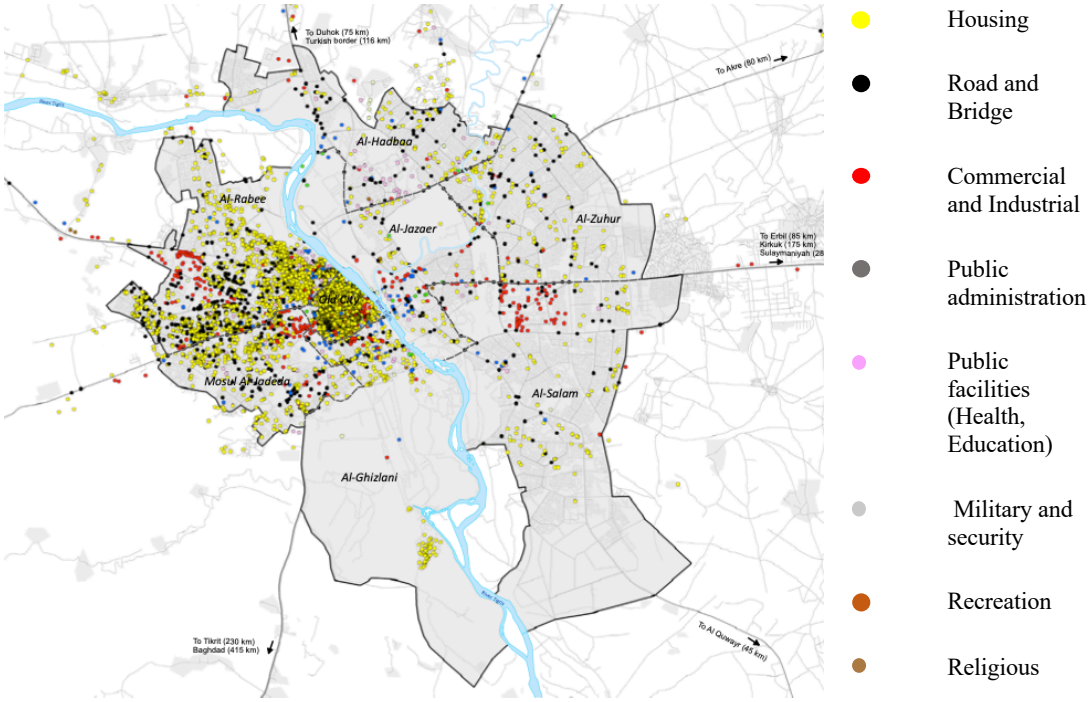

Figure 4. Damaged sites in Mosul per sector according to UN-Habitat damage assessment (Source: UN-Habitat).

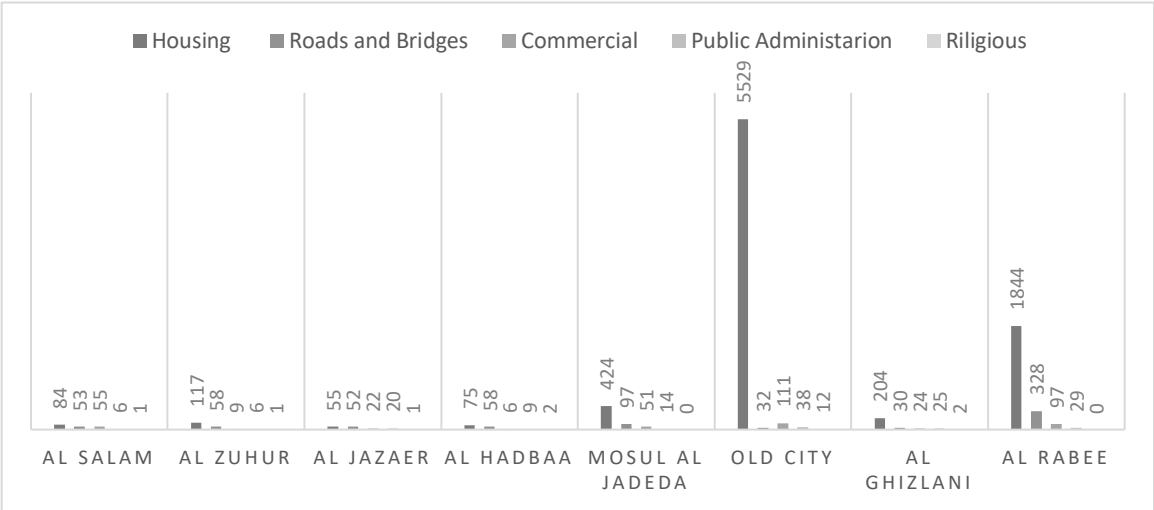

Figure 5. Number of destroyed buildings of each area in Mosul districts (Source: author).

On the other hand, Salah Al Din, which sustained 20% of the share of total damage, had the highest percentage of destruction to rural housing assets across the seven provinces. In general, the level of damage was distributed equally between major damage and completely destroyed. Yet, in provinces like Diyala and Babel, the most impacted housing assets are destroyed beyond repair.

In Mosul, the Old City shares the biggest percentage in housing damage among the rest of the areas.

Expected outcomes

Identifying the architectural design role in the post-war reconstruction process can contribute to create a coordinated approach and control the current unguided reconstruction process. The post-war design principles and priorities can be implemented by the local authorities responsible for the reconstruction and the architectural design team. Therefore, it is expected that the results allow the design team to establish policies for protecting the historical houses from further damage and to move to a more sustainable reconstruction plan.

The research results regarding the historical background will provide the local people a vision to be careful and aware of the protection of valuable elements, materials and the design strategies while rebuilding their houses.

The identification of the current housing challenges will help the design team and the local authorities responsible for the reconstruction to build a systematic approach that can meet the needs of people who lost their houses in an efficient and sustainable manner.

The data collection of the housing architectural destruction scale in this research, as the first and only attempt so far in Mosul, will contribute to the establishment of a database that supports future research developments.

Research structure

The thesis is organized in six chapters. In the first chapter, after the introductory chapter, a brief historical context identifies and addresses the influence of each political period that controlled the region from the ancient times to the recent years. Thus, understand each period's impact on the architecture and then identify the origin of elements used in the traditional architecture. In chapter two, architectural design elements and building materials of the traditional house are defined. Chapter three presents the findings of the field work in Mosul and analyses the impact of the conflict on the housing sector and the housing challenges facing the local people of Mosul currently. Chapter 4 presents the findings of the assessment of housing architectural destruction scale by means of qualification, quantification and distribution of the constructional rubble generated from the housing sector. Chapter 5 studies the application of reuse and recycle practices during post-war architectural design stage. In chapter six, design guidance is presented based on the understanding of the historical house, post-war housing challenges and destruction

scale, reuse and recycle application possibilities. The last chapter summarizes the main conclusions from the previous chapters.

1. IRAQ: AN HISTORICAL OVERVIEW

The land of Iraq has witnessed layers of historical periods that shaped the architecture and affected it in different ways. Each period added its own architectural style, elements and building materials.

The affected cities have suffered as a result of continuous civil and international wars; economic sanctions; ethnic and religious conflicts; rampant corruption; dictatorship regime, Finally, the fall of Iraq under ISIL control just worsened the situation.

The historical background chapter addresses the significant influences on the architecture that resulted from each empire and political period, from the ancient times (Mesopotamian architecture) to the recent years. In order to analyse each period's impact on the architecture and thus identify the origin of the architectural elements, each conflict that happened in Iraq up to the 2014 war against the Islamic State in Iraq and the Levant (ISIL) is studied.

This chapter defines the origins of some important architectural design elements and techniques added to the local architecture through these historical periods. The chapter focuses on identifying the writings, inscriptions, ornaments and more decorative features added to the local architecture through the years. The definition of these features will help the post-war architectural design to consider the significance of elements found in the rubble and reuse it in an appropriate way that insures the right preservation of each element. Thus, it will make the process of characterizing the rubble during its separation and storage easier.

1.1. The Historical origins: Traditional Architecture

Iraq is the name of the state that currently partially covers the territory of the civilization of ancient Mesopotamia. The territory that is currently Iraq was initially settled in approximately 6000 B.C. along the Tigris and Euphrates rivers [1]. The Sumerians who inhabited southern Mesopotamia created many of the innovations that made civilization possible [1]. They invented written language, which they imprinted on clay tablets. This cuneiform writing has revealed much of what we know about how Sumerian society worked and the history of that time period [2]. Cuneiform tablets have also preserved the earliest literature, including the Epic of Gilgamesh, a flood story that closely parallels the Great Flood of the Old Testament [1] [3].

The region between Tigris and Euphrates rivers was known as Mesopotamia in ancient times, where the first permanent structures were built in the 4000 BC [4]. The Sumerians, Akkadians, Assyrians and Babylonians dominated Mesopotamia from 3000 BC to the fall of Babylon in 539 BC [3]. Sumerians were the first society to construct designed cities as a built and advanced form [5]. Mesopotamian empires moved their capitals over the centuries, according to the wish of each new emperor. The historical region of southern Mesopotamia (south Iraq now) was the centre of Sumer civilization [8]. Uruk was the capital of Sumer [6]. Uruk was an ancient city of Sumer located east of modern city of Samawah, Al Muthanna, east of the Euphrates River. Uruk played a leading role in the urbanization of Sumer with 40,000 residents [2] [6]. The Epic of Gilgamesh was the first recorded description of urban planning, starting with the description of Uruk "Go up on to the wall of Uruk and walk around. Inspect the foundation platform and scrutinise the brickwork. Testify that its bricks are baked bricks, and that the Seven Counsellors must have laid its foundations. One square mile is city, one square mile is orchards, one square mile is clay pits, as well as the open ground of Ishtar's temple. Three square miles and the open ground comprise Uruk. Look for the copper tablet-box, undo its bronze lock, open the door to its secret, lift out the lapis lazuli tablet and read." [3].

Courtyard houses, temples and palaces were developed during the Mesopotamian empires [2] [7]. Ziggurats were pyramidal temples that were built in Sumer and continued to be developed in Babylon and Assyria as well [5]. The temples were situated in the centre of the cities [3] [5] [6]. The districts around the temples were religious and commercial buildings [3]. The residential buildings were dominated by courtyard house, where the house is laid around a square space with other rooms opening into it [5]. The primary feature of the house was the courtyard (Tarbasu in Akkadian) [4] [6] [7]. The Sumerians also developed the arch, which enabled them to develop a strong type of dome. They built this by constructing and linking several arches. Sumerian temples and palaces made use of more advanced materials and techniques, such as buttresses, recesses, half columns and clay nails [8].

Sumerians invented one of the earliest writing styles called Cuneiform [2]. Cuneiform was known by its wedge-shape marked on clay tablets [1] (Figure 6). In Mesopotamia, cuneiform inscriptions are found lying within buildings' walls, especially in Babylon (Figure 7).

After the fall of Sumer, the Akkadian empire lasted about 150 years in the last third of the 3rd millennium BC [5]. Akkad (located between the modern cities of Samarra and Baghdad) was the capital of Akkadian empire. From 911 to 609 BC the Assyrian empire was the main empire of that time [3]. Assyria was centred in Nineveh (Upper Mesopotamia). Assur, Nineveh and Nimrud are the main cities that the Akkadians developed [9]. The ancient city of Nimrud in the south of Mosul, in the plains of Nineveh in Upper Mesopotamia, was a major Assyrian city from 1350 BC

to 610 BC [2]. Nimrud gained strength when king Ashurnasirbal II chose it as the capital of Assyria. The city is full of priceless artefacts called Nimrud ivories now. The ivories are small carved figures and plaques mostly covered by gold, silver or precious stones (Figures 8 and 9). They were used mainly for decorations, carved with motifs, and were used to decorate special objects such as pieces of furniture [1] [10].

Figure 6. Ancient cuneiform writing script from palace of Assurbanipal in Nineveh, Assyria (Source: The British Museum).

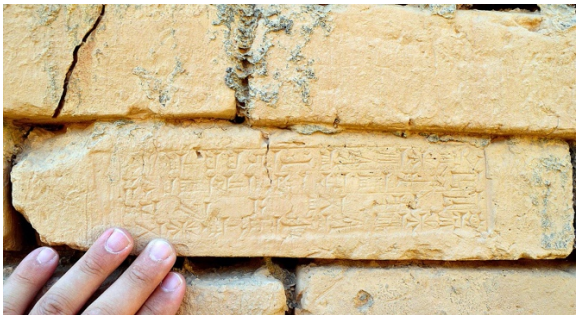

Figure 7. Mudbrick from the processional street of Babylon stamped with the name of Nebuchadnezzar II (Source: Osama Shukir Muhammed Amin).

Furniture inlaid with carved ivory plaques was highly prized by the Assyrian kings. During the ninth to seventh centuries BC vast quantities of luxury goods often embellished with carved ivory in local Syrian and Phoenician styles, accumulated in Assyrian palaces, much of it as booty or tribute. The objects in Figures 8 and 9 belong to a group of plaques depicting animals and stylized plants. They were made by master carvers in a delicate openwork technique characteristic of Phoenician ivory carving. However, the style and subjects depicted have close parallels on stone relief sculptures from Tell Halaf, in northern Syria, and a debate exists over which tradition produced these fine panels [11].

The favoured design of the masonry walls in the Mesopotamian house was rounded bricks, which are somewhat unstable, so Mesopotamian bricklayers would lay a row of bricks perpendicular to the rest every few rows [8]. The advantages to plan-convex bricks were the speed of manufacture as well as the irregular surface that held the finishing plaster coat better than a smooth surface from other brick types [8]. Bricks were sun baked to harden them. These types of bricks are much less durable than oven-baked ones, so buildings eventually deteriorated [9]. They were periodically destroyed, levelled, and rebuilt on the same spot. This planned

structural life cycle gradually raised the level of cities, so that they came to be elevated above the surrounding plain [8]. The resulting mounds are known as tells and are found throughout the ancient Near East [5]. Civic buildings slowed decay by using cones of coloured stone, terracotta panels, and clay nails driven into the adobe-brick to create a protective sheath that decorated the façade. Specially prized were imported building materials such as cedar from Lebanon, diorite from Arabia, lapis lazuli from India [5] [7].

Figure 8. Cloisonné furniture plaque with two griffins in a floral landscape, Phoenician style (Source: Rogers Fund).

Figure 9. Openwork furniture plaque with a grazing Oryx in a forest of fronds (Source: Rogers Fund).

Babylonian temples are massive structures of crude brick, supported by buttresses, the rain being carried off by drains. One such drain at Ur was made of lead. The use of brick led to the early development of the pilaster and column, and of frescos and enamelled tiles [1] [10]. The walls were brilliantly coloured, and sometimes plated with zinc or gold, as well as with tiles. Painted terracotta cones for torches were also embedded in the plaster. Assyria, imitating Babylonian architecture, also built its palaces and temples of brick, even when stone was the natural building material of the country, faithfully preserving the brick platform, necessary in the marshy soil of Babylonia, but little needed in the north [11] [12].

The Mesopotamian nature produced the fired brick colour forming the urban façade theme which depends on shaded features and certain ceramic elements, continued to exist even in

modernity, with the addition of bare face concrete walls. However, after 2003, Iraqi cities mainly Baghdad urban scene witnessed the rise of all shiny colours, in a chaotic way [3].

Nineveh was taken by Medes in 612 BC, after the collapse of the Assyrian empire [13]. Medes took over the region that currently Kurds control, and he is believed to be the ancestor of the Kurds [14]. The Persian invasion of Mesopotamia started when Babylon, as the last major power western Asia, fell under the Persian control in 539 BC, after the battle of Opis. After that, the region of Mesopotamia started to be a part of Persian empires of Medes, Achaemenid, Seleucid, Parthian, and Sassanid sequentially [14].

Persian invasion of Mesopotamia resulted in a strong exchange in art and architecture between both civilizations [4] [5]. The Persian architecture adopted elements from Greek architecture. Iwan was inserted as a new element in the region [13]. Iwan is a hall supported by arches and is opened on one side. The arch surrounding the opened side of Iwan is usually decorated (Figure 10). The barrel vault replaced the use of columns to support the roof [11]. Hatra is the best informative example of a Parthian city. Its plan was circular and was encircled by inner and outer walls nearly 2 kilometres in diameter and supported by more than 160 towers [15].

Figure 10. Decorated Iwan arch with faces in Hatra (Source: UNESCO).

Sassanid was the last Persian Empire in the area known now as Iraq [14], which was the richest Sassanid province [14]. Meanwhile, in the southern Arabic peninsula, in Mecca and Medina, the Muslim community was getting bigger and expanding to the regions around. Abu Bakr, the first caliphate after the death of prophet Muhammed, decided to conquer and establish Islam in the Mesopotamian region in 633 A.D. [16] [17]. When Ali became the fourth caliphate, he moved his capital to Kufa [16]. Later, Baghdad was built along the Tigris River by the Abbasid caliphate, as his new capital in the 8th century [18]. Since then, Baghdad became the leading metropolis of Arab and Muslim world for five centuries [19]. The Islamic architecture in Mesopotamia was influenced by the previous empires of Sumer and Persia especially but it had its own distinguished features such as Mosques, tombs, palaces, and forts [17]. Domes, Muqarnas, Islamic geometric patterns, Minarets and arabesque were the main architectural

characteristics of Islamic architecture [18]. Because of its role in recording the word of God, calligraphy is considered one of the most important Islamic arts. Nearly all Islamic buildings have some types of surface inscriptions in the stone, stucco, marble, mosaic and/or painting. The inscription might be a verse from the Qur'an, lines of poetry, or names and dates [20].

Like other Islamic decorations, calligraphy is closely linked to geometry. The proportions of the letters are all governed by mathematics. Inscriptions are most often used as a frame along and around main elements of a building like portals and cornices [18]. Islamic and Persian artists developed geometric patterns to a degree of complexity and sophistication previously unknown. These patterns (Figure 11) exemplify the Islamic and Persian interest in repetition, symmetry and continuous generation of patterns [20].

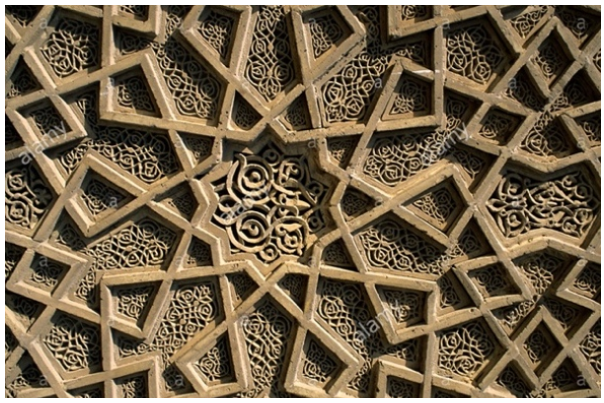

Figure 11. Detail view of a spandrel over an archway decorated with a star and polygon pattern carved in terracotta [18].

They built mosques on a monumental scale using brick construction, stucco ornament and architectural forms developed in Mesopotamia and other regions to the east [21]. The earliest mosque was built by Al Mansur in Baghdad. The great mosque of Samarra built by Al Mutawakkil was 256 by 139 metres in plan. A flat wooden roof was supported by columns [17]. The mosque was decorated with marble panels and glass mosaics (Figure 12) [16]. The prayer hall of the Abu Dulaf Mosque at Samarra had arcades on rectangular brick piers running at right angles to the qibla wall [19]. Both Samarra mosques have spiral minarets, the only examples in Iraq [18] [19].

The Mongols destroyed the Abbasid caliphate in 1257 [21]. They destroyed the House of Wisdom in Baghdad that contained precious historical documents [22]. The city has never regained its previous pre-eminence as a major centre of culture and influence [7]. Some historians believe that the Mongol invasion destroyed much of the irrigation infrastructure that had sustained Mesopotamia for millennia [3]. Timur also conducted massacres of the indigenous Assyrian Christian population, hitherto still the majority population in northern Mesopotamia, and it was during this time that the ancient Assyrian city of Assur was finally abandoned [23]. Mesopotamia was contested between the Ottoman and Persian empires, leading to frequent wars

for a hundred years. Throughout the period (1533-1918), Mesopotamia fell under the rule of the Ottomans [21]. It was made up of three provinces, called vilayets in the Ottoman language: Mosul Vilayet, Baghdad Vilayet and Basrah Vilayet. The Ottoman architecture in Mesopotamia was influenced by Persian, Byzantine Greek and Islamic architecture [23].

Figure 12. Decorative stucco panel from Abbasid Samarra, 9th century. This form of decoration usually features geometric and vegetal patterns (Source: Miguel Hermoso Cuesta).

1.2. Modern Architecture

After World War I, British forces invaded the Mesopotamian area and defeated the Ottomans [21]. The British joined the three vilayets into one kingdom, administrated under British control with the name State of Iraq [24]. When modern Iraq established in the 20's of last century, there was an important position within the governance system called "Government Architect". The Colonial British Architecture (CBA) concentrated in main cities in Iraq such as Baghdad, the capital, and Basra, the main port on the Gulf [10]. Their main job was to supervise building and construction in the city, all buildings whether they were public or private, and sometimes they were asked to design and supervise the construction of important buildings [25]. Later on, the Public Work Department (PWD) was established that had the same job [24].

Among the staff of this department were some of important British Architects, such as James Mollison Wilson (1887-1965), who was the Deputy Director of Civil Works in Baghdad in 1918, H.S. Maison and J.B. Cooper (1899- 1983), and many young British architects. All of them were a starting point of Modern Architecture in Iraq, as they designed and built many important buildings, some of them still standing but almost all demolished for many different reasons, like the Royal Palace for King Faisal I, [26].

The British architects began to transfer their expertise from working in British Colonies to Iraq. The first change was in urban fabric for Baghdad city, like straight and open roads, demolishing

unsuitable buildings, and reusing other buildings, new road networks, and straightening and widening the exit roads [27].

Also, some changes were required to accommodate the new needs of cities, therefore establishing new urban extension, in the eastern and western sides of Baghdad. Also, they began to build new residential districts, to be more suitable for soldiers, far from traditional residential areas.

In this period, the first generation of Iraqi Architects arose, which worked with British architects holding positions in PWD, such as Ahmed Mukhtar Ebraheem. So, this period was the base stone for new architecture movements in Iraq, from classics to new classics, from colonial architecture to modernism's style, with Ahmed Mukhtar Ebraheem and other pathfinder architects, as seen in various buildings erected after 1940's in Baghdad [26].

By the 1950s, the urban picture of Baghdad was turned upside down. New streets that cut through the traditional fabric increased and the suburbs expanded, prompting efforts to come up with basic urban planning for the city or parts of it [27]. However, the influence of modernism thinking on the society has been the greatest [28].

Dealing with the hot dry weather in Iraq, modern architects used different treatments to reduce sun exposure and reduce heat gain, like screens mainly used by Iraqi architects with local craft ornamentations applied on brick and hollow block screen walls in front of wide windows of modern style. This appeared in the campus of Mustansiryia designed by Qahtan Awni, and in perforated curtain walls in the Ministry of Industry and Minerals by Fadhil Ajina [26].

The goal of Iraqi architects at that time was not to convey the values of modernity prevailing in a particular country, nor copy a common architectural composition and planting it in different regions of climate and topographical nature, different in historical values and national characteristics. On the contrary, the local architectural heritage was used to extrapolate positive elements and revive them using technological progress. Some architects have used this technique intelligently through a look at the international style to blend it with the elements of modernity to create a style of architecture Iraq-specific. The result was a modern architecture, but it was influenced and adapted to local architecture [25].

Iraqi modernists worked on the heritage elements like historical Islamic arches and the traditional ones in many ways to fit them into regionalized modern architecture. Each architect had his own way of applying these elements on the buildings they designed [22]. Mohamad

Makyia, Rifaat Chaderchi and Nasir Al Asadi were the main architects to work with modern arches [28].

1.3. The last three decades

During the late 80s and 90s, Iraqi architects turned into stone facing, due to the end of the production of bricks and the economic sanctions on Iraq. So, stone facing (which is not strange to the Iraqi cities as it is the main building material in northern Iraq) was added to the urban scene in the cities in middle and southern Iraq, such as Baghdad [30]. Some of the façade treatments were European classic inspired while others were modern plane with little ceramic additions [24].

In August 1990, within days of the Iraq's invasion of Kuwait, the United Nations imposed the first in a series of sanctions on the country [22]. Crude oil exports, which provided over 90% of Iraqi exports, were banned. The Iraqi government immediately instituted a system of food rationing, which remains in place to this day [26].

In the aftermath of its Gulf War defeat, Iraq was politically divided between the Centre/South, which remains under the control of the government in Baghdad, and the three Northern provinces, which are under the control of the Kurdistan Regional Government (KRG). The North is in turn divided between two rival Kurdish political parties, each with its own army: the Kurdistan Democratic Party (KDP) and the Patriotic Union of Kurdistan (PUK).

International humanitarian agencies entered Iraq in the wake of the Gulf War. In the North, accessible via Turkey until 1994, NGOs began programs without securing the approval of the government in Baghdad, although under US military pressure, the Iraqi government did supply visas to NGO staff afterwards. A few NGOs began programs in the south, mostly in and around the port city of Basra, but the government has never encouraged the expansion of the number of NGOs in the areas under its control. The UN agencies at first hesitated, waiting to enter the country until they had negotiated an agreement with the Iraqi government [31]. Once they had done so, they began operations countrywide.

For five years, the government of Iraq was allowed to import humanitarian supplies under the sanctions. However, due to the ban on oil exports, it claimed to have few funds to pay for them. In 1995, Baghdad finally agreed to a 1991 UN proposal to allow the proceeds from the export of oil to flow through a UN bank account in order to purchase humanitarian supplies. The 986 programs (named after the Security Council resolution creating it), commonly known as the Oil-for-Food Program, was born [31].

The Iraq War was a protracted armed conflict that began in 2003 with the invasion of Iraq by a United States-led coalition that overthrew the government of Saddam Hussein [29]. The conflict continued for much of the next decade as an insurgency emerged to oppose the occupying forces and the post-invasion Iraqi government. An estimated 151,000 to 1,033,000 Iraqis were killed in the first three to four years of conflict. US troops officially withdrew in 2011 [29]. The invasion and occupation led to sectarian violence, which caused widespread displacement among Iraqi civilians. The Iraqi Red Crescent organization estimated the total internal displacement was around 2.3 million in 2008, with as many as 2 million Iraqis having left the country [32].

In January 2003, a delegation of scholars, museum directors, art collectors and antiquities dealers met with officials at the Pentagon to discuss the implications of the invasion [33] [34]. They warned that the National Museum in Baghdad was the most important non-religious cultural property site in the country. One member of the delegation, McGuire Gibson of the University of Chicago, twice returned to the Pentagon to discuss precautions the Coalition should take [31].

As the conflict neared, the Archaeological Institute of America, the International Council of Museums, the International Committee of the Blue Shield and other professional organizations issued public warnings, reminding U.S. leaders of their responsibilities under international law, notably the 1954 Hague Convention for the Protection of Cultural Properties in the Event of Armed Conflict. They urged that protection of Iraq's cultural sites and institutions be a high priority for the occupying forces [35].

Significant steps were taken by academics and military planners to identify and locate sites in order to avoid targeting or causing needless collateral damage to archaeological or cultural sites during pre-invasion target planning. Given the extent of the air campaign, little substantial damage occurred to cultural property by U.S. forces during the first phase of the air campaign (March to April 2003) and during the high-speed ground campaign that culminated in the fall of the Saddam regime on April 9, 2003 [34]. The most significant losses began on April 10th.

The cultural sites were not protected from early April 2003. No protective actions at major cultural sites in the cities and archaeological sites in the countryside were taking place, neither preventing actions against looting and destruction were taking place [31].

Attacks on the heritage sites began soon after the old regime collapsed, as part of widespread looting and destruction of government buildings and other targets [32]. Archaeologists and

experts had warned that looting would begin as soon as public order broke down, just as it did in the aftermath of Operation Desert Storm, when several regional museums were looted.

While the cultural damage (looting and intentional destruction by civilians) may be greater in scope, damage to important cultural sites is no less significant. Significant collateral damage occurred as a direct result of insurgents' use of cultural property. Examples include the central area of the holy city of Najaf, destroyed in a confrontation of coalition forces with Mahdi Army irregulars in August 2004 and ground attacks that reduced cultural properties in Tal Afar, Ramadi, Samarra and a number of other cities to rubble [35].

Like the rest of Iraq, Mosul city and its surrounding areas have witnessed a growing wave of extremism and sectarian and ethnic violence following the collapse of the former regime in 2003. The escalation of fighting, particularly between 2006 and 2008, has sparked a mass exodus of thousands of people from their hometowns towards safer areas and destinations. Mosul city itself has acted as both a receiving city of internally displaced persons (IDPs) and as a rejecting one. Enormous numbers of Muslim Sunnis, of both Turkoman and Arab origin, fled their towns and villages south and west of Mosul and sought safety inside the city, among a predominantly Arab Muslim Sunni population. Conversely, a great number of Mosul's ethnic and religious minorities (Christians, Kurds, Shabak, Turkoman Shiaa and Yazidis) fled to other areas, in some cases under direct threat of violence.

Elsewhere, serious damage occurred to important archaeological sites, such as ancient Babylon and Ur, two of the most important ancient sites in the world. In September 2003, U.S. forces handed authority over Babylon (known as Camp Alpha) to Polish troops who camped there until January 2005, when authority for the site reverted to the Iraq State Board of Antiquities and Heritage [31].

Beginning in 2003, diverse and significant actors, both domestic and international, engaged in reconstruction activities in Iraq, and the total budget committed to Iraq's reconstruction was unprecedented among post conflict operations undertaken by the international community [29]. At the Madrid Donor Conference in October 2003, the international community, represented by 38 countries, the European Commission, the International Monetary Fund, and the World Bank, announced overall and indicative pledges amounting to more than US$33 billion in grants and loans [30]. Reconstruction brought some improvements to Iraqi livelihoods, but despite the billions of dollars spent, overall reconstruction actions were gradual and limited.

In June 2014, big cities in Iraq gradually started falling under the control of the terrorist group called the Islamic State of Iraq and the Levant (ISIL), also known as the Islamic State of Iraq

and Syria (ISIS), taking advantage of the instability in Iraq and Syria. In Iraq, seven provinces have been directly affected by the terroristic attack, namely: Baghdad, Nineveh, Anbar, Kirkuk, Diyala, Salah Al Din and Babel. The Islamic State has deliberately targeted heritage sites and developed a continuous practice of destruction of the archaeological sites, museums, local shrines alongside its continued attacks on holy places. The Iraqi army launched a battle to retake the invaded cities that started in October 2016 and ended in July 2017. Both the ISIS's devastation and the air strikes by the Iraqi army resulted in further destruction of the built environment, mainly the housing sector but also including cultural heritage sites and monuments, religious buildings, hospitals, educational buildings, and infrastructure. The Iraqi forces supported by a United States-led coalition force, retook Tikrit (Saladin province) in March 2015, Biji (Salah Al Din province) in October 2015, Sinjar (Nineveh province) in November 2015, Ramadi (Anbar province) in December 2015, and Fallujah (Anbar province) in June 2016. Mosul (Nineveh province) was the Islamic State's last major stronghold in Iraq. Finally, in July 2017, the Iraqi Prime Minister Haider al Abadi declared victory over ISIS in Mosul [36].

The recent regional ISIL-created conflict in Iraq has resulted in a humanitarian crisis with the internal displacement of over 5 million Iraqis and the destruction of infrastructure and services in the former ISIS-occupied areas [32]. The United Nations Office for the Coordination of Humanitarian (UNOCHA) Affairs estimates that about 6.2 million people are in need of targeted humanitarian assistance, including food, shelter, clean water, sanitation services, and education support. The Northern provinces are hosting a large share of Syrian refugees and Iraqi Internally Displaced Persons (IDPs) [31]. The scale and speed of the displacement because of the crisis make it a challenge for the government to deliver quality services, especially in the newly liberated areas, where the infrastructure destruction has been most severe and service delivery has been adversely impacted [37].

Mosul holds the largest share of total housing damage in the seven provinces [37]. Because of these destructions, many distinctive architectural features have been lost (Figure 13). For example, all Ottoman pencil-shaped minarets (well-known example: Al Qalamya) which appeared at the end of 18^{th} century in the shrines of the Prophets Johan, Gorges and Shith. The conical cupolas that were famous during the Zengid age have been destroyed, except for the last small one at Hassan al Bakri Mosque, in addition to countless wonderful Mihrabs and Minbars [38].

Nineveh is the second province in Iraq in terms of population, after Baghdad. Located on the banks of the Tigris River, Mosul is the main city of Nineveh province and shares the largest percentage of the total housing damage and heritage destruction among the seven provinces that

were invaded by the Islamic State. Today, over one million persons displaced from Mosul, which made Mosul the centre of humanitarian operations [39]. The environmental impacts in Mosul are considered as the highest matter because of the high level of destruction [39].

Figure 13. Amidst the rubble, a damaged stone tablet with cuneiform writing [38].

Three years have passed since the end of the war, and while much of East Mosul has returned to normal, West Mosul still lays in ruins with shell-shocked buildings and streets covered by piles of rubble. The Old City is still in ruins with no running water or electricity. Reeking corpses still remain in the ruins and the few shell-shocked homes that are still standing are yet to be cleared of unexploded bombs.

ISIL conducted a large destruction campaign at Mosul's cultural heritage sites and monuments trying deliberately to wipe out the city's history. ISIL destroyed the ancient city of Nineveh, the Palace of Sennacherib and all its monuments and the famous gates of the city and the entire 12 km long wall surrounding the city [36].

The Islamic State (ISIL) has released a propaganda video purportedly showing its militants taking sledgehammers to the Iraq's UNESCO World Heritage city of Hatra [40]. The clip is the last in a series published by the jihadist group to advertise its iconoclastic fight against shrines, statues and artefacts of ancient civilisations, which it designates as "false idols" to be destroyed according to a strict interpretation of Islamic Law. The slick seven-minute footage titled "smashing idols" begins with aerial footage of what appears to be the 2,000-year-old archaeological site in Iraq's Nineveh province, some 290 km north-west of Baghdad (Figure 14).

Figure 14. ISIL militants have destroyed remains of the 2,000-year-old city of Hatra, a well-preserved complex of temples south of Mosul (Source: Associated press).

Furthermore, the damage to Mosul's cultural heritage during military efforts to oust ISIL from Mosul and the surrounding areas is severe. Parts of the Old City have been completely destroyed in the final phase of liberation. Several months of armed conflict in the struggle to retake the city has left behind a devastated urban landscape, characterised by destroyed monuments, demolished houses, damaged buildings, destroyed infrastructure, extensive piles of rubble and areas contaminated by human bodies and unexploded bombs [40].

Conclusions

The study of the historical context of the region of Iraq allowed identifying some of the contribution of each historical period to the local architecture from the ancient times. This chapter showed the influence of Sumer and Babylon, south Mesopotamia, on Assyria, northern Mesopotamia, the ancient civilisation that frames the origins of Mosul.

The present study allowed understanding the origins of the courtyard in the traditional house during the Mesopotamian empires and the addition of Iwan to the courtyard later during the Persian Empire. The focus on the detailed additions to the decorations was important in this chapter as the definition and description of the architectural design elements is the focus of the next chapter. Understanding the different types of ornaments in this chapter is crucial for the characterization of rubble and the storage reuse of these elements when they are found in the rubble according to their historical significance. The ivories from Nimrud are used mainly as furniture decorations. The study shows that although cuneiform inscriptions are found on the walls of the buildings in Babylon, they can be found in Upper Mesopotamia as well.

The Islamic influence was significant in the additions and the changes to the decorative elements as well as the architecture of the region. Calligraphy inscriptions in the marble began to appear on the surfaces of the courtyards reflecting religious writings and poetry.

The present study allows to identify the houses with historical values and the houses that have no historical value in the future parts of the research. By contextualizing the production context,

it allows a better understanding of the architectural characteristics and the design elements of the existing traditional houses in Mosul in the next chapter.

The political context provided in this study reveals that the last conflict against the Islamic state in Iraq and the Levant came after a series of conflicts and that the region already was in need for the reconstruction. The invasion of ISIL only worsened the situation and enhanced the need for reconstruction.

2. THE OLD CITY OF MOSUL

Nineveh, the capital of Assyria, gained its importance since the ancient times besides its influence by the neighbouring empires in Iraq. Mosul, the centre of Nineveh, witnessed important historical periods that affected its development and resulted in the emergence of the traditional architecture existing in its Old City. The first chapter of this part of the research provided essential historical background of the origins of some important architectural elements in Nineveh affected by the historical context of Iraq. This chapter addresses a closer definition to the traditional architecture in Mosul. The Old City is extensively studied in this chapter, as it was the only area of Mosul until the middle of the twentieth century when Mosul started expanding outside the Old City walls. Thus, this area is distinguished for its traditional houses. The Old City is, also as mentioned in the introduction, the area that shares the most housing destruction in Mosul.

The main goal of studying the local architecture is to: (1) define the main design characteristics and materials used in order to better understand and characterise the rubble generated from the last war against ISIL; (2) to contribute to the final goal of creating an integrated design harmonious with the local architecture of the Old City in Mosul and consider locally resourced materials.

A close historical background of the city is provided first. The Old City in Mosul features and layout are analysed as well as the characteristics of its traditional houses. The architectural elements of the traditional house that are analysed include: courtyard, Iwan, openings, roof, building layouts, Shanasheel, Malqaf and building materials. The techniques, decorations and ornaments are also defined. The main goal of this part is to define the main design techniques that can benefit the post-war design and to help the characterization of rubble generated from the last conflict.

Four different houses from different districts in the Old City were selected to strengthen the qualitative analysis by identifying common features in different contexts, allowing comparison and validation of the characteristics. All four selected houses have currently been turned to rubble after ISIL's war. Considering that the rubble in the Old City contains materials from heritage public buildings and traditional houses, one heritage building in Mosul is selected (Al Nuri Mosque).

2.1. Brief History of Architecture in Mosul

Mosul was a part of Assyria from the 25th century BC [7]. Historically, the city emerged around 7th to 6th century BC after the destruction of the ancient Assyrian capital called Nineveh [1]. The Greek historian Xenophon, who visited the region some 200 years later: "a settlement called Mepsila existed on the West side" [41]. Mosul's name is believed to have come after the name of this settlement, or it was given by the Arabic tribes who conquered it [39]. Mosul or Al Mawsil in Arabic means the linking point [131].

According to [9], Christian sources from Syria mentioned the existence of a monastery on the west side of the river around 570 AD. At the time of the Arab control, the monastery had already been expanded to a settlement with some Christian houses surrounding churches and a Jewish neighbourhood [21].

The city of Mosul gained its importance during the hundred-year Arab rule of the Rashidun Caliphate. The streets of Mosul were paved, and defensive walls were built around the city [17]. Around 50,000 inhabited Mosul under the rule of Marwan II, the last Umayyad caliph who was known as the builder of Mosul, during the short period of his rule (744-470 AD) [11]. The ship bridge was built which was the only bridge built linking both Western and Eastern Mosul over Tigris River up to the 20th century; the covered bazar known as Al Qaysaria; and Umayyad Mosque which influenced main mihrab of Al Nuri Mosque [41].

From the 9th to the 11th century, the region witnessed a period of internal conflict and political confusion [17]. In this period, while Mosul was ruled by the Hamdanid and Uqaylid dynasties until 1057 AD, it was flourishing in trading, sciences and arts [11].

2.1.1. The period from the 12th century to the 16th century

After the Seljuk occupation, the Al Jazira region (now part of Syria and Iraq) was ruled by the dynasty's governors. One of them (the Zengid) rose to power in 1127 and established an independent rule [18]. Imad Al Din Zengi from Mosul came to power and became the Atabeg (governor) of Mosul and another city in Syria. The Atabeg dynasty continued to rule Mosul for 130 years from that year. This period is regarded as Mosul's golden years [12]. The Atabeg rulers were supportive of arts and sciences. Several mosques, shrines, and educational buildings were built in Mosul [19]. Some of these buildings were standing until the 20th century, later, they were destroyed by the recent conflicts [19].

When Imad Al Din Zengi started his rule, Mosul was in ruins [42]. Imad Al Din built several palaces and the city was dominated by beautiful buildings [43]. He added another layer to the walls surrounding the city and built towers to reinforce the walls. Later, his son Nur Al Din carried on with the work and in 1170 he called for building a new Grand Mosque of Mosul (Al Nuri Mosque), and a madrassa (a school) and a minaret (Al Hadba Minaret) [42].

The rule of Badr Al Din Lu'lu (1219-1259) is considered as the climax of the Atabeg rule in Mosul. His period of ruling was the beginning of the so-called "school of architecture in Mosul" [44]. The period witnessed the start of using delicate ornaments of arabesques made from local gypsum, muqarnas domes and the carved alabaster (local marble from Mosul). He ordered for the building of 14 shrines, rehabilitated Qara Sarai palace that was built first by Imad Al Din, several churches and monasteries [45].

By the 13th century, Mosul had 3 mosques' complexes, 36 markets, 28 schools and 18 schools for teaching Quran, 8 churches and more than 200 hammams (public baths) [46].

According to [47], this period that was known as the golden age came to an end in the 13th century when Mosul was controlled by Mongols and later by the Ilkhanate and Jalairid Sultanates. The Mongols control decimated the people of Mosul. The urban growth of the city was restrained. The unstable politics for three centuries affected the economy and then the building markets. The north of the city was abandoned and only the area around Al Nuri Mosque remained inhabited.

2.1.2. From the 16th century to the 19th century

While Mosul was controlled by the Ottomans from 1517, it was a military based city, which led to the end of investment. This situation lasted for more than a hundred years until the city could revive again. Later, Mosul was "integrated into the Ottoman Empire gradually and revived its place among the cities of the Fertile Crescent" [48].

Mosul was known as the most independent city of the Ottoman Empire, during their rule, around four centuries [48]. The local governors of Mosul were assigned with duties from the empire. The governors' families were considered as the upper class; thus, they built distinguished houses and affected the houses of the people surrounding them. Among these rulers was Al Jalili [49]. During his time, the walls surrounding the city were renovated and the rich people in the city built new houses, markets mosques, and schools [16]. The urban expansion occurred again; Mosul expanded to the south beyond the defensive walls. According to [49], by 1820 there were around 25 Friday mosques in Mosul, most of them were built during the rule of the Jalilis. The Ottoman Empire

centralized the government's rule in Mosul by the end of the 19th century. The Sultan ended the rule of Jalilis in 1834 and appointed new foreign governors.

2.1.3. The 20th century

After World War I, the failure of the Ottoman Empire led Mosul to become a part of the British authorization from 1918 to 1926, along with Baghdad and Basrah [25]. The British encouraged the implementation of many infrastructure plans in Iraq, they built roads and bridges [27]. Eventually, the British stopped their growth because of the lack of financial gain. It was at this period when Nineveh Street, the main east west road in Mosul, was built through the historic market area in the city and multi-story shops were built around (Figure 16). The development of Nineveh Street (Figure 17), in 1916, was followed by the creation of a new bridge (Figure 15), also connected to the Old City.

Figure 15. Mosul's old and new bridges, 1933- 1934 [24].

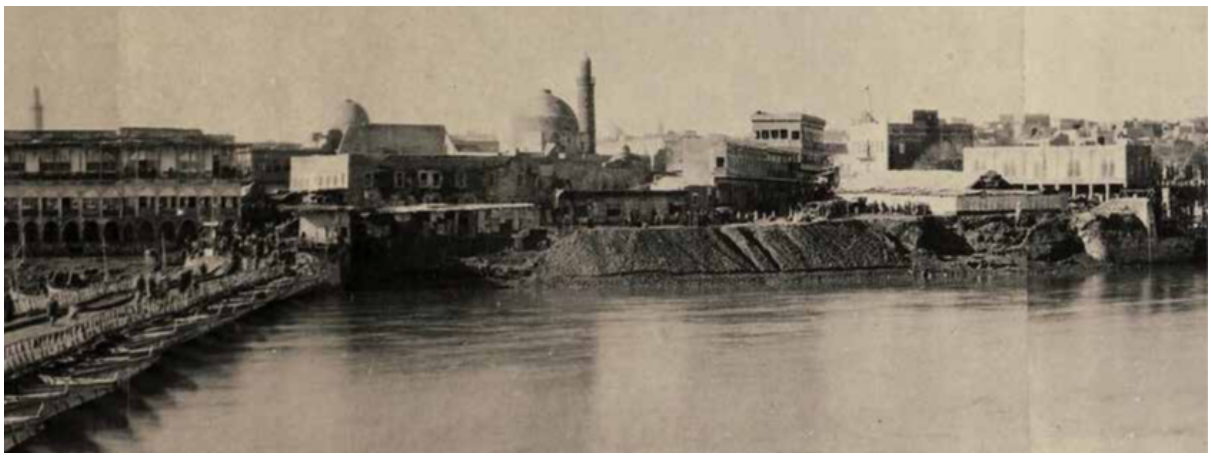

Figure 16. View of the Old City from the left bank of Tigris River, 1933 [24].

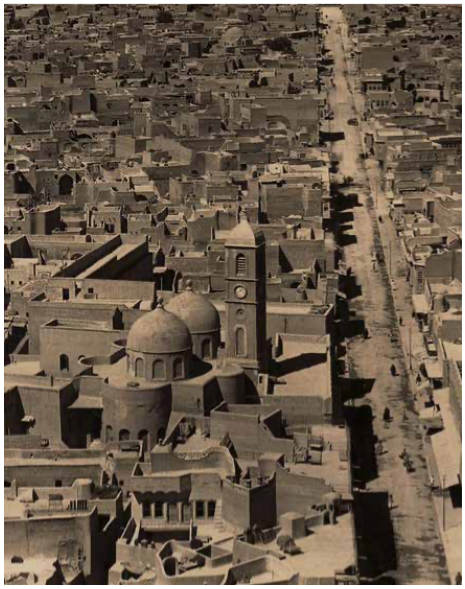

Figure 17. Nineveh street in Mosul, 1933 [46].

Iraq as a country was established in 1926 and Mosul was a part of it. Mosul was appointed the capital of Nineveh province since then [28]. It was a royal rule in Iraq until 1958. During that time, Mosul grow beyond the fortification walls until they were brought down in 1933. The Old City witnessed the creation of new urban housing areas in the northern side and beyond it, as well as the the southern part of it.

During the 1970s, when the Republic of Iraq was established, Mosul grew, and the eastern bank of Tigris River started to be built [31]. The 5th bridge in Mosul, which connects Eastern Mosul and the new urban developments in Western Mosul, takes the way through north of the Old City "severing the Old City from its citadel Bash Tabyia and other 12 and 13-century important Atabeg buildings, such as Saykh Fathi mosque, madrassa Al Nuriyya and mashad (shrine) Al Imam Yahya ibn Al Qasim" [41].

In the last decades, the Old City developed a few modern buildings with new construction materials such as concrete. Many historical houses, in the other hand, were ignored or damaged to rebuild new ones or because of the cost of rehabilitating them. Nevertheless, the greatest destruction of the historical houses was during the invasion of ISIL which purposefully destroyed some of the Old City's main featuring buildings. Besides the damage occurred during the airstrikes attacking ISIL from 2016 until 2017.

The current city of Mosul, including Western and Eastern Mosul, is considered one of Iraq's main cities. After Baghdad, it is the second largest city. According to a report provided by UN-Habitat in 2017, the city has 251 neighbourhoods (mahala) in total, 91 neighbourhoods of them are in Western Mosul (in the Old City and the other quarters in the west) and 160 neighbourhoods in Eastern Mosul (Figure 18).

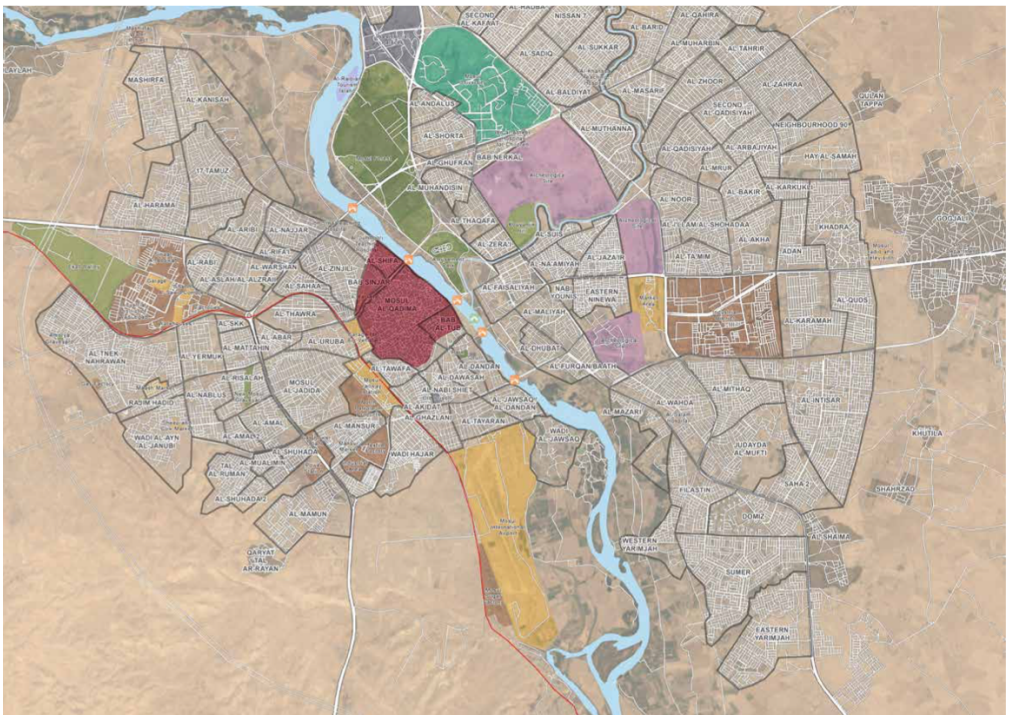

Figure 18. Mosul map in 2017. The Old City is highlighted in red colour (Source: REACH Initiative).

2.2. Main features of the Old City

Traditionally, historic Islamic cities are surrounded by defensive walls and have a citadel (Qal'at). The citadel is located on a higher level, usually on a hill. The centre of the city is occupied by the mosque. The traditional market (Bazar) is surrounding the mosque and taking place on the main axes of the city that lead to the main city gates. The palaces (Sarai) are situated near the city walls. The residential neighbourhoods and the secondary streets take place in the remaining spaces. The layout of the Old City of Mosul was mostly kept for the duration from the 8th to the 19th century (Figure 19) [43].

Thirty years after the blockade of Nadir Shah in 1743, Mosul walls in the north were still standing, but the parts on the riverfront and in the south were fallen. The walls and the citadel collapsed in the start of the 20th century. Although, both were restored during the Ottoman Empire rule [39].

The court space in the mosque in the Islamic city is considered as the largest open space as it was designed to be serving a few neighbourhoods. Since 1170 AD, when Al Nuri Mosque was constructed, the mosque was the main mosque in Mosul. Mosul had only Al Nuri Mosque until the Atabeg time.

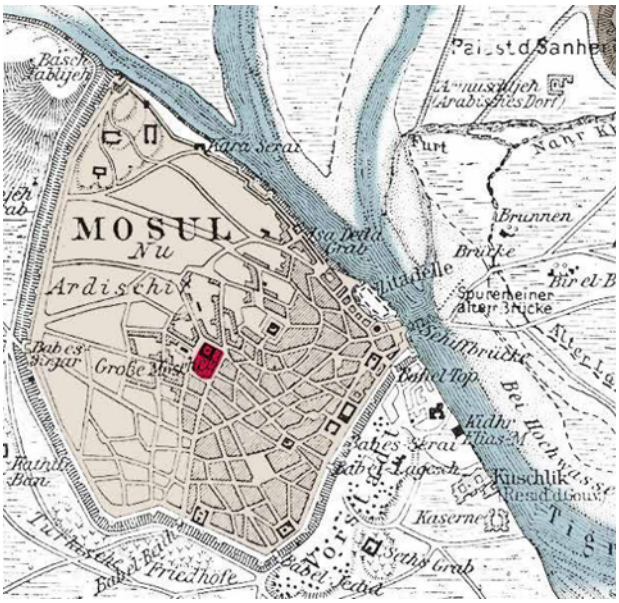

Figure 19. Map of Mosul's Old City with defensive walls (Source: UNESCO).

The construction of the main public buildings in the historical Islamic cities was carefully selected by the ruler of the city [50]. Al Nuri Mosque was established with a significant value as the city's great mosque. The choice of its geographical location in the centre of the Old City was intentional by Nur Al Din Zengi. It has shaped a core site in the urban development of the Old City of Mosul. The historical expansion of the city over the time shows how effectively the complex of this mosque has influenced the layout of the city. Before the 20th century's interventions, the street layout of the Old City was characterized by a network of streets going through the gates towards Al Nuri Mosque [49].

Tigris River also have had its importance in influencing the growth of the city. A strong street network was heading from the residential quarters towards the river. Along both street networks, most of the religious buildings were established. These public buildings were presented as urban symbols and orientation points. Before their destruction in the last conflict against ISIL, the minaret of Al Nuri Mosque and the bell tower of the Al Saa'a Church (Our Lady of the Hour) were the guiding points for the city visitors and dominating monuments in the skyline of Mosul. The Minaret of Al Nuri Mosque was not just a symbolic landmark for Mosul but rather for Iraq. Its tilt was a defining feature of Mosul (Figures 20 and 21).

Figure 20. Al Hadba Minaret seen from the alleyway [42].

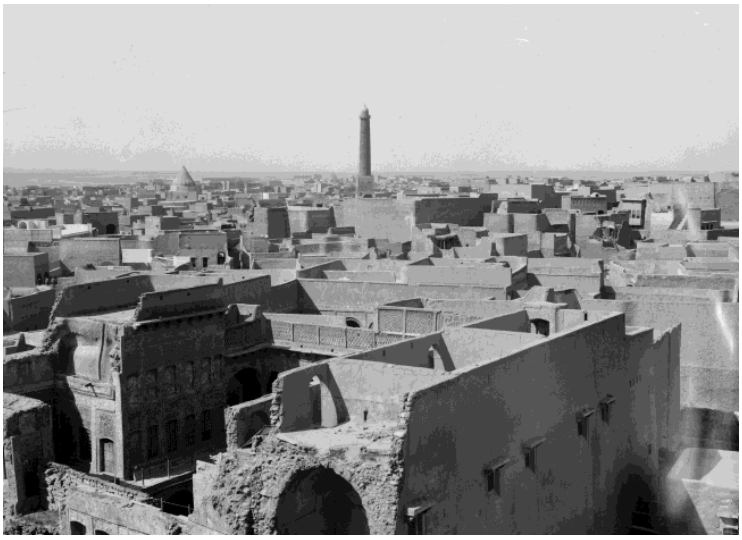

Figure 21. Al Hadba Minaret and the Old City (Source: Mosul Municipality).

In 2014, ISIL fighters rushed to rise their flag on the Mosque's Minaret, and its leader announced the "new caliphate" from its prayer hall. When the group tried to destroy the Minaret for the first time, a human chain made by the local people stopped the destruction. The final blow happened in 2017 during ISIL's withdrawal, when the group rushed to blow up a series of explosives inside the minaret and the prayer hall.

Later, when the city expanded considerably, one mosque was not enough to serve the growing population. Thus, the Old City had two other mosques' complexes including: the old Umayyad Mosque in the east and Al Khidr Mosque in the south.

The Bazar (market) is another important feature in the Islamic city. The commercial area usually surrounds the main mosque in the city. In the case of Mosul, Bazar is covered and is located around

Al Nuri Mosque. It is called Al Qaysaria and it has more around 300 shops [51] [52]. The mosque and the Bazar are linked by their establishments and locations. During the expansion of Mosul outside the defensive walls in the Ottoman rule, Bazar in the centre of the city lost its importance and expanded to the main streets in the new neighbourhoods.

Sarai (the palace for the governor) is located outside the Middle Eastern and North African Islamic cities [53]. Sarai and Al maidan (the public square) were the main administrative areas of the city. Mosul, unlike the rest of the Middle Eastern cities, had its Sarai situated inside the city. However, by the end of the 19th century the Sarai moved outside the city to the south. Later, Suq Al Sarai (commercial area) appeared around Al Sarai. It became the main Bazar in Mosul.

The Old City in Mosul enjoys a diverse architecture, the city's mosques, shrines and churches are representative of its public architecture, reflecting the artistic styles of the periods from which they occurred (Figures 22 and 23). Mosul's riverfront panorama, which was completed along the Tigris in the 20th century, represents an example of its architectural style. The riverfront panorama is formed by the ruins of the citadel of Bash Tabiya; the ruins of Sarai palace; the building of Shaykh Al Shatt; Al Aghawat Mosque; the Atabeg Al Khidr Mosque and other featuring buildings.

The diversity of the local people of Mosul, their diverse religions and traditions, is seen throughout the Old City by leaving their individual marks and creating Mosul's local architecture. Atabeg mosques in Mosul are believed to be inspired by the architecture of earlier churches, which are also inspired by earlier examples of the Assyrian empire's architecture [54]. Other cities of religion in Iraq have been inspired by Mosul's architecture. Such as Erbil Citadel, where its Iwan design, carved marble decorations and the basements design are employed in its larger houses.

The residential architecture is known, in many cases, to be inspired by the city's religious buildings, but in a more simplified manner [55]. As an evident of this inspiration is the case of Iwan, the vaulted room, opened on one side and closed in the three other sides [56].

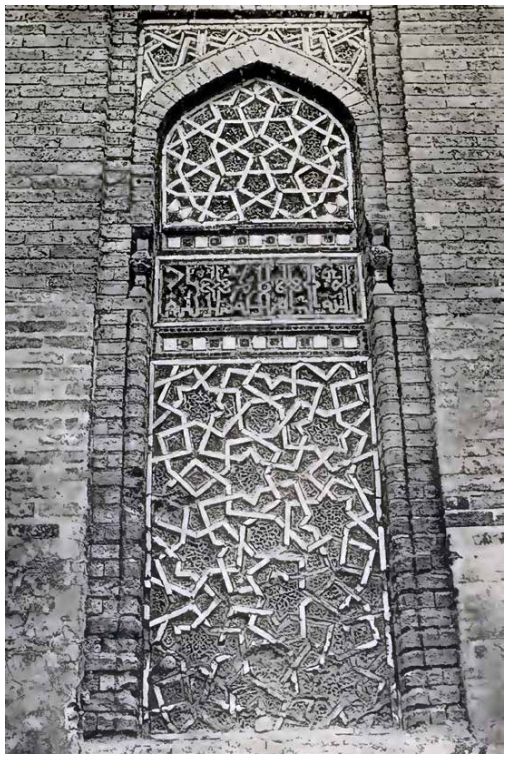

Figure 22. Window detail of Mashad of Imam Yahya Ibn Al Qasim, 1920 (Source: UNESCO).

Figure 23. Entrance doors in Mashad of Imam Awn Al Din in Mosul (Source: UNESCO).

2.3. Traditional Houses

The zigzagged streets and the courtyard houses are representative of the Old City's current residential urban fabric (Figure 24), with constructions that go back to the 18th and 19th century, arched passageways (Al Sabat) and decorative gates. The Old City is a compacted built area, with no green zones. The green areas in the Old City are only the large courtyards of some houses.

Mosul was historically inhabited by different religious and ethnic groups including Arabs (Sunni Muslims), Kurds (Muslims), Yazidis (non-Muslims), Turkmen (mostly Shi'ites Muslims), Shabak (Shi'its Muslims), Assyrians (Christians), Chaldean (Christians), and Jews. The residential quarters (neighbourhoods) that form the Old City are mixed of these ethnically and religiously

diverse local people.

The house in the Old City is looking inwards with very small openings, if exist, to the street. If the openings to the exterior exist, they are located in the upper floors. If on the ground floor, they are located above the eye level. The Shanasheels (covered balconies) were designed to provide a street view without being seen.

Figure 24. The zigzagged streets of the Old City (Source: author).

2.3.1. Main design elements

Just like the other historic cities of the Islamic areas, the traditional courtyard houses in Mosul are very diverse. They are varied in their courtyard shape and orientation resulting from the organic changing of the house and the city. The houses can be designed to have one or more courtyards and can have one or more floor levels. In general, the houses in Mosul have an average of 10 to 200 square meters. The walls are made of stones and mortar made of local gypsum and clay. The ceilings are also varied in their types, but mostly the vaulted ceilings are employed, they are made of mudbricks or stones. In fewer cases, the flat ceilings are used. The flat ceilings are made of wooden beams and pressed gypsum.

The traditional household in the Old City is flexible in using the spaces. The functions of the spaces in the traditional houses are exchanging throughout the day and throughout the seasons during the year. The rooms in the upper floors are used more in winter, while in summer, the basements and the rooms on the ground floor with less exposure to the sun are more used. The movements during the day are even more than the seasonal one due to the difference of temperature between the days and nights. The daily and seasonal exchanging of the spaces is a result of the weather conditions. Mosul has arid climate with a long extremely hot summer with an average of 43 °C. There are spaces in the traditional house in Mosul that are transitional, and others are usable spaces [57].

The gate

The gate, the main entrance, is considered the only decorated element in the exterior façade. It represents the importance of the house and the social status of its residents, being an indicator of the importance of the building, of the identity of its residents and their social standing. The shapes of the gates are varied in the Old City. According to [58], in which more than 280 gates are recorded, 40% of them are rectangular shapes without decorations and 60% of them have decorations varying in their styles and the complexity of the decorations. There are pointed arches shapes, some drawing signs from the Islamic architecture and others are semi-circular. (Figure 25).

Figure 25. Entrance gate typologies [58].

The frames of the gates are also varied in their decorations. Most of the decorations of the gates' frames are from Alabaster. The decorations of the arches as sculpted vine leaves were a preference of rich people in Mosul as it is showing in their houses' entrances and, in some cases, it is churches (Figure 26).

Figure 26. Entrance of a church in the Old City [58].

Mejaz

Mejaz is a transitional space from the gate to the courtyard (figure 27). This passageway can be just a simple corridor leading to the main parts of the house, in other cases like the houses of the wealthy people, it contains chairs made from stone and it contains an additional room for the guards or as a reception area. For privacy concerns, this space is not directly opened to the courtyard. In some cases, it is designed in an L shape. Only in the cases where the spaces facing the main entrance are less private such as Iwan and staircases, Mejaz is directly opened to the courtyard.

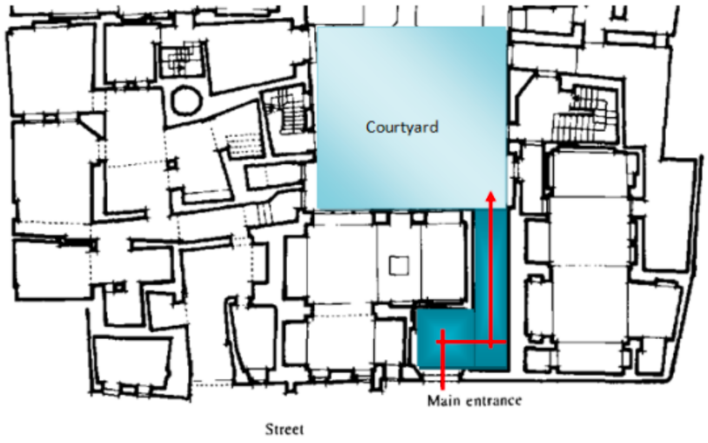

Figure 27. Mejaz path in a traditional house leading from the main entrance to the courtyard [58].

Iwan

Iwan is a transitional space. It is a vaulted room closed on three sides and opened on one side (figure 30). Iwan is an important distinctive architectural element in the traditional courtyard house. The doors and windows of the private bedrooms are opened to Iwan. It is used as a living room in summer and/or winter depending on its orientation and on the time of occupying it during the day. Iwan is located in the ground floor. The elevation of Iwan is fully decorated. In

Mosul, most of the ornaments used in Iwan are made of plaster and the doorframes are made of Mosul's local Alabaster.

Sirdab

Sirdab (the basement) in the houses of Mosul is used as a storage and in summer it is used as a main room as it resists the high temperatures. It is usually located under the courtyard. It also serves the first floor as a constructional element. The basement contains a group of columns in the middle; these columns are connected by semi-circular aches made of marble. In some cases, the basement is only 1 or 1.5 meters below the house, in this case it is called Rahra (Figure 29).

The roof

The roof in the traditional house is flat surrounded with high walls sometimes the walls are the same height as the other floors (Figure 28).

Figure 28. An overview of the Old City of Mosul showing the flat roof used in the traditional house (Source: Mosul Eye).

Tarma

Like Iwan, it is a transitional space, often situated on the first floor of the house. Tarma is a room open on one side, not vaulted but supported by 1 or 2 columns, which opens into Riwaq.

Figure 29. Iwan and its arches in the traditional house in Mosul. The basement (Sirdab) is shown under Iwan (Source: UNESCO).

Riwaq

Riwaq is a balcony facing courtyard of the house (Figure 30). It is a transitional space used for accessing the rooms in the first floor of the house. Just like Iwan and Tarma, Riwaq is used as a solution for the climatic conditions inside the house. It helps to prevent the direct exposure of the room openings to the sun and helps to provide a shading area in summer on the entrances of the rooms in the upper floors. The low altitude helps the sunrays to pass through the rooms in winter. Riwaqs are usually surrounding the courtyard. It is supported by pillars on the courtyard side. These pillars are connected by semi-circular arches.

Rooms

The rooms in the traditional house are accessible through Iwans, Tarmas and Riwaqs. They are flexible in their functions during the year. They have only one entrance, and one or more window facing the courtyard or the Iwan (Figure 30).

Courtyard

The courtyard is the centre of the traditional house in Mosul (figure 30 and 31). It is an exterior multipurpose space where most of the activities of the family are taking place. It can be rectangular or square, and it is where most of the activities of the family take place. It has climatic and social benefits as it provides light and ventilation to the surrounding spaces as well as the privacy it provides for the rooms. On the sides of the courtyard are the rest of the transitional and habitable spaces. The rooms open directly to the courtyard or through a transitional space. The orientation, dimensions and decorations of the courtyards are varying in the traditional houses in Mosul.

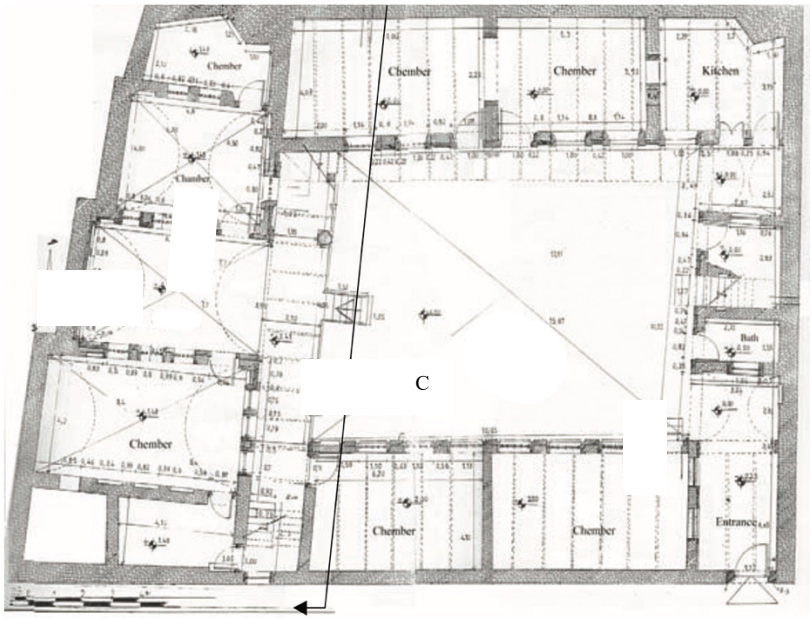

Figure 30. Typical plan of a traditional house in Mosul [60].

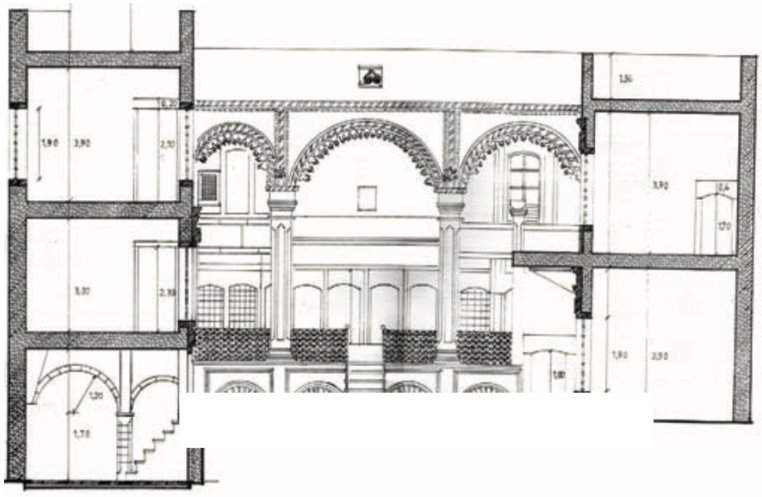

Figure 31. Section of the same traditional house above [60].

Passive cooling architectural features

Shanasheel are closed balconies over the street (Figure 32). It is considered an important architectural feature as well as an efficient ventilation element. By opening and closing Shanasheel, the air ventilation and natural lighting can be controlled during the day. In Mosul, like other historic cities with similar arid climate in the region, there are several ventilation and passive cooling architectural features [59].

Figure 32. Street view from Mosul showing Shanasheel [11].

The wind tower (Malqaf) conveys and pushes the cool air towards the lower floors through its vertical shaft, which reaches the level of the basement (Figure 33). Malqaf, commonly used in Mosul, is a type of skylight with ventilation flowing on its vertical sides. It is higher than the level of the roof, to catch the cool and clean air, redirecting the fresh air to the lower rooms. The wind tower located on the roof to catch proper wind in high levels, so it carries less dust. The void channel leads the air to the ground, where it passes through wet materials or humid underground tunnels, resulting in cool air flowing into the rooms. Wet burlap is used to both filter the dust and cool the air. In general, wind towers consist of four major parts: the shaft, which directs the air down into the house, the air shelves, or partitions, which separate inlet air from outlet air, flaps that redirect wind circulation, and a roof.

Figure 33. An example of Wind tower (Malqaf) (Source: author).

2.3.2. Decorative elements

The decorations in the traditional house in Mosul are concentrated on the inner elevations towards the courtyard. While the exterior elevations are characterised with simplicity except the decorations of the gates' frames. The inner walls are characterised by their ornamental constructional and architectural elements and decorations.

Table 4. The different forms of ornaments made of marble in Mosul.

In which part of the house	**In which form**
Al Dallayat	Pillars, arcs which consist of ornamental elements. Frames (without decorations)
Windows	Frames (with decorations) windows' frames with various styles of ornaments such as (Al Adl, Al door, Al. kassami, Al kakhma, thu-nabain wa-miftah) Frames (without decorations) Framing by more than one framework with decorative and different treatments Without decorations Cladding the walls with decorative marble or non-decorative Niches in the walls
Doors	Cornices
Iwan	Cladding Niches in the walls Niches in the corners or walls (Muqarnas*) Arc (and it is almost a pointed arc)
Walls overlooking the courtyard	Architectural elements look like windows in terms of its composition.

The local marble from Mosul is used for the decorations of the courtyard elevations as well as its use in the door and window frames (Table 4) (Figure 34). The local marble in Mosul is used for building pillars and arcs that include ornamental elements known as Al Dallayat. The arc of Iwan is built usually with marble.

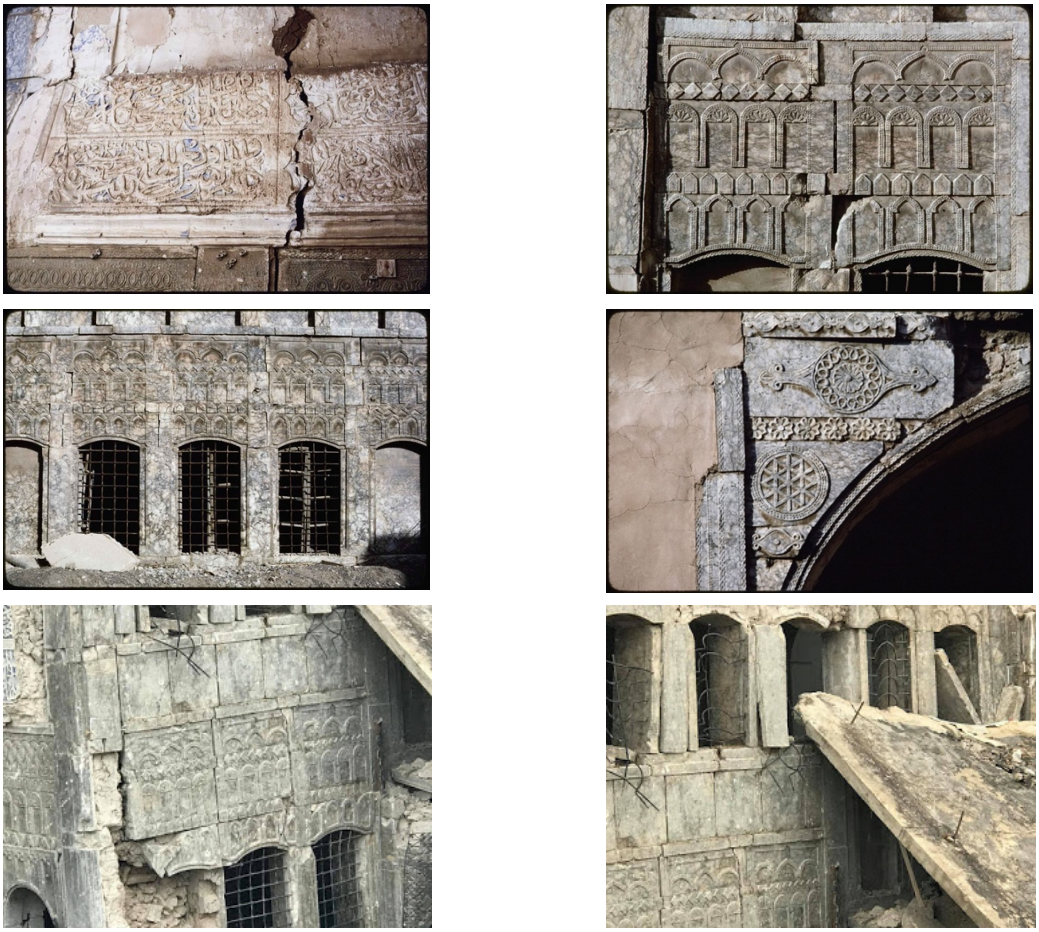

Figure 34. Examples of the traditional housing decoration using marble (Source: UNESCO).

2.3.3. Measuring architectural characteristics

In order to measure the application of the previous architectural elements, decorations and building materials in the traditional house in Mosul, the research studies four traditional houses from Mosul (Ziada, Abdouni, Al Tutunji, and Al Galilean house) built in different historical periods. The houses are described in terms of their design elements, materials used and special architectural treatments. After collecting the literature available about the traditional houses in Mosul, the research found out data about these four houses specifically. Therefore, during the field visits to Mosul in June 2019, one of the main goals was to visit the four sites. Due to the challenging time of the visits, only two of these four houses (Ziada house and Al Tutunji house)

were accessible with the permission that was obtained to the author. The visits were limited by time with no permission to take photos. Thus, the below data was collected from a few studies [9] [11] [60].

Tables 5, 6, 7 and 8 show a comparison of the main characteristics of the four different traditional houses in the Old City. The information for measuring the characteristics of each case is based on the description available on the literature mainly. The two visited houses are further viewed as how they were observed during the visit.

Table 5. Main characteristics of Ziada house from the second half of the nineteenth century.

Entrance	Transitional space behind direct access		
Courtyard	One courtyard		
Ewan	Higher than the courtyard floor		
Al Rahra	A level lower than the courtyard		
Openings	Rooms entrances		Opening to the Iwan (transitional space)
	Internal windows		Opening directly to the courtyard or transitional spaces
	External windows		No opening to the outside
Architectural treatments	Main entrance		Arc tapered framing of stone without decorative treatments
	Windows		Arc oblate - framing of marble without decoration
	Corridors		Arc tapered - framing with marble without decoration
	Iwan		Arc tapered and framing by marble with decorative and written treatments
	Rooms entrance		Without arc - framing with marble without decoration
	Walls	Overlooking the rooms	Niches in the walls Muqarnas Treatments with plaster: frames from ornate plaster; cladding the walls with marble
		Overlooking the courtyard	Cladding with decorative marble or non-decorative marble Niches in the walls Stucco cladding
		External walls	Stucco cladding
Materials	Plaster, stone and marble		
Structural system	Bearing walls with columns and arches in the basement		

Table 6. Main characteristics of Abdouni house from early eighteenth century.

Entrance	Indirect (entry is through a transitional space)		
Courtyard	Two courtyards		
Ewan	A few steps higher than the courtyard floor		
Al Rahra	A level lower than the courtyard		
Openings	Rooms entrances		Opening to the Iwan (transitional space)
	Internal windows		Opening directly to the courtyard or transitional spaces
	External windows		Small openings to the outside from the upper floor
Architectural treatments	Main entrance		Arc tapered framing of stone without decorative treatments
	Windows		Arc oblate - framing of marble without decoration
	Corridors		framing of marble with decoration
	Iwan		without decorative treatments
	Rooms entrance		Without arc - framing of marble with decoration
	Walls	Overlooking the rooms	Niches in the walls Treatments with plaster: Decorative ledges; decorative tapes; frames from ornate plaster; cladding the walls with marble
		Overlooking the courtyard	Cladding with decorative marble or non-decorative marble Niches in the walls Stucco cladding
		External walls	Stucco cladding
Materials	Plaster, stone and marble		
Structural system	Bearing walls with columns and arches in the basement		

Table 7. Main characteristics of Al Tutunji house from 1815.

Entrance	Indirect (entry is through a transitional space)		
Courtyard	Two courtyards		
Ewan	A few steps higher than the courtyard floor or the same level		
Al Rahra	Not existing		
Openings	Rooms entrances		Opening to the Iwan (transitional space)
	Internal windows		Opening directly to the courtyard or transitional spaces
	External windows		No opening to the outside
Architectural treatments	Main entrance		Arc tapered framing of stone with decorative treatments
	Windows		Arc tapered arc or arc oblate - framing of marble with decoration
	Corridors		Arc tapered - framing with marble with decoration
	Iwan		Arc tapered and framing by marble with decorative and written treatments
	Rooms entrance		Without arc - framing with marble with decoration
	Walls	Overlooking the rooms	Niches in the walls Treatments with plaster: frames from ornate plaster
		Overlooking the courtyard	Cladding with decorative marble or non-decorative marble Cornices of marble and plaster
		External walls	Stucco cladding
Materials	Plaster, stone and marble		
Structural system	Bearing walls with columns and arches in the basement		

Table 8. Main characteristics of Al Galilean house from 1748.

Entrance	Indirect – entry is through a transitional space		
Courtyard	Two courtyards		
Ewan	A few steps higher than the courtyard floor		
Al Rahra	Does not exist		
Openings	Rooms entrances		Opening to the Iwan (transitional space)
	Internal windows		Opening directly to the courtyard or transitional spaces
	External windows		A few small openings to the outside and only from the upper floor
Architectural treatments	Main entrance		Arc tapered
	Windows		Without arc or circle arc or arc oblate
	Galleries		Arc tapered Without arc
	Iwan		Arc tapered and framing by more than one framework of marble with decorative and written treatments
	Rooms entrance		Without arc or arc oblate
	Arcades		Framing of marble with decoration
	Walls	Overlooking the rooms	Niches in the walls Forms of niches in the corners of walls Treatments with plaster including: Decorative ledge; decorative tapes; frames from ornate plaster; written plasterboard.
		Overlooking the courtyard	Cladding with decorative marble or non-decorative marble Stucco cladding
		External walls	Stucco cladding
Materials	Plaster, stone and marble		
Structural system	Bearing walls with columns and arches in the basement		

As discussed previously, the courtyard in the traditional house in Mosul is the centre of the house. Iwan in the side of the courtyard is surrounded by the rooms from three sides and opened to the courtyard from one side. The courtyard is the focus of the structure, as it is considered the lung of the house, and all the other spaces are organized around it and are overlooking it [52]. It distributes the circulation between these spaces.

The traditional house is characterised by the openness towards the courtyard and, the (almost) isolation from outside, to enhance its privacy. Reaching the inner courtyard is not direct from the gate; it is achieved by a chain of intermediate spaces. The privacy of the traditional house is also supported by directing the openings toward the courtyard. Even the openings to the inner courtyard are not direct, through intermediate spaces such as Iwan, Riwaq and Tarma, for

privacy reasons and to protect from the direct exposure to the sun. The openings to the street are very limited, they are small and located in the upper floors. Shanasheel, the closed balconies, are other examples of privacy and protection from the direct sun, they also provide a shaded area.

2.4. Characterization of the Rubble Generated from Housing Destruction

According to the previous study of the origins and the extension of architecture in Mosul city through the history, it becomes clear that the constructional rubble generated from the destructed houses is different in Mosul's different areas. The houses in the Old City are traditional with original local building materials.

Typically, constructional rubble in Mosul from damaged houses comprises concrete, masonry bricks, building stones, gypsum used in traditional mortar and plastering, tiles, reinforcement bars, timber, doors' and windows' frames and glass. The UN-Habitat report expected that a large amount of dust is present in the rubble of Mosul due to its semi-arid climate [40]. The rubble management team will need to consider this issue during their decision-making process.

The rubble generated from the houses with historical value (traditional houses) in the Old City area, consists of materials, comprises plaster, stone and marble. The basic building system is bearing walls system with structural system in some parts such as the basement, the arcades and domes usage in the roofing, which was characterized by the diversity of forms (Cradle dome, Bakdasheya dome, Tisht dome) [61] [62]. One of the most important constructional materials used in constructing Mosul's traditional house is flint stone, plaster, marble, limestone (Al Hillan) (Figures 35 and 36).

The walls are built with flint stone and plaster, where the bases are built with the same materials in addition to hydraulic lime. The domes are built by adding fresh gypsum to plaster and Al Khirshan (old building plaster characterized by low weight), Mosulian marble (Al Farsh) which is used to build the entrances, pillars, arcs, window frames, lower edges of the walls, stairs, pavement, wall cupboards, decorative frames, and other decorative needs of the house [62].

Mosulian marble is used in places that should not be exposed to weather conditions, especially rain, whereas Al Hillan stone is used in open areas such as courtyard pavement. There are diverse uses of building materials in the traditional house, Mosulian marble, for example, can be used as a construction material as well as for cladding and decorative surfaces (Figures 37 and 38). The usage of these materials is attributed to their abundance in places close to the city, and there is accumulated experience for preparing these materials since the old ages (Assyrian

age) and after. There are other materials used in buildings, but its usage is less than the basic ones, such as wood, glass, ceramic, brick, bitumen, and others.

Figure 35. Al Tutunji house after destruction (Source: Iraq Heritage Stabilization Program).

Figure 36. Al Tutunji house after destruction (Source: Iraq Heritage Stabilization Program).

Figure 37. The use of marble in the basement of a traditional house in Mosul (Source: Mosul Eye).

There is richness in treating elevations and decoration inside Mosulian traditional house but outside the house is characterized by simplicity, where the inner walls are treated through ornamental construction and decorative architectural elements (Figure 38).

Figure 38. Arabic inscription in marble on the inner wall in Al Tutunji House (Source: Aliph Foundation).

There is a focus on using marble that is used to build door entrances, window frames with various styles of ornaments (such as Al Adl, Al Door, Al kassami and Al Kakhma). There is a relation between the style used in the entrance frame (the frame in Gate) and window frames in the same house. There are various kinds of decorations made of marble used in the traditional house, such as geometrical ornaments, plant ornaments, written ornaments, abstract ornaments, and ornamental units overlapped with the ornamental elements mentioned above. The local marble is used to establish columns, arcs that consist of ornamental elements called (Al

Dallayat). The arc of Iwan is built with marble (figure 36). Marble is also used for making Al Mashaki, which are considered as architectural elements and look like windows in terms of its composition but are not opened from behind. They usually have the same style of the entrances and windows in order to achieve unity in terms of style in the traditional house.

These ornaments are achieved by two basic forms as follows: 1) Relief ornaments: The most used ornaments, which consist of plant and geometrical ornaments overlapping each other and symmetrical. It might consist of writings that refer to the building and who built it. 2) Inscribed ornaments: They are of limited use, either inside units of symmetrical dimensions, or opposite to each other inside geometrical units. Ornaments are implemented on entrances, window frames, arcs, columns, column basis, wings elevations overlooking the courtyard and enveloped covers of the Iwan and Mashaki. In addition to Mosulian marble, some other materials were used in decoration and ornaments such as plaster in making plaster ornaments, and iron in making balustrades.

Conclusions

Mosul city flourished during the Islamic rule; therefore, it follows the other Islamic cities mainly in the creation of its layouts. Up to the 20th century only the Old City area existed in Mosul, which makes it the only area that holds the houses with historic values. The churches and Mosques in the Old City were built besides each other in the centre of the Old City and were surrounded by the houses. The Old City is a compact city. Therefore, the public heritage buildings are found in neighbouring the residential units directly. The urban fabric of the Old City does not contain public green areas, as the courtyards were the only open spaces built.

The traditional houses in the Old City were built taking into account two main design factors: privacy and protection from the direct exposure to the sun. Significantly, it was noticed during the analysis of the house's different components that those two factors were concurrent in almost every design decision. For example, Shanasheel provides a shaded area with the street view without being exposed to the outside. On the other hand, the small openings in the external walls were small and concentrated on the upper floors, provided less exposure to the sun and more privacy at the same time. The opening is made through the intermediate spaces that are open towards the courtyard (through Ewan and Galleries). These intermediate spaces provide privacy as much as they provide shaded areas. In addition, the opening toward the main courtyard inside the house strengthens privacy and serves as an open ventilated space that usually has a fountain and a private green area.

There are two kinds of entrances namely the primary and secondary entrances. The rooms are either within the main parts or conceived in separated parts. The basement will either be fully under the ground floor or its ceiling higher than the level of courtyard ground and under the building structure called “Al Rahra”. In addition, the galleries that are either parts of the building construction, or of light materials which in general do not carry loads above, are called cantilever.

Mass composition is dominated by an irregular geometry and controls space through the surroundings (especially the private courtyard). There is diversity in the materials that are used to build the houses for their multipurpose use. This is because the material can be used in the process of building the main structure in addition to their use as fine treatments on the wall in the house. Plaster, stone and marble have been used as structural materials, as well as decoration materials in surfaces covering.

The internal walls were treated by decorative treatments such as niches using marble and plaster as well as the framing of all kinds of openings. On the other hand, exterior walls have a limited treatment through framing the opening with marble and stone. The main entrance has distinct rich decoration treatments and framing with stone.

3. POSTWAR HOUSING CHALLENGES

The main goal of the evaluation of post-war housing settlements is to understand better the state of post-war housing settlements, the current urgent rebuilding activities and how they affect the existing local architecture of the houses described previously, and the future reconstruction process. The main issues to be addressed in this chapter are: (1) the post-war housing challenges affecting the rebuilding activities and the return of Internally Displaced People (IDPs); (2) temporary housing solutions for the people who lost their houses.

This chapter focuses on post-war housing challenges of the people of Mosul of three different groups: (1) the group of people who stayed in the city mainly east of Mosul and the groups who decided to stay in Mosul but built new houses in areas around the city, (2) people who fled the city (IDPs) who also are divided into two groups: within the camps and out of camps, (3) people who returned to Mosul.

This chapter presents findings of the field work that included: observational visits in Mosul and cities in which people of Mosul stayed; interviews with officials from Mosul, Iraqi governmental authorities, officials from Kurdistan region and NGOs (non-governmental organizations) staff; and over 100 interviews and conversations with local people and camp managers.

This study analyses the impact of the conflict on Mosul and its population for over two years after the Iraqi government announced the liberation of Mosul from ISIL in July 2017. The study gives a comprehensive picture of the post-war state of housing of the city by considering the discussion of the aspects of local people displacements, informal settlements, temporary housing solutions, the rehabilitation of durable shelters, and return challenges.

3.1. Data collection and methodological approach

The assessment of the post-war housing challenges and temporary housing solutions has been developed using a range of methods, including review of governmental reports and shelters' programme documents, review of reports from different active international organizations [39] [40] [63] [73] [66] [76] [75] [67], face-to-face interviews and a field trip to Iraq. The trip was conducted for two months, May and June 2019. Over 100 interviews were conducted with local people including people who stayed inside the city, people in camps and returnees. Interviews were conducted with officials from the government of Iraq, Kurdistan Regional Government,

UN agencies and other stakeholders. These interviews were carried out in the cities of Mosul, Duhok and Erbil.

The trips to Mosul were the most challenging due to security issues. Visits to Mosul, which were scheduled for post-war studies, were for two purposes: post-war (current) housing assessment and the results are presented in this chapter; and evaluation of the architectural damage and the results are presented in Chapter 4.

Figure 39. The field visits to Mosul showing the streets (Source: author).

For the post-war housing assessment, the author conducted five trips to Mosul: In the first one, a visit to Mosul University was conducted in order to interview: Ahmed Al Omary, head of The Architecture Department and Dr Muzahim Al Kayatt, president of Mosul University and the committee responsible for the national effort to restore services in the Nineveh province. Dr Muzahim Al Kayatt provided the author with a permission to enable her to take pictures in specific places where it was not possible without a permission and to help her to get through the security check points around the Old City of Mosul. Thankfully, Dr. Muzahim Al Kayatt also contacted Ivan Thung, urban data analyst at UN-Habitat and Sadeem Ismael Senior engineer at the United Nations Development Programme (UNDP) in Iraq and Thaer Ghanim, programme manager at

UN-Habitat, in order to introduce the author and to ask for permission to get the latest data conducted and the latest reports by the UN agencies in Iraq. The second trip included interviewing Abdulsattar Al Habbow, director of Mosul municipality and Dr Suhaib Yehya, head of consultancy engineering bureau, from Mosul University. The trips that followed the first two were focused on observational walkthrough visits (Figure 39 and 40).

A trip to Erbil city was scheduled to interview Bayan Dizayee, the former Minister of Construction and Housing in Iraq. For security issues it was not possible to meet the local people (who stayed in the city or the few who returned at the time of the visits) for interviews inside Mosul. The visits to Mosul, despite of obtaining a permission, were limited by time, resources and access to the sites selected for the observation owing to logistical and security issues. In particular, access to civil society and locals was restricted. However, the limitations were not significant enough to affect the outcome of the assessment.

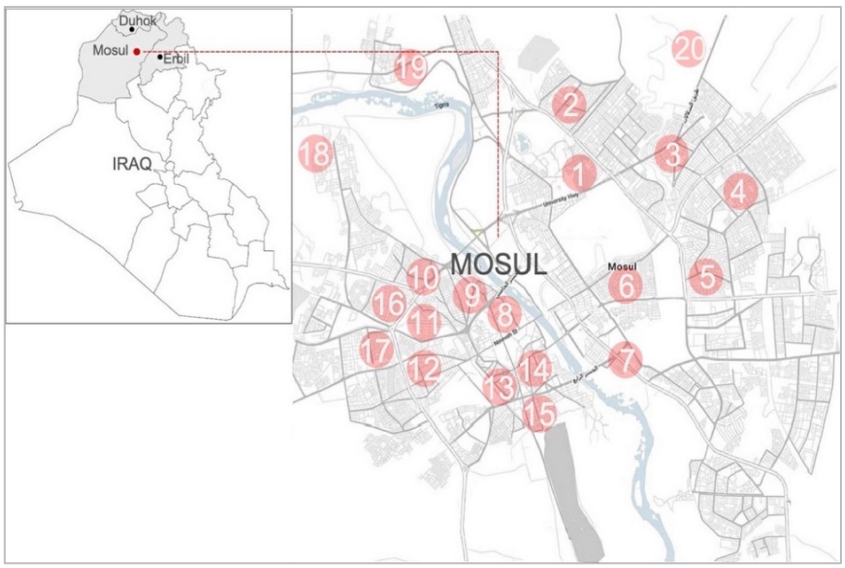

Figure 40. Main areas visited during the field trip to Mosul as observational walkthrough visits and face-to-face interviews with local people (Source: author).

Seven camps (Shariya, Domiz 1, Domiz 2, Kabarto 1, Kabarto 2, Darashakran and Sheikhan camp) in Mosul, Duhok and Erbil city were inspected (Figure 41) for interviewing local people from Mosul. Assessment of the temporary shelters including relevance, validity of design, development results and efficiency of the shelters was based on the selected case studies and the observational visits to individual shelters in different buildings out of the camps that were upgraded by the local authorities and the international organizations.

The field trip to Iraq basically enabled the author to get more contacts from the officials who were interviewed and got the permission to contact them during the research. Therefore, in the

period from September 2019 to June 2021, whenever there was a need to get specific data, the interviews were carried out remotely by electronic mail and other internet platforms.

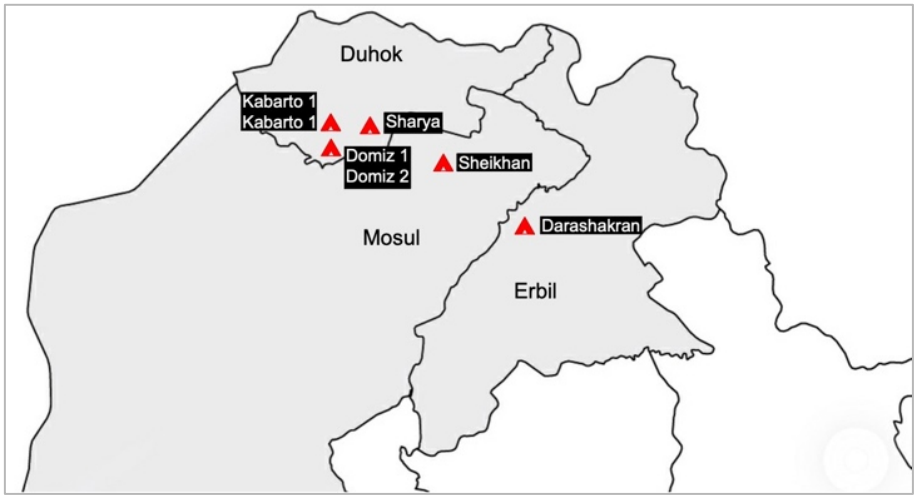

Figure 41. Locations of the camps visited in Mosul, Duhok and Erbil (Source: author).

Several challenges and limitations were mitigated through the design of the assessment's methodology and the close cooperation between the author and the officials mentioned above, local people and ground partners. However, remaining key challenges to the assessment included: data limitations, security challenges, the verification process and the constant changes in camps and numbers of Internally Displaces Persons (IDPs) and returnees.

The complexity of the political and security situation led to significant delays in data. The security challenges in Mosul restricted the accessibility of some locations especially in the Old City, the time of visits and the photography. The visits to Mosul and inside its areas required special permission from the local authorities.

The explosive hazards led to more limitations. The city was not cleaned totally from the explosive ordnance. In the Old City, local people tried to mark some houses that contain unexploded bombs (Figures 42 and 43). Inside the Old City, field visits were accompanied by two members of the author's family and a local driver from Mosul city.

The post-war housing assessment relied to on the reports gathered during the fieldwork supported by the data available from the internet. Camps in the north of Iraq are fuelled by both the ongoing Syrian refugees and the people fleeing from ISIL conflicts in the north of the country. Therefore, urgent housing projects host both refugees and Internally Displaced Persons (IDPs), though the two groups rarely mix. As it is known in the war environments, the highly changing situation in both Mosul and areas they fled to lead to constantly changing the housing solutions. The ongoing ISIL destruction in Mosul caused the flowing of new IDPs every week.

At the same time, some IDPs were returning to villages recently freed from ISIL. At the time of writing, incoming IDP flows exceed outgoing flows, so new camps established, and existing ones are expanded. This flexibility makes the planning of permanent housing even more challenging.

Figure 42. Lack of cleaning the unexploded ordnance in Mosul by the official authorities. As the return of people increases, they start marking some houses as EOD (Explosive Ordnance Disposal) (Source: author).

Figure 43. Houses In the Old City were used for manufacturing weapons by ISIL and were used to store their explosive hazards [UN Environment] (Source: author).

The variability also disturbs the research because even the recent information become outdated and makes it hard to find accurate data. Nevertheless, the research managed to cover the recent housing solutions by observing the different housing activities implemented by the local people of Mosul inside the city and in the areas to where they fled.

Furthermore, several different actors that operate do not always coordinate or communicate. The Iraqi government and the UN agencies with other international organisations are monitoring IDP temporary housing. Finding data on IDP camps and other temporary housing projects often depend on whether an NGO has conducted a survey.

3.2. Mosul Population

The demographic matter in Iraq is a sensitive subject due to the recent ethnic conflicts. Mosul especially is known to be socially, culturally, religiously and ethnically diverse. Through the history of Mosul, it had a mixed population of Arabs, Kurds, Turkoman, Shabak, Assyrians, Arman, Chaldean and Yazidis. The movements of the large scale of the population of Mosul during the former regime and particularly the following decade, made it challenging to obtain accurate census data [63]. Mosul city comprised 1,137,000 inhabitants according to the statistics department of Nineveh province before the invasion of ISIL in 2014.

Two thirds of Mosul's population lived in western Mosul (the right bank of Tigris River) until the early 1990s. Later and after Iraq-Kuwait war, the city increased its expansion to the left bank of the river significantly, when its population size became comparable to the population of the right bank [63].

The statistics of the ethnic and religious composition of the city are not accurate currently, even though the city is known for always being comprised of a majority of Arab Sunni population. According to [64] around 80% of the population are Arab Sunnis, followed by Christians, Kurds, Yazidis, Turkomans and Shabak. Historically, the city is known for its mixed population. However, there were concentrations of certain groups in certain areas of the city. The Christian population mostly concentrated in western Mosul, especially in the Old City where the city has its old churches. Kurds and Shabaks population concentrated in eastern Mosul (Figure 44).

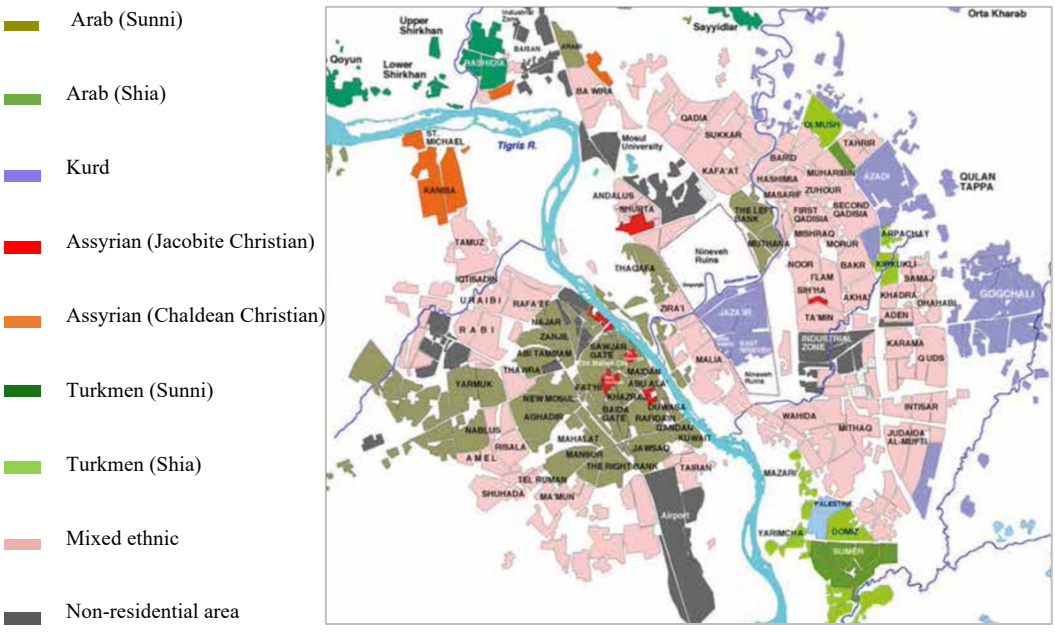

Figure 44. Ethnic composition in Mosul (Source: Mosul Municipality).

After 2003 and before the invasion of ISIL, the city witnessed the incoming IDPs and rural migrants from southern villages. They settled mostly in the south-western areas of Mosul such as: Al Yarmouk, Hammam Al Alil and Al Risala.

3.3. Internally Displaced Persons (IDPs)

Since the end of the war, and while more of East Mosul is starting to recover, West Mosul still lays in rubble with severely destroyed buildings (Figure 45). The Old City is still in ruins. Which caused continuous displacements of Mosul's local people. The continuous conflict and violence have mainly targeted the city's religious and ethnic minorities. Kurds, Christians, Turkomans and Yazidis have been forced to flee. While the situation was not safe for every group to stay in the city, some local people from the areas inhabited by Arab Sunni's remained in their homes.

Forced migration happens when one or more causal factors affect a region, causing its population to flee their homes unexpectedly in large numbers. When the displaced people cross an international border, then they are considered as refugees; otherwise, when they are displaced inside the boundaries of the same country they are identified as IDPs [31].

Figure 45. Aerial view of Mosul in August 2016 showing the severely damaged Old City (Source: UNESCO).

Gradually, when Iraqi government announced the liberation of Mosul from ISIL, some local people began to return to the Old City and started clearing the rubble and rebuilding their homes and businesses themselves without governmental support, volunteering and helping each other. During summer months of 2014, approximately 500,000 people were displaced from Nineveh province [31]. As the minorities were the target of ISIL, large numbers of their communities fled outside Iraq, but the majority decided to stay inside the country and move to safer areas to be internally displaced [37].

While most of the IDPs who have returned to the city are returning to East Mosul, only 5,000

local people returned to the Old City in West Mosul. 150,000 of the local people from the Old City are still displaced out of their homes according to the report provided by Reuters in 2018. Most of these displaced people are still living in different temporary housing situations. Others relocated to East Mosul. Most of the people who left their homes moved to the north of Iraq, in Duhok and Erbil. While the families with a better financial status moved to Turkey. Currently there are no accurate data about the existing residents in Mosul. The returning families are forced to live in unsafe houses that still contain unexploded bombs or have the risk of being collapsed.

The humanitarian urgency in Iraq have become the highest concern since the last internal displacement crisis in 2014. Although the statistics are not accurate to the date of writing this research and they keep changing due to the unstable situation, the research is based up on the understanding of the average estimations provided in different reports conducted by several international organizations including UN agencies. The reports are estimating about 3.2 million IDPs inside Iraq. 500,000 IDPs fled from Nineveh. 200,000 of them from the Old City in Mosul: 32,000 of them displaced within the city of Mosul, 74,000 fled from Mosul to Duhok, 48,000 fled from Mosul to Erbil, Najaf, Baghdad and Karbala.

The protection of the local people of Mosul and their basic human rights became compromised with the lack of support from the local authorities. The situation of the displaced people from Mosul in the host cities and areas around the city is worsening due to the continuous displacement that caused overcrowded residential areas and the lack of public services. The choice of the area of displacement was determined by the religious or ethnic affinity.

Minorities tried to seek protection in areas where their identity resonates with that of the host area [65]. While minorities of the Shi'a have been displaced to provinces such as Karbala and Najaf. Yezidis of Nineveh have mostly fled to the KRI or to Kurdish-controlled parts of northern Nineveh [39]. Christians have been displaced to cities of Christian majority such as Ainkawa in Erbil and some places in Baghdad. Camps and most of the temporary housing areas are divided according to ethnic or religious belonging. Although IDPs have experienced less violence than stayers during the battle for Mosul, they have had their houses destroyed just like stayers. In some cases, IDPs' properties were destroyed by ISIL as a punishment for their departure from Mosul.

3.3.1. Affected groups and neighbourhoods

ISIL looted, confiscated and destroyed all types of private properties (houses, agricultural land and commercial buildings) belonging to the local people who left the city. Housing destruction primarily focused on the city's religious and ethnic minorities (Turkomans, Kurds, Shabaks,

Christians, and Yazidis), as well as the local people who worked or were associated with the Iraqi government and its police or the security forces. Houses owned bythe minorities have been usurped by ISIL's Shari'a (legal or religious) court. ISIL marked the houses owned by Christians with the letter "ن" or "N" (signifying Nasara, which means Christian in Arabic), and the houses owned by the Shia Turkomans and Shabaks with the letter "ر" or "R" (signifying Rwafidh, which means rejecters in Arabic), in preparation for their destruction (Figure 46).

Figure 46. Christian houses marked to be confiscated or destructed by ISIL [39].

The majority of the houses which were marked to be confiscated or destroyed were in: the Christian neighbourhoods of Al Arab, Shurta, Nour, Muhandiseen, Majmoua, Thaqafa, Faisaliah, Zohour, Dawasa, and Dandan; the neighbourhoods of Al Thaqafa, Al Bakir, Al-Maidan and Al Saa'a in the Old City; and the Shia, Turkoman and Shabak neighbourhoods of Atshanah, Karamah, Quds, Nour, Bab Shams, Nour and Adan [39]. There are also other marked houses spread across the city.

ISIL also organized auctions and opened a new market called the "Spoils of the Nasara", where the items, decorations elements and art objects were looted from the houses of Christians and churches in Mosul were sold. In addition, the city's Sunni population has been affected by houses confiscation or destruction threats. Lawyers and doctors received letters from ISIL members threatening their houses unless they stop practicing their jobs. In addition, the houses of the families who left the city without permission from ISIL were seized [66].

3.4. Postwar housing shortage

Following ISIL's invasion of Mosul, investments in the housing sector and all ongoing projects were stopped [39]. As the local people who left the city, their empty houses were taken over by ISIL members. Under the current conditions, most of the local people who chose to stay in the city are largely unable to invest in their housing units for the lack of resources.

Despite of the large threats of destruction to the houses during the occupation of ISIL, as the United Nations offices in the city expected, more than one million of the local people fled during the airstrikes to liberate the city from ISIL. The United Nations also suggested that many people, particularly the minority groups, may not return to Mosul for reasons related to their safety, the fear from further violence and because they no longer trust the future of Mosul [66]. A few IDPs have returned to rehabilitate their houses and sell them, according to the information provided by the municipality of Mosul. The people who left during the liberation battle are the ones mostly expected to return to their houses as soon as they are rehabilitated. The group of people who left Mosul in the early displacements are facing the consequences of property rights, as their houses have been occupied by other people [65].

The airstrikes conducted by the Iraqi government during the battle to liberate the city from ISIL, caused more destruction of the housing sector and increased the housing shortage. It is anticipated by the local authorities in Mosul that informal housing has increased due to the lack of an updated and effective master plan for the city.

Many IDPs are unable to return because their houses have been destroyed, either by ISIL or during the battle, and renting or buying a new house is prohibitively expensive. Some houses are still standing, though they have been severely damaged, but are in need of major interventions that IDPs cannot afford. Other IDPs are unable to return because their homes have been unlawfully occupied by other people and they lack the necessary documentation to reclaim their houses.

Until the mid of 2017 there were no plans or housing projects ongoing in Mosul. Destruction of the houses is a major issue in West Mosul given the scale of destruction. There are no current plans from the Government of Iraq and the local authorities in Mosul to deal with housing shortage. Most stayers lack the resources to pay the costs of rebuilding their own homes, and the reconstruction assistance being provided by NGOs and the Iraqi government is insufficient to meet their needs. Even those who have money to repair or rebuild their homes are sometimes reluctant to do so because of uncertainty about the future and fear that ISIL or another extremist group will recapture the city.

3.4.1. Informal settlements

The former regime provided strict prevention policies against informal housing units for security reasons. After the fall of that regime in 2003, informal units became a housing solution because there was a political pressure preventing their destruction [67]. From that year, Mosul expanded significantly. Most of its new housing areas are illegal as its being built on public land outside the administrative limits of the city. These areas are either located to the west of Mosul in the

areas of Tal Al Rumman, Al Mamoun, Musherfa, Wade Al Ein and Harmat, as well as some areas to the east: Rashediya, Besan, Al Qahira, Al Tahrer, Arbachiya, Adan, Al Karama and Al Intisar. Some illegal settlements are built on agricultural land located on its east, northeast and to the north, outside the boundaries of the 1973 master plan of Mosul.

According to the Ministry of Housing in Iraq, these informal or illegal settlements happened because of the following factors:

- High prices of the houses within the city's centre due to the housing shortage
- lack of affordable prices for the middle and low-income households;
- The lack of sufficient investment in affordable housing projects;
- The outdated 1973 Master Plan.

Between 2003 and 2014, the Directorate of Planning of Nineveh Province registered 32,000 violation cases in Mosul. Half of the cases were related to informal housing units, the other half are related to land subdivisions. After the last conflict and the large percentage of the local people who lost their houses, a big increase in informal housing units occurred (Figure 47).

Figure 47. Informal settlements have been constructed outside the municipal boundaries North of Mosul (Source: author).

Although, in theory, public services should not reach the informal settlements areas, many of them are well serviced. Some informal housing units are getting better services and infrastructure than the formal areas. The informal settlements are causing additional pressure on the public services that are planned to serve the neighbouring formal areas close to them. The layout of some informal housing areas corresponds to the design standards of the formal areas, hoping to be considered in the future as a formal settlement. However, in other informal areas it does not imitate the standards.

The neighbourhoods of Adan, Al Kahira, Al Tahrir, Al Karama, Al Mamoun, Musherfa, Harmat, and Tal Al Rumman are the cases that have become formal settlements in Mosul. Before the occupation of Mosul by ISIL there were no national policies to upgrade the informal settlements. The only case of upgrading an informal to formal settlement is Tal Al Rumman IDP camp, which happened under the supervision of the UNHCR, which later redeveloped as a formal residential area.

The growth of the residential areas occurred in villages around Mosul, which did not exist until 2000. The built-up area of Mosul was around 144 km^2, growing at a rate of approximately 50% in 2014 [63]. In 2004, a draft of Mosul master plan proposed additional 142 km^2 residential area. However, it was not implemented. In 2014, more than 60 km^2 of residential area was implemented as informal settlements. Thus, almost half of the proposed residential area in 2004 mater plan have been used. This growth was implemented in East Mosul only and it occurred without a guiding plan, although, the unimplemented master plan of 2004, proposed growth residential areas in West Mosul also (Figure 48).

The unplanned growth of the informal houses is developing another pressure on the local authorities with the way they can deal with it. Recent data drawn from the informal settlements survey conducted by the Ministry of Planning (MoP), admits that more than 3.3 million people live in informal housing units in Iraq.

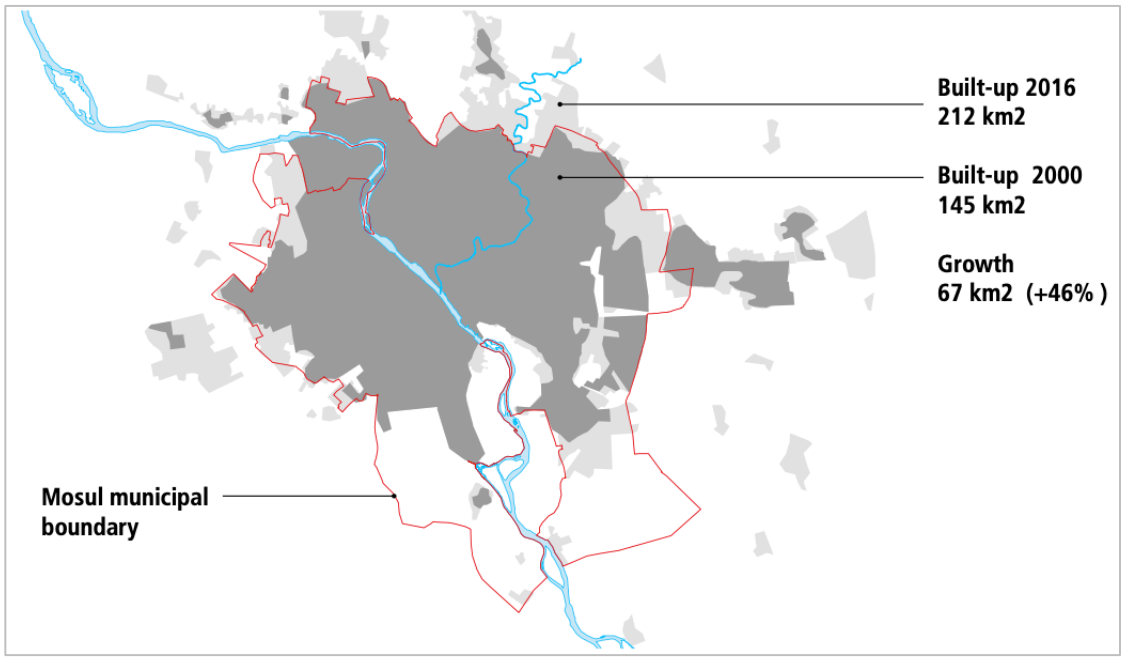

Figure 48. Growth of built-up area of Mosul between 2003 and 2016 (Source: UN-Habitat).

An initial review of available imagery and data suggests that informal housing units are mainly located on the following sites (table 9):

On agricultural land outside the city boundary: In some cases, these areas used to be villages that have been incorporated into the city. Such areas have grown significantly over the past year by over 9%.

In residential areas: Unauthorised subdivision and construction on government owned land. The owner not presenting valid building permissions or without owning the legal title to the land. This number has not grown significantly within the city boundary, because most official residential land is already developed.

In slum residential areas: Settlements, both inside and outside villages that have been developed without a regular street pattern, and do not comply to service-level requirements mandated by law, e.g. number of schools, roads, public space. Such settlements have grown organically. Buildings are often temporary in nature and poorly constructed.

On private land: Construction on private land that breaks the land use classification provided by the masterplan.

On excavation sites: Construction on historic sites, such as the units developed on the Nineveh excavations site. Approximately 700 housing units have already been built on historic sites within Mosul, although the number has not grown significantly between 2017 and 2018.

Table 9. Informal developments in and around Mosul (from official municipality maps).

Type	February 2017	August 2018	grow th
On agricultural land or green apace	9,533	10,401	9%
On heritage sites	668	672	1%
Around existing village areas	1,420	1,547	9%
Other (e.g., on residential land)	24,346	24,935	2%
Grand total	35,967	37,555	4%

3.4.2. Illegal subdivisions on agricultural land

Approximately 17,550 houses would be needed to address one-third of the pre-crisis housing shortage of Mosul according to the Municipality of Mosul. The private sector is the main provider of housing today. Most of the recent housing is considered illegal because it is built on agricultural land without permission from the local authorities. As these settlements are officially not allowed to be connected to the municipal network, residents have participated themselves by illegally providing these areas by the public services or extending existing networks. Despite these individual actions there are still many of the areas that have little access to basic services such as schools. In North Mosul, there are thousands of illegal housing subdivisions implemented on agricultural land by private sector developers (Figure 49). They buy the land from farmers and use it in housing taking advantage of the lack of law enforcement. More than 1,620 hectares of unregulated subdivisions have been built since 2004, which is about eight times the size of the Old City [72]. Although these are considered illegal, they do answer a real demand for new expansion areas. More broadly, informal settlements increased significantly after 2003, due to a shortage of land allocated for housing, lack of services and infrastructural investment, corruption and poor governance, compounded by significant waves of displacement in 2003 and 2007-2008.

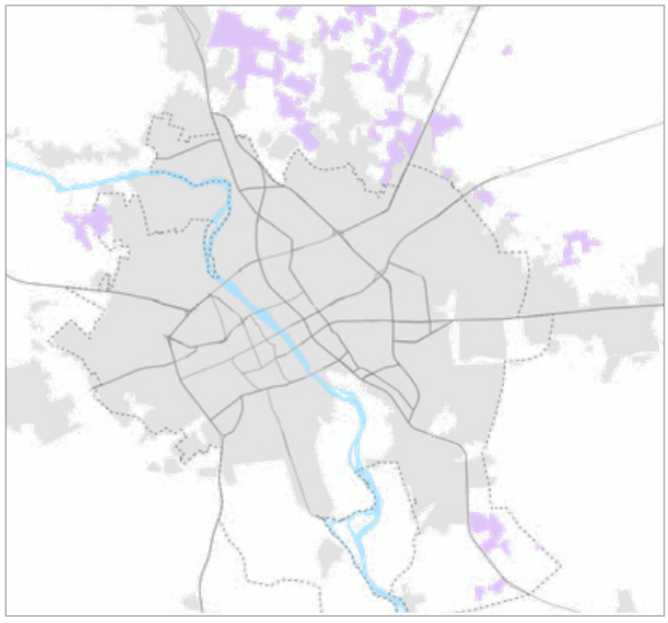

Figure 49. The coloured areas refer to the illegal housing areas on agricultural land [40].

Some of the informal housing units in Mosul (Figure 50) became known as self-governed. Between 2006 and 2014, leaders of ISIL settled in the neighbourhoods of 17 Tamouz, Al Eslah, Al Zerae, and Al Nahrawan [36]. This does not mean that extremism did not grow in other neighbourhoods. According to some local people, radicalism developed in those parts of the

city, which are mostly located on the west side. It is also believed that the armed groups and terroristic cells that entered the city in the start of the invasion of Mosul, first settled in the western side of the city, then moved to the eastern side after they gained power and control over the city.

Figure 50. Areas in dark grey colour refer to the self-governed Informal settlements in Mosul (Source: author).

3.4.3. Temporary shelters: Overview of IDPs current housing conditions

The situation in Iraq has been unstable for several years because of both the internal conflict and the impacts of the Syrian crisis (Figure 51). The response from the international humanitarian organizations has taken a range of approaches, from mobile assistance for populations on the move, to a variety of interventions for displaced, host communities, refugee and returnee caseloads in multiple settlement situations, including camps, which have been the preferred form of assistance from the government.

Iraq's internal conflict against armed opposition groups has resulted in a prolonged crisis that has left almost 3.2 million people displaced. The economic crisis has seen a 40% drop in oil revenues, resulting in the collapse of the social protection floor across the country and seriously compromising the ability of communities to access basic services, maintain incomes and meet every day needs [69]. Overcrowding, dwindling resources, perceptions of disproportionate assistance, lack of (or competition for) employment opportunities, and continued insecurity threatened to exacerbate already fragile ethnic and sectarian tensions across the country, particularly as sections of the non-displaced population are already in a situation of destitution. By the end of 2016, it was estimated that over 10 million people in Iraq required some form of humanitarian assistance, of whom a large proportion were host communities [70].

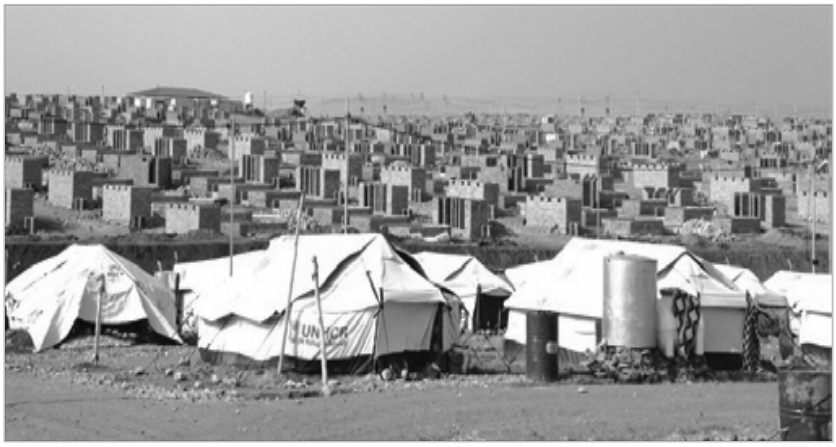

Figure 51. Camps have been established in Iraq since 2013 to host Syrian refugees (Source: author).

The Shelter and Non-Food Items (Shelter-NFI) Cluster in Iraq was activated in January 2014 to address the IDP crisis, with a Shelter Sector Working Group already established to focus on the Syrian refugee response. Given that many host communities (particularly in northern Iraq and the Kurdistan Region of Iraq) were composed of a mix of vulnerable non-displaced, refugee and IDP families living in similarly substandard shelter and settlement conditions within proximity of each other, the international agencies that are active currently merged to consider both IDP and refugee responses in this mixed crisis (Figure 52) [64]. In parallel to allowing longer-term displaced families achieve and maintain adequate shelter, agencies in Iraq have also had to prepare for regular waves of new displacement across the country, as the active conflict continued. This required a phased and incremental approach, covering emergency, post-emergency and early recovery activities, often in the same locations during the same timeframe. The agencies based their tasks as response strategies in the following three packages: 1) first, response to address the emergency shelter needs of the newly displaced (Figure 53); and 2) second, response to upgrade shelter for existing IDPs in critical need. However, due to the scale of emergency needs, funding for first, and sometimes second responses, has had to be prioritized over the longer-term responses. For 2017, the strategic objectives also included: replenish core households' items (second responses) and expand shelter and housing options for vulnerable households, according to standards [71].

Figure 52. "Transit camps" with tents as a temporary measure were initially established for temporary accommodation of the influx of Syrian refugees. These grew in number and size over time, and structures were partially upgraded [72].

Figure 53. Temporary tents' kits were distributed as one of the urgent shelter responses options (Source: author).

The first camp constructed to host Syrian refugees in the Kurdish Region of Iraq was established in March 2013 in Dohuk Governorate, with a camp population of approximately 55,000. In 2014, four additional camps for refugees were established in neighbouring Erbil Governorate, with a total population of 27,700. In the winter of 2014-2015, 13 camps were established for IDPs escaping conflict in Southern and Central Iraq.

In early phases, IDPs were principally provided with tents as an emergency shelter solution, along with the required basic camp infrastructure. In the later-established camps, there was a greater variety of shelter types, ranging from prefabricated shelters to tents on concrete platforms. Concurrently, an increasing number of camp residents engaged in incremental upgrades, using construction materials from local markets. Local authorities initially restricted the use of permanent construction materials (e.g. concrete and blocks), though later opened up to their utilization in a controlled manner. In early 2015, the vast majority of shelter coverings in the camps were still constructed with soft materials. This was even more prevalent amongst IDPs with individuals with disabilities, as they were less likely to have access to resources to improve their shelters.

Prior to implementation, the international organizations worked with UN agencies and the refugee community representatives assessed the IDPs in need, in different types of disabilities. Many of the families with persons with disabilities reported that the organizations' field staff were the first humanitarians to engage with them directly, or that they had received no prior assistance addressing their specific needs [31].

In camp settings, the shelter strategy principally focused on four points: land allocation for new camps; expansion of existing camps; provision of emergency shelter for new arrivals; and shelter improvements for refugees in camps prior to the influx. The strategy highlighted the general needs of different vulnerable groups, but there was no specific technical guidance on shelter construction or upgrading for persons with disabilities.

The organizations targeted refugee populations in camps in Dohuk and Erbil governorates. Domiz camp was initially selected, following a multi sectoral needs assessment carried out by another organization, which identified gaps in specific service provision for IDPs with persons with disabilities. The camps in Erbil were later identified as having similar gaps. IDP camps were not targeted under these projects, even though the organizations had other projects and funding streams that targeted the shelter needs of IDPs. The projects included the upgrade of housing conditions of IDPs out of camps.

Potential individual IDPs were identified in close coordination with agencies, camp management and other actors providing services within the camps. Following the initial pre-identification process, social and technical assessments were carried out at the IDPs level and were scored based on weighted vulnerability (both socio-economic and technical, as well as severity of disability and mobility or quality of life issues). This scoring phase determined which IDPs were to be assisted, in which order, and played a role in defining the unit costs.

Both skilled and unskilled workers from the camp population were employed to implement the projects. The aim was to include one unskilled labourer from each beneficiary household as a means to provide a source of income. Each project was implemented by a separate team of six to ten individuals, supervised by a project coordinator. Area-based teams worked in pairs, with technical staff focusing on technical assessments, design solutions and construction. Materials were delivered to each IDP, and works were carried out by labourers.

3.4.4. Main types of shelter assistance

Emergency shelters

The Basic Emergency Shelter Kit is designed to provide the materials and tools to construct a simple shelter for displaced families. By removing one component, the poles/sawn timber, the kit can be more portable and lighter. This version is presented as a mobile emergency shelter kit.

Emergency Shelter Support can be provided for many different contexts and situations. The organizations in Iraq are providing it to be used for shelter to displaced families to erect temporary shelters to provide privacy and dignity. The emergency shelter kit can be used to seal off unfinished and abandoned buildings, erect forms of shading, provide separation in community buildings, and erect toilet and communal kitchen infrastructure. The kits are designed to be

multifunctional and multipurpose based on needs and context. Some examples of uses are shown in the diagrams in figure 54 and figure 55.

Prefabricated shelters

The international organizations and the local authorities aimed at offering more durable solutions to protracted displacement, enhancing protection and livelihoods opportunities, as well as considering ways to reduce tensions with host communities and prevent further conflict. It did so by establishing four sites with prefabricated shelter units and infrastructure. The project planned and built four sites equipped with durable, prefabricated, shelter units for vulnerable IDPs across the country. Special consideration was also given to displaced families living in unfinished buildings, public buildings such as schools and mosques, in tents out of camp and in rental accommodation (at risk of eviction). These were considered to be in worse living conditions with less access to social and public service and the local authorities needed to make public buildings (particularly schools) available to serve local populations, including newly arrived IDPs.

Figure 54. Examples emergency shelters for the displaced people of Mosul (Source: Shelter Cluster).

Each emergency shelter kit delivered to the IDPs had one woven bag containing:

2 tarpaulins (shelter grade);

4 timber lengths or poles (2.3 m);

1 rope (30 m);

1 wire (5 m);

0.5 kg roofing nails;

0.5 kg wire nails;

1 claw hammer;

1 shovel;

10 tent pegs.

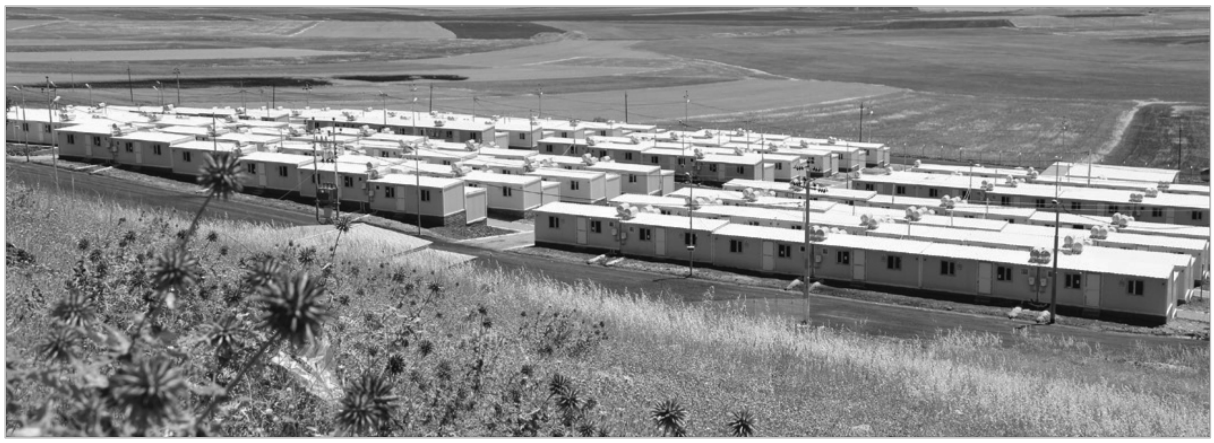

Figure 55. Darkar camp [71].

After a competitive bidding and selection process, the materials for the prefabricated units were procured from the local markets (though originally imported from neighbouring countries). Once the site preparation and basic infrastructure were ready, the implementing partners transported the materials to the site, where small workshops were established to assemble the units. This partially avoided the potentially negative impacts of using imported prefabricated solutions.

The prefabricated shelters covered a small percentage of the total needs in the country and the uniformly designed prefabricated units reduced costs, but flexible designs/sizes could have better addressed households' needs.

The prefabricated units included a living space with kitchen separated the sleeping area, as well as a bathroom (Figure 56).

Figure 56. Shelter layout (Source: Shelter Cluster).

3.4.5. Rehabilitation and durable upgrade of temporary housing

Tents are an emergency solution used by default to respond to immediate shelter needs of people fleeing violence, or when affected by natural disasters [64]. When installed in camps, tents can offer minimum living conditions in terms of safety, dignity, protection from harsh weather and thermal comfort [64]. The material they are made of (canvas coated with waterproofing materials) are naturally be subjected to tear caused by prolonged exposure to climatic conditions such as rain, snow, humidity, sunshine light, and significant temperature changes, as between summer and winter and day and night [71]. Thus, a timely replacement of tents is extremely important to maintain living conditions up to standard.

Sealing off: The sealing off kits are designed to provide families with an essential package of items to seal their living space as quick relief, short-term shelter solutions [73]. While sealing off kits are not intended to provide the same level of assistance as a full-scale rehabilitation project, they can already assist as part of a longer, incremental approach where more durable interventions will be obtained over time. Due to the comparatively low cost of this approach compared to other shelter interventions, distribution and installation of sealing off kits can be viewed as a cost-effective way to reach rapidly large numbers of affected families with lifesaving shelter assistance, in a wide variety of different locations, urban and rural, in order to provide at the minimum adequacy of shelter.

The sealing off kits should be designed to improve sub-standard shelters for the most vulnerable families by achieving the following:

Protection from climate

• Close openings (doors, windows, walls) providing protection from rain, wind, heat, cold and dust;

• Close gaps in doors and window frames, preventing draughts and leaks;

• Seal off small holes/cracks in shelters, reducing draughts, leaks and insects or vermin;

• Enhance the thermal insulation of doors, windows and floors;

• Reduce condensation on cold walls and ceilings.

Privacy and dignity

• Construct temporary partitions within shelters, for example where multiple families may be

living together, separating male and female areas in communal facilities, or separating family living spaces from shared / communal spaces;

• Fix broken (or install) locks on doors and windows;

• Seal bathroom fixtures and fittings using silicone sealant to ensure effective, safe use and proper disposal of wastewater;

• Allow segregation of areas.

Health, safety and security

• Repair temporary walls or doors to the exterior perimeter to reduce likelihood of intruders;

• Ensure the shelter is closed, reducing risk of theft, vandalism or damage;

• Install handrails, barriers and balustrades on the roof or other communal areas (e.g., stairs) to reduce the risk of falling, tripping and injury;

• Cordon off unsafe or hazardous areas, such as piles of debris or structurally damaged parts.

Sealing-off kit suggested contents

The below list of items has been developed as general guidance to the organisations, based on recent programmes implemented in Iraq and the region [71]. It covers the main groups of items that are likely to be required in a sealing off kit in order to make the implementation of activities effective and improve the adequacy of shelter. It aims at providing all the items, affected families may require, in order to bring a shelter up to an adequate level.

It is suggested that the kit includes the following items:

1. Construction materials

- Tarpaulin and plastic sheeting;
- Framing materials – square-cut timber;
- Other framing material;
- Exterior grade plywood sheeting;
- Fixings and rope;
- Sealants and adhesives;
- Metal straps and angles;
- Insulation materials.

2. Tools

3. Personal and site safety equipment

The final lists of materials and quantities are defined based on assessments carried out by the Shelter Cluster at selected sites and/or households and be balanced by the overall recommended cost package defined for sealing off kit assistance, as well as the security of tenure of the beneficiaries. All dimensions and specifications are considered in the context of availability and ability to respond to the required needs. Items are chosen as how they are fit for purpose but may change based on need, context and availability.

As the kits are intended to be distributed directly to families, it is crucial that they receive sufficient technical support to ensure that the kits are deployed effectively and meet their intended purpose. Support to beneficiaries should include safety awareness to prevent harm or injury to those involved in the installation. As the local authorities suggested the organizations to assist with the following knowledge and support to beneficiary communities:

- Training in safe use of tools and personal safety equipment;
- Training on good practices of construction using the materials provided in the kit;
- Providing guidance on a range of construction options available within acceptable scope;
- Raising awareness of potential risks, hazards and dangers within the shelter or settlement, and means of their mitigation;
- Fire prevention and response;
- Regular installation guidance and frequent follow up to ensure that materials are used to the best of their potential according to the families' unique preferences.

The organizations should also consider the requirements of families with specific needs and other aspects of local contexts that may require additional technical support and oversight in the implementation.

Within camps:

In some locations, shelters have been established from the start in so-called "permanent" (or "tent-free") camps with concrete slabs, kitchens and bathrooms, or planned as transitional settlements with prefabricated composite panel caravans forming single-family dwelling units. In other areas, where "transit camps" were initially established for temporary accommodation of the internally displaced persons, a process of transformation and shelter upgrading has been underway since 2014. Tents as temporary and emergency shelter solutions have been phased out and replaced with more durable shelters (Figure 57).

A key aspect of camp activities has been installing, upgrading and maintaining camp infrastructure, from public service facilities, educational buildings and recreation areas, to roads, electrical connections and drainage [68]. Close working relationships with WASH and CCCM actors have been required, in order to coordinate both hardware and software components, with increasing coordination and engagement with local authority counterparts, as management of camps and their associated infrastructure and service provision was handed over to primary duty bearers. Although rules vary between camps, single-storey construction (masonry or using mixed materials) has been permitted, resulting in the stabilization of the areas as settlements.

Works for more durable shelters also included mobility upgrades within plots or across the camps such as some upgrades that focused on improving the accessibility of life of individuals with disabilities (Figures 58 and 59).

Internally Displaced Persons (IDPs) in critical shelter arrangements were extremely vulnerable, with little protection from the harsh weather conditions (below 0 °C during the coldest months and above 50 °C during the summer). Furthermore, IDPs in these shelters generally suffered from inadequate water, sanitation and hygiene (WASH) conditions, health services, as well as educational and employment opportunities. Multiple displacements were common, causing long-term instability and vulnerability for IDP families. Furthermore, IDPs were increasingly difficult to access, caught behind front lines, or held at security screening centres.

Figure 57. IDP camps, in some cases, initially consisted of emergency shelter solutions (e.g. tents), which have been gradually replaced by more durable shelters (Source: author).

Figure 58. Concrete pathway and railing leading from shelter to shared/communal latrine (Source: author).

Figure 59. Concrete slab improving wheelchair access. Handrails, concrete stairway and pathway (Source: author).

A variety of upgrades focused on improving the design to suit the climate of the area such as the shaded areas (Figure 60) and fencing around prefabricated shelter.

Figure 60. Examples of the upgrades in the camps to increase the shaded areas (Source: author).

Upgrade of tent plots with concrete structures

Walls could be fully or partially raised with concrete blocks to a normal ceiling height (around 2.1 meters). The roofing structure could be supported by wooden or metallic poles and covered with the used tents, plastic sheets, corrugated iron sheets, sandwich panels, or traditional compacted earth [74]. Such structure would provide appropriate living conditions, offering better solidity, more appropriate space, and stronger protection from weather conditions, thus achieving an overall improved dignity.

The project of upgrading the shelters (Figure 61) was also able to adapt to the cultural needs of the displaced families in its second implementation phase (ongoing at the time of writing), thanks to lessons learned from its first phase. Although the design was agreed with the local authorities in the first phase (based on the average household size of six), due to cultural reasons some families complained about the size of the shelter units. This led the organization to adopt a different design (with larger space) in the most recent site, where the family size is even higher. Finally, the floors of the living space were initially damaged due to washing inside the units, and floors were not waterproof, except in the bathrooms. In the following phase, this challenge was addressed by producing clear instructions that were printed and distributed to the families.

Figure 61. IDP families before (bottom) and after (top) the shelter improvement (Source: author).

In the observation visit to this camp, the families were satisfied with this improvement, as they think it provides appropriate living conditions, with only minimal maintenance. In one field visit to Khanke camp, it was observed that the roofing structure was on steel beams. This proves that the bearing load of such walls is quite high. Similar to the concrete structure described above, an adobe (mudbrick) structure would provide appropriate living conditions, offering better solidity, more space, and stronger protection from weather conditions and thus achieving an overall improved dignity. In comparison to the shelters built with concrete blocks, thermal comfort seems to be either comparable or even better for adobe shelters.

Out of camp:

While the preferred response option for the authorities in Iraq has been the establishment of formal planned camps for both refugees and IDPs, 62% of the Syrian refugee population and 86% of the IDP population across the country have been living outside camps within the host community, though there has been insufficient focus on their needs and conditions. As the crisis in Iraq continued, greater efforts towards supporting self-reliance, sustainability and building resilience has become increasingly urgent. This had to be addressed within affected populations, as well at the administrative level through local authorities.

As of December 2016, 45% of the displaced population were in rented accommodation (including hotels), facing increasing financial pressure, because of saturation in the rental market and high rental costs, leading to greater vulnerability and particularly a risk of eviction, as resources were depleted, and families fell into debt [68]. In addition, the ability to rent private accommodation did not necessarily correlate with achieving adequate shelter, with 17% of families living in what was considered “critical shelter” types unfinished (Figures 62 and 63) or abandoned buildings, schools or religious buildings and informal settlements [65]. A main approach of organizations working outside of the camp context has been to improve shelter alongside securing tenure to ensure displaced families do not fall into deteriorating shelter and settlement situations over time. Therefore, the shelter response had to adopt a holistic and cross sector approach towards meeting complex, multi-faceted, needs outside of camp settings, over a longer duration.

Figure 62. Unfinished buildings were occupied by some people. Where agreements were possible with landowners, repairs, light or durable upgrades were made. In some cases, frame tents or sealing-off kits were provided (Source: author).

Figure 63. IDPs live in a variety of conditions, including in rented accommodation, collective centres (such as schools) and spontaneous, self-settled, sites. Most of the displaced population (both refugees and IDPs) lives outside of camps (Source: author).

Approaches have included combinations of the following:

- Standardized and complementary mobile or basic emergency shelter kits to respond to anticipated new and large-scale displacement, intending to address emergency, lifesaving, needs in a variety of potential transit, non-camp and camp-like settings;
- Sealing off shelters through distribution of sealing-off kits or implemented sealing-off activities. Inter-agency joint methodologies and mobile site monitoring by CCCM teams have been developed to ensure site, shelter & settlement, WASH and protection issues are addressed;
- Development of emergency sealing-off kits for rapid distribution in the case of a large influx, returns, or for acclimatization measures;

- Repair, rehabilitation and “durable upgrades” of collective centres and unfinished/abandoned buildings, including the installation of appropriate shelter level water and sanitation facilities, as part of shelter actors’ responsibility;
- Phased and incremental approaches towards collective centres, unfinished and abandoned buildings and spontaneous sites transitioning to more formally managed settlements. These include sealing-off (often non-structural, for acclimatization purposes), followed by rehabilitation and durable upgrades to ensure protection against climate in the short term, while longer term shelter needs are addressed comprehensively;
- Tenure security and incentives have been integrated through negotiated bi- or tri-partite agreements between beneficiary, land or building owner, and sometimes with local authorities and/or the agency. For example, in exchange for allowing a displaced family to remain in a house with set rent levels and duration, durable upgrading works to the property (such as installing windows and doors, or bathrooms) would be undertaken. Cash-for-rent and other cash-based programming have also been piloted;
- Community construction activities, such as quick impact projects, to support over stretched public services in host communities with large populations of refugees and IDPs, often engaging cash-for-work or skills building modalities.

Requirements for shelter upgrading or rehabilitation may be situated within a range of shelter and settlement typologies from areas of transit to formal camps, spontaneous sites, collective centres, hosted and rented accommodation, and return locations. Criteria assessing the adequacy of shelter goes beyond “covered living space” and includes sufficient and appropriate access to services and infrastructure, such as water and sanitation. Shelter interventions in unfinished and abandoned buildings therefore include improvements to these key services and utilities at the building, household or shelter level [65]. At settlement level, this responsibility is undertaken by duty bearers with the support of the international organizations.

Building status

The local authorities stated that, prior to commencing interventions, a number of pre-requisites need to be in place in order to ensure the legality of shelter improvement support in a particular building or site. Confirmation that the building conforms to governmental planning and building regulations is required, as well as that potential interventions meet local legislative requirements, conditions or constraints and have official approval from the authorities. In some cases, at the physical level, the condition of the building may be so substandard that it would pose more risk to residents to promote their continued occupancy (for example, in buildings where the structural integrity has been so severely compromised as to present a serious danger), and so it would be better to facilitate a discussion on relocation. This also has budgetary implications, whereby the

excessive cost of rehabilitating a building in such poor condition is hard to justify against the number of potential beneficiaries if the greatest needs are to be met.

Ownership of the building must be determined before agreements on occupancy and rehabilitation can be made in order to best protect the rights of displaced populations to attain durable shelter, as well as to protect the rights of owners and landlords, and reduce likelihood of conflict or tension in the community that may negatively impact displaced families.

During the process of identifying and confirming building and ownership status, ongoing consultation and involvement of affected families, target groups and key stakeholders (particularly local authorities, community representatives and building landowners) are necessary in order to come to agreement on whether works will be acceptable to all parties, and the acceptable extent of those works. This should be a participatory process of engagement that enables decisions on assistance to be made rapidly, informing the next stages in the process, but is also an important opportunity to advocate and negotiate for the rights of displaced and conflict-affected persons to achieve durable shelter. Technical design should only proceed once it is clear that agreements will be accepted and signed.

Technical design

The local authorities and the international organizations agreed that once general needs and pre-requisites are clarified and confirmed, a technical building survey by a qualified engineer is needed to determine the exact scope of works required to make the building safe and adequate. This builds on the information collected through preliminary assessments of intervention priorities and occupants' shelter needs, to enable a detailed plan for shelter assistance to be developed. This will lead to detailed design, drawings, bills of quantities and other planning and monitoring tools (e.g. scope of works, schedule of works) necessary for the implementation of works to agreed designs, quality, specifications and timeframe.

The design of interventions and specification of materials were supposed to conform to Iraqi National Building Codes, as well as to local regulations (Table 10). Where deviations occur, for example due to lack of market availability, alternatives should be approved by the relevant local government department. Design should include consideration of connecting to services and utilities, as well as the ability of beneficiary families, owners or local authorities to operate, maintain and repair the works undertaken (including the bearing of costs).

Table 10. Safety and adequacy design considerations (according to Shelter Cluster Iraq regulations [64]).

Safety includes consideration of:	Adequacy includes consideration of:
Natural hazards (e.g. high winds, floods, health)	Adequate privacy
Localised risks (e.g., fire, pollution)	Adequate space and lighting
Other risks (e.g., ERW, areas of conflict)	Physical accessibility
Risk and hazard prevention, preparedness, mitigation, and response (e.g. fire, falling/trip hazards, injury, electrocution)	Adequate security
	Security of tenure
Siting and location of shelter	Structural stability and durability
Structural integrity	Protection against the elements
Layout and detailed design	Heating and ventilation
Construction quality	Adequate basic infrastructure, such as water supply, sanitation and waste-management facilities
Quality of materials	Suitable environmental quality and health-related factors
	Adequate and accessible location with regard to work and basic facilities
	Affordable cost

Where the distribution of kits consists of items which could lead to invasive repairs or upgrades to buildings (e.g., sealing-off kits, tenant-driven upgrades), beneficiaries should be assisted to obtain formal permission from building owners before installation of such items. Otherwise, there is a risk that beneficiaries will inadvertently breach the terms of their verbal or written lease agreement, wherein repairs or upgrades by the tenant without permission from the building owner are often not permitted, thereby putting themselves at risk of eviction.

Implementation of shelter assistance in the context of unfinished and abandoned buildings (such as rehabilitation/durable upgrading or sealing off) may occur through a number of different forms. Some of the main benefits and obstacles of various approaches are suggested below (Table 11), although these will be highly context-specific and should be evaluated more closely as part of the Technical Design phase alongside agency capacity and experience; budget and time availability; capacities, vulnerabilities and interests of owners and affected households; local authority requirements, and other factors.

Table 11. Suggested approaches (by Shelter Cluster Iraq) of the main benefits and obstacles as part of the technical design phase [73].

	Form	Brief description	Benefits	Obstacles
In-kind assistance	Agency implementation Contractor	Implementing agency tenders and contracts a professional contractor to undertake works	Generally faster construction times. Quality assurance. Reduced unit prices for materials through bulk/wholesale purchasing. Useful for high value projects, standardised, or large-scale works (procurement thresholds).	May not accept small works or variations to best meet beneficiary needs. May not engage with local community or benefit local economy. Other commitments may have knock-on delays.
	Agency implementation Local labour	Implementing agency recruits local labourers or labour teams to undertake the works	Supports local economy and employment (host, displaced). May contribute towards social cohesion. Builds skills amongst recruits. Greater likelihood of acceptance by local community. Interventions attuned to needs. Simultaneous construction across multiple sites.	Recruitment and training of labourers, labour teams and team building is time-consuming and requires significant prior planning. Complex management required of materials, tools and labour. High resources needed for supervision. Higher likelihood of slow progress or lower quality.
	Owner-driven	Assistance is provided to the building or landowner in order to undertake works	Provides an incentive towards security of tenure for occupant displaced families. Opportunity for assuring quality.	Close technical support and supervision required to ensure quality and timeliness. Improvement in building standard may prompt an increase in rent or risk of eviction.
	Tenant-driven	Assistance is provided to the tenant/occupant in order to undertake works	Interventions meet needs more effectively. Empowerment of affected families. Skills building opportunity.	Quality control issues. Requires high technical supervision and resources. Risk of diversion of assistance to meet other, more pressing needs. Requires close negotiations and monitoring with owners.

Cash-based	Vouchers	Materials/tools in order to undertake the works are purchased on the local market through redeeming vouchers at shops.	Supports local economy and may indirectly contribute towards social cohesion. Control over quality / specifications.	Access to markets is required. Wide and consistent availability of items on local markets is necessary. High resources needed for subsequent implementation to time/quality.
	Cash	Cash is provided to allow beneficiaries to purchase materials / tools and/or hire labourers in order to undertake the works.	Allows beneficiaries to contribute to self-assistance with dignity. Benefits local economy. May result in more rapid delivery and greater quality, meeting needs in most appropriate ways.	May increase vulnerabilities /conflicts in or between households (including with host community). May not be used to meet effectively shelter needs if other needs are more pressing. High resources needed in terms of management and supervision.

Technical inspections are normally made by agencies based on scopes of work and bills of quantity. The involvement of local authorities and key stakeholders (IDPs, owners) in monitoring progress is advised by the UN agencies.

As clarified by the signed agreements once works have been completed, there may be a Warranty Period during which time defects should be corrected and Technical Acceptance by the implementing agency (and local authorities if relevant). Handover to owner and/or occupants should be undertaken.

Post completion: As suggested by the agencies, in order to evaluate whether assistance has been effective in improving the safety and adequacy of shelter, Satisfaction Surveys should be undertaken after completion with project beneficiaries. Post-Distribution Monitoring (PDM) may also be required if items, kits, cash or vouchers have been distributed to beneficiaries. Other means of monitoring and evaluating the impact of the interventions may be through: post-completion technical surveys, focus group discussions with communities (host, beneficiary), key informant interviews with other stakeholders (including land/building owners and local authorities).

Agencies suggest that the actors implementing rehabilitation have a responsibility to monitor the following aspects:

- The reduced/free rent period is honoured;
- Any disputes are identified and resolved;
- Occupancy rates are defined;
- Beneficiary intentions for after the reduced/rent-free period are defined;
- Special needs of the families beyond the scope of the shelter assistance are referred to other agencies and service provided as possible.

The needs encountered by the newly displaced, those experiencing multiple and/or prolonged displacement, returnees, host and non-displaced communities have been of large scale and complexity. This has made it necessary to try ways to integrate effectively sectors, for reasons of stimulating longer-term impacts, cost-effectiveness and sometimes due to changing security and access situations.

Examples include hiring local labour from the host city and/or IDPs to implement the construction of shelters with training in operation and maintenance to ensure that shelters and settlements remain in serviceable condition and to strengthen a sense of ownership.

Over 80% of the IDPs from Mosul, reported partial or significant damage to their homes and cite this as a key obstacle to returning. Furthermore, as over half of the above-mentioned IDPs families report that their houses are completely destroyed [39], small repairs will be insufficient to cover this caseload. Government and private sector interventions are essential. However, even before the crisis, the housing market was unable to deliver housing at scale, even though demand was high [63]. Key constraints include access to funding for individuals for the construction or reconstruction of their property, a lack of suitable residential land due to past planning failures, and a government-driven housing delivery model [72].

At the national level, 64% of IDP households reported that improvements to their shelter were needed [65]. 44% of IDP households had issues with their shelter, which were most commonly related to the lack of insulation (19%), the risk of fire (16%), and a leaking roof when raining (12%) [65]. In a country with extreme weather and hot summers, these issues affect the day-to-day life and comfort of IDP households.

About 10,000 individuals of the in-camp population originating from Mosul indicated they had previously rented a house or apartment prior to the crisis (Intention survey January 2018, CCCM). Furthermore, a significant number of residents who fled West Mosul did not go to camps but sought refuge in East Mosul. Displaced households within the same district are not recorded as such by Ministry of Displacement and Migration (MODM) or humanitarian

agencies yet should be considered displaced to all intents and purposes. Because of increased demand of already scarce housing, rental prices in East Mosul have increased and are still rising.

The monitoring of new arrivals between January and April 2018 (the shelter cluster in Iraq) suggested that 50% of new arrivals of approximately 3,400 families were displaced because of financial/economic reasons, for example the lack of jobs or money to pay rent. Around 5%, approximately 340 families, indicated that they had been evicted by their landlords [66].

3.5. Ongoing self-reconstruction process in west Mosul

Currently, the main actors for housing rehabilitation in Mosul are UNDP, UN-Habitat, UNHCR, Human Appeal, and Norwegian Refugee Council (NRC). Many agencies cover damage categories; 1 (minor) and 2 (major) and in exceptional cases 3 (severe) to rehabilitate houses to the minimum repair standard. The data below suggests that the housing rehabilitation activities does not match the severity of damage in the city, because:

- Severely damaged/destroyed buildings are in many cases not covered by housing rehabilitation programmes;

- Residential dwellings above shops, of which the top floor is often damaged, should be considered for repair as it facilitates the return of shopkeepers;

- Coordination in the Old City remains difficult.

The implementation of a rapid and targeted self-reconstruction process for the returning residents of the Old City is of paramount importance. Self-build reconstruction aims to develop an active framework for rapid reconstruction with the participation of the local community.

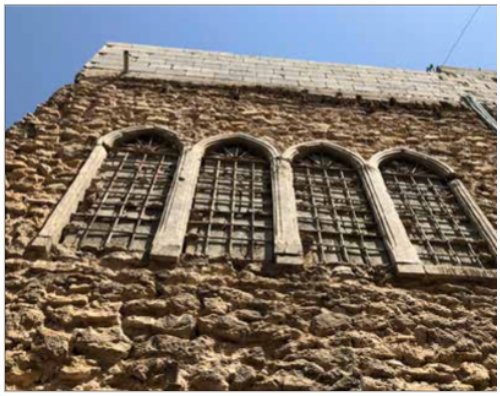

Figure 64. Ongoing reconstruction in the Old City. Examples of the result of residents not having access to traditional building material. Local residents' engagement in the reconstruction of private houses (Source: author).

The process that is currently being developed is an urgent response to the needs of the displaced communities to re-construct their homes, religious, educational and public spaces. Setting up a self-reconstruction system for the Old City represents an absence of issues like the lack of availability of appropriate construction materials and expert help (Figure 64). There is a growing feeling that there should be more immediate long- and short-term action taken to create the conditions for the community to re-build their own properties.

3.6. Return challenges

By June 2016, the Iraqi Forces supported by U.S. and Coalition air force had retaken most of the territories held by the Islamic State in Iraq and the Levant (ISIL). Operations started to liberate parts of Nineveh in October 2016. By the beginning of 2017, Iraqi forces and the international Coalition had liberated East Mosul from ISIL. According to the International Organization for Migration (IOM), during that operation to liberate the city, 182,000 people displaced from East Mosul, receiving temporary housing camps. 70,000 of them returned to their homes by March 2017. Around 300,000 people stayed in liberated East Mosul.

When the operations ended in East Mosul and despite the damage, life began to resume quickly in that part of the city. Basic services started to open, such as commercial and educational services. In West Mosul, the operations to liberate it started in February 2017. Up to 750,000 of the local people decided to stay in West Mosul at the beginning of the conflict. According to IOM, the fighting to liberate West Mosul from ISIL caused the displacement of additional 153,000 local people by March 2017. Total displacement from both East and West Mosul, after accounting for returns, was 270,000 by March 2017 [39]. By July 2017, approximately a million people had been displaced by the conflict in Mosul, and some 200,000 had returned and 822,000 remained displaced [70].

Following the number of internally displaced persons (IDPs) in Iraq that returned to their Area of Origin (AoO) over 2016-2017, the rate of return has slowed and has remained low since 2018. By May 2019, IOM estimated that 76% of IDPs from Mosul had returned to the city. While

approximately 305,000 remained displaced in other areas of Iraq. Interviews with local people from West Mosul, who are displaced in IDP camps, revealed several concerns. The experiences of these IDPs differ from the people who stayed in the city. Although there are common patterns occurred in the observational walkthrough visits and interviews across the visited IDP camps, there are important differences in the experiences of IDPs.

In 2019, the Iraqi government initiated a plan to close IDP camps in order to facilitate returns. As of February 2020, 1.4 million IDPs remained in protracted displacement throughout the country. This includes almost 55,730 individuals who reside in 43 IDP formal camps, or 67 camps when including sub-camps in composite camp areas.

A study implemented in liberated areas in the north of Iraq which host the displaced people from Mosul, found that security in the area of origin appeared as the main factor influencing the decision to remain in displacement or return to Mosul (Figure 65) [74]. 52% of local people returned because security was considered good in their area of residence, mainly the people from the eastern side of the city. While 28% of IDPs remained displaced because of the security issues. Secondary factors encouraging the displacement were lack of services and damage or destruction of property back home.

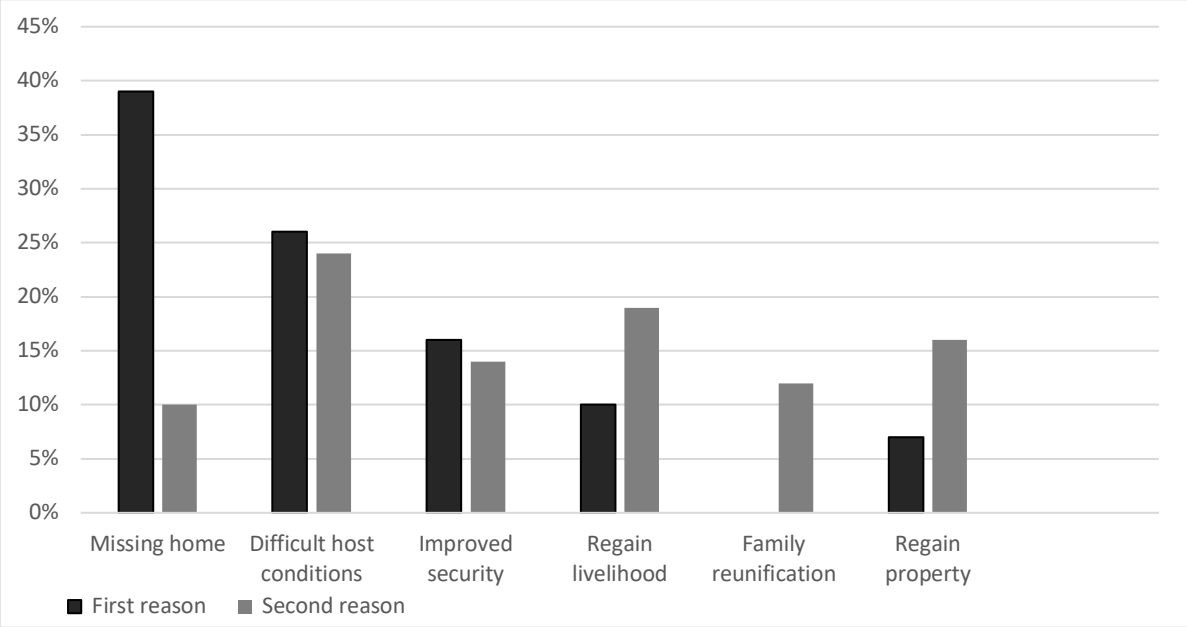

Figure 65. First and second factors for return among IDPs [74].

Hazards' risk: There have been some concerns over whether the returns are safe. Major concerns have been raised regarding explosive ordnance contamination. In the first two days of in an assessment conducted by United Nations Mine Action Service in November 2017, in the

first two days of the assessment more than 100 explosive bombs were reported by local people of the Old City to the clearance teams on Nineveh Road [75].

ISIL hiding: After East Mosul was liberated from ISIL, a report found that there were security concerns, including claims of revenge attacks from unknown armed groups and attacks from ISIL fighters in West Mosul, and threats from extremist sleeper cells throughout East Mosul.

Destroyed houses: Many IDPs are unable to return because their houses have been destroyed, either by ISIL invasion or during the operation to liberate the city from ISIL and renting or buying new houses is expensive. Some houses are still standing but require major interventions that IDPs cannot afford.

Occupied houses: other IDPs are unable to return because their homes have been illegally occupied by other people and they lack the necessary documentation to reclaim their houses. In some cases, security forces have been implicated in the unlawful occupation or transfer of properties. This pattern of confiscation suggests that security forces may be using the social and legal vulnerability of the local people of Mosul accused of association with ISIL to occupy their properties.

Safety in host cities: some IDPs expressed a preference for staying in their camps because they feel that they are safer there than they would be in West Mosul.

Looting of homes and high levels of crime in west Mosul were also identified as obstacles to safe return.

Slow reconstruction, poor quality of services and lack of financial support: Many IDPs expressed frustration with the unguided slow process of reconstruction in West Mosul, poor quality of basic services, and lack of financial support for the people who lost their houses either during ISIL rule or the subsequent airstrikes to liberate Mosul.

They lack of the necessary documents that would enable them to access Iraq's social welfare system, particularly individuals with family ties to ISIL. Family members of suspected ISIL members have been unable to obtain essential documents including birth, death, marriage and divorce certificates, identity and welfare cards, and passports because obtaining these documents requires a security screening by Iraq's Interior Ministry, Intelligence, or National Security Service (NSS) officers. Families of suspected ISIL members often fail these background checks. Furthermore, obtaining documentation can be particularly difficult for women because in Iraq, social welfare entitlements are often registered under the names of male heads of household and are difficult to transfer to the name of the wife if her husband is dead or missing. Interviewees

reported that many IDPs are afraid to return to west Mosul because they fear retaliation because of their actual or perceived association with ISIL. This is particularly true of children, wives, and mothers of alleged ISIL fighters. Even though in most cases, the ISIL fighters are missing or dead, their living relatives cannot escape the stigma of association with the group.

Conclusions

The understanding of Mosul population's ethnicity and religious background is important for the design team during the reconstruction of the city. ISIL was targeting the minorities' houses by different types of violations including confiscation, selling their heritage items and mostly destroying them. Therefore, the revival of the architectural features that belong to these groups in the reconstruction plan will be essential.

The urgency of the reconstruction of Mosul is shown throughout this research in almost all the aspects of the current (post-war) housing conditions and challenges. The scale of the displacement has resulted in significant overcrowding host cities, hosting the IDPs from Mosul, such Duhok and Erbil. The efforts of upgrading the living conditions of the IDPs in these cities are continuous but still do not cover the housing needs. The current housing solutions in those cities are still considered short-term solutions although they have been upgraded. The host cities are also hosting refugees from Syria, which just makes the situation more complicated.

In the other hand, in Mosul, there are still no governmental plans to deal with the housing shortage. A lack of public awareness in relation to the ongoing reconstruction efforts in Mosul and the options available, for example, financial compensation options for self-reconstruction of private properties and the demonstration of the need of a city-wide public campaign on the value of historical buildings. Poorly guided and hasty reconstruction activities are presently underway, without an appropriate understanding of the urban context or adhering to any building guidelines. As a result, the historic and heritage identity of the Old City is at risk.

While in camp contexts, several intervention opportunities exist to help support people in the design of their shelters, including participatory design, knowledge sharing, and the participation of the IDPs' skilled and unskilled workers in the implementation of the projects. In Mosul, most of the design and construction work transpired through informal self-help and community-supported processes. These practices suffered from several issues such as inadequate quality and design errors.

The local people who lost their houses are finding it easier to build new houses in illegal or informal areas. Without a holistic plan to rebuild their houses in a supervised way, Mosul locals

will continue the increase of these informal unregulated areas.

The majority of the remaining IDPs are unwilling or unable to return to their areas of origin. Some have nothing to return to following the destruction of their homes. Nor are durable solutions guaranteed when people are able to return to their areas of origin.

4. DAMAGE ASSESSMENT AND RECONSTRUCTION CHALLENGES

Between 2003-2013, a decade after the fall of the former regime in Iraq 2003-2013, Mosul had been controlled by armed groups. This period before the ISIL invasion of Mosul, also resulted in the destruction of the houses. However, most of the severe destruction in the housing sector occurred after August 2014. The present chapter is based on the understanding that the houses in Mosul city were already in a state of damage for ten years before it was officially invaded by ISIL in June 2014 (based on the findings of chapter 3).

Several months of armed conflict in the struggle to liberate the city from ISIL has left behind a devastated urban landscape, characterised by destroyed monuments, demolished houses, damaged buildings, destroyed infrastructure, extensive piles of rubble and areas contaminated by unexploded ordnance.

This chapter aims at assessing the scale of architectural damage in Mosul by means of qualification, quantification and distribution of the constructional rubble generated from the last war. Categorizing and estimating constructional rubble quantity allows verifying the possibilities of the application of reclaim, reuse, and recycling of the materials and products in the reconstruction design approach. This chapter outlines the importance of the assessment of construction rubble in Mosul for providing a necessary tool to evaluate the true size of rubble and make adequate decisions for its minimising and sustainable management.

In the present chapter, rubble of the Old City is studied by defining the destroyed areas using the data collected from the fieldwork (during May and June 2019), satellite images, and comparing reports from Mosul municipality and the international organizations including UN agencies and others mentioned through the chapter. Interviews to the committee responsible for the reconstruction of Mosul, decision-makers in Mosul municipality and data analysts at three United Nation agencies working on ground were conducted [39] [40] [63] [73] [66] [76] [75] [67]. They put in evidence existing post-war efforts of the government and the international aids for the reconstruction of Mosul. The study shows a strong concentration of the rubble in west Mosul and in particular in the Old City.

This chapter is divided into four main parts: (1) Characterization of rubble; (2) Quantitative analysis of rubble; (3) Distribution of the rubble in Mosul; and (4) Current efforts for the rehabilitation in Mosul.

4.1. Data collection and methodological approach

The main reasons behind the choice of Nineveh's governorate and its main city (Mosul) for post-war related studies were presented in the previous chapter (Chapter 3). A special attention is given to the Old City of Mosul (Figure 66) in this chapter because of its important heritage value and because it is the most affected area in Mosul.

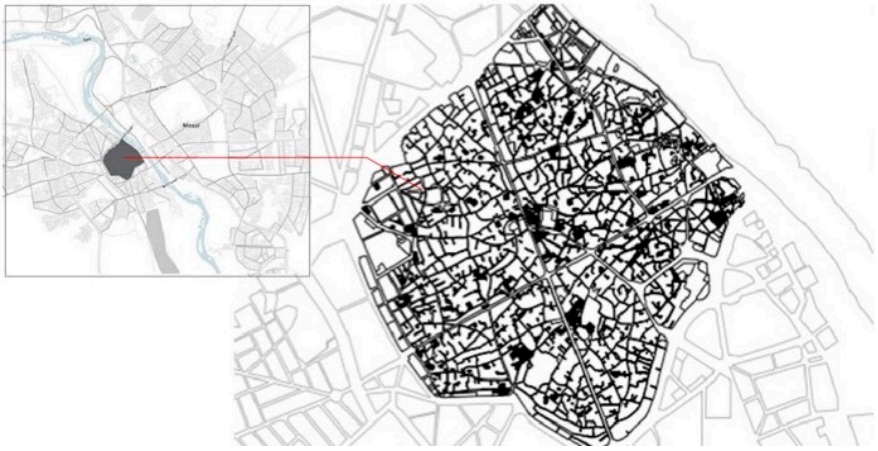

Figure 66. The Old City in Mosul (Source: author).

Walkthrough visits, interviews with local people, interviews with local authorities and international organizations were conducted in Mosul (during May and June 2019, as explained in detail in the previous chapter). The officials' interviews followed a scheme divided into five main parts: (1) general information, (2) existing studies, research and reports, (3) involvement of the government and the international organizations in reconstruction process, (4) actions taken for rubble management, (5) actions taken for heritage protection. With some officials, they preferred an open discussion instead.

The interviewed officials helped the author to get access to confidential reports published by Mosul municipality, Ministry of Housing in Iraq and UN agencies. The following officials helped the author with the permissions needed every time she had access to the Old City to take photos and to inter specific buildings and streets: Dr Muzahim Al kayatt, president of the Nineveh University and the committee that is responsible for the national efforts to retrieve the services in Nineveh province; Abdulsattar Al Habbow, director of Mosul municipality; Ivan Thung, urban data analyst at UN-Habitat; Bayan Dizayee, former Minister of Housing and Construction of Iraq; Hassan Partow, programme manager (post conflict and disaster management branch) in UN Environment; Thaer Ghanim, programme manager in UN-Habitat; Ahmed Alomary, Head of the Architecture Department in Mosul University; Dr Suhaib Yehya,

head of consultancy engineering bureau in Mosul University; Sinan Subhi, deputy director in Nineveh environment directorate; Sadeem Ismael Senior engineer of the United Nations development programme in Iraq.

The destruction scale of the Old City was determined by gathering satellite images from DigitalGlobe and Earth Explorer. Using satellite images, the destroyed areas in the Old City were identified before the fieldwork. Then, the destroyed sites were visited by walkthrough observational visits. Later this was compared to the data collected from the interviews with local authorities and then the map of the destroyed buildings was drawn using AutoCAD.

The identification of the potentially contaminated sites was made by using the map of Environmental Hazards Assessment provided by the UN Environment and local people of Mosul who marked some sites.

Whenever ground-based data gathering was not possible due to the challenging security conditions and the inaccessibility of areas, data gaps were filled with remote based data, such as remote contacts with locals and satellite imagery, existing public information and data available online from humanitarian agencies.

The limitations of this work are as follows:

1. It is necessary to distinguish between rubble and the broader category of disaster waste that refers to "all solid and liquid waste generated from a disaster, not limited to rubble: concrete, steel, wood, clay, tar elements from damaged buildings, infrastructure, household furnishings, parts from power and telephone grids such as electrical poles, wire, electronic equipment, transformers, parts from water and sewerage distribution centres, natural rubble such as trees, mud and plants, chemicals, dyes and other raw materials from industries and workshops, waste from relief operations, damaged boats, cars, buses, bicycles, unexploded ordnances (packaging materials, pesticides and fertilizers, paint, varnish and solvents and healthcare waste" [75]. The disaster waste management guidelines were developed by the Office for Coordination of Humanitarian Affairs (OCHA), the United Nations Environment Programme (UNEP) and the Swedish Civil Contingencies Agency (MSB) [76]. The assessments related to the rubble address the construction rubble generated from the houses from the conflict in the city of Mosul, until its liberation in July 2017. In this context, rubble includes damaged houses' constructional materials. It does not include furniture neither the waste produced on a daily basis by the housing sector.

2. While information about the impact of the conflict in Iraq exists, its use is limited for two key reasons: the information is fragmented, and critical data are often confidential (agencies have data they are so far not able to share). Lack of baseline information, i.e. absence of baseline information at the city level, is another challenge. Most of the humanitarian actors on the ground report damages to facilities, not in the perspective of baseline information. This limits the ability to conduct a systematic assessment of the effect of conflict on the sectors and services. The study has focused on closing this gap by comparing the reports from different actors on the ground, government and humanitarian actors, with the satellite imagery and observational visits. Some reports were provided as a copy when they were sourced from the humanitarian international organizations such as [39] [40] [63] [73] [66] [76] [75] [67]. While the reports requested from the Municipality of Mosul, Nineveh environment directorate and some of the Ministry of Housing and Construction of Iraq reports were not provided to keep as copies, instead they were provided only to review at their offices.

4.2. Scale of destruction

Characterization of the rubble is crucial to identify the composition of construction waste. To achieve continuity in post-war architectural design approach, it is necessary to look back at the history of Mosul architecture to allow categorizing the rubble generated by the conflict according to its heritage value. This chapter is built on the understanding of the traditional architecture in Mosul and Nineveh province and the importance of the architectural heritage in the Old City of Mosul. Definition of the main characteristics of the historical buildings: materials used, design techniques, decorations and ornaments in Iraq and Mosul specifically, was presented in Chapter 2.

The armed groups ahead of the invasion of Mosul city under ISIL control caused damage to the housing sector, but it was not responsible for the severe destruction of it [32]. After August 2014, most of the houses that hosted ISIL fighters were attacked and destroyed under airstrikes during the governmental and international operations as it was reported that some of them were repeatedly bombed (Figures 67 and 68).

Figure 67. Satellite picture showing Al Nuri Mosque in the Old City with the surrounding residential buildings before (left) and after (right) the strikes (Source: earth explorer).

Figure 68. Picture published by Reuters after airstrikes in Mosul (Source: Reuters).

4.2.1. Destruction of heritage

One highly noted aspect of ISIL's system of destruction in Syria and Iraq that came to the media's attention was their program to destroy the cultural heritage by destroying artefacts in archaeological museums, iconoclastic breaking and bulldozing of archaeological sites, exploding of shrines, and other historical sites of local communities and the burning campaign of the libraries and archives [77]. The historical houses were not an exception of this campaign.

The destruction of cultural heritage in Iraq by ISIL served two purposes, to prove its dedication to its own belief system in the eyes of its followers and as a tool to gain the attention of the wider world [77]. Connected to the problem of cultural terrorism is the illegal trade in antiquities, an issue that is a source of revenue to terrorist groups and has the same effect as the destruction of antiquities, for once an item is sold on the black market, it is rarely recovered and for all intents and purposes is lost to the world [78].

ISIL considered all relics that came before Islam to be polytheist. They abolished statues, sculptures and many artistic objects. ISIL used the destruction of decorations and sculptures to show their power. They were using the destruction to hide other actions, including the stealing of ancient relics [79].

The Islamic State has developed an unusual practice of deliberately damaging archaeological sites and museums, alongside its continued attacks on local shrines and holy places that are dear to local communities. In well-publicized news reports, often issued by ISIS itself, valuable heritage sites in Nineveh, Nimrud, and Hatra, and possibly Ashur and Palmyra were reported to have been attacked or threatened to be destroyed. They used a series of carefully disseminated videos and imagery.

Outside Mosul city, ISIL almost fully destroyed the Assyrian city of Nimrud (11th century BC) [78]. ISIL fighters used heavy equipment in the city of Khorsabad (9th century BC) to target its thirteen human-headed winged-bull/lion statues (Lamassu) that are approximately 2,700 years old [78]. On February 26, 2015, ISIS posted a video on YouTube platform, showing the deliberate destruction of what seemed to be authentic ancient sculpture in the Mosul Museum and the archaeological site of Kuyunjuk (the citadel of ancient Nineveh) in Iraqi Kurdistan (Figure 69).

Figure 69. Image taken from a video reportedly released by Media Office of the Nineveh branch of ISIL on February 25, 2015, allegedly showing an ISIL militant destroying the statue of Lamassu, an Assyrian deity, with a jackhammer in Nineveh (Source: AFP).

This destruction can be seen as a form of place-based violence that intends to annihilate the local sense of belonging, and the collective sense of memory among local communities to whom the heritage belongs [77].

Within the city of Mosul, the devastation of cultural heritage occurred in five main waves:

1. July 2014
2. September 2014
3. Late December 2014

4. January 2015
5. March 2015

Each demolition was executed by a group of ISIL militants headed by a ‘shaykh’ whose identity was often known to the local populace [38]. Due to these circumstances, the assaults on cultural property were not anonymous acts perpetrated by shadowy figures, but crimes that are attributable to individuals with the possibility of criminal prosecution in the future [80]. Some assaults provoked resistance from local people of Mosul, who, in exceptional cases, prevented destruction (like the case of the minaret Al Hadba) [66]. According to witnesses from local residents of Mosul, some mosques and churches were thoroughly searched prior to demolition and all valuables were transferred to unknown locations [38].

The destruction of the Islamic period architecture in Mosul has irreversible consequences both on the world cultural heritage and on Mosul’s urban integrity [80] (Figure 70). Nearly all of the architectural landmarks that formed a unique panorama of the city have been removed (such as the Mosque of the Prophet Yunis in Nineveh, the Shrine of Imam Yahya ibn Al Qasim, the Mosque of the Prophet Seth, and the Mosque Al Khidr). In this devastation, nearly the entire religious buildings established during the reign of Badr Al Din Lu’lu’ (AD 1259), representing Mosul’s School of medieval architecture, have been erased from the city. This school represented a composition of Christian and Shi’ite architectural forms (Figure 71), unique in the Islamic world and little researched by scholars [18].

Figure 70. Ruins of Grand Al Nuri Mosque, Mosul, Iraq (Source: Reuters).

Figure 71. Damage of Minaret of a Shi'a Mosque (Source: author).

Several important examples of the peculiar group of Early Ottoman mosques (16th - 18th century AD) disappeared as well. The city, previously one of the most attractive historical centres of the Near East, has lost many of the elements that created its identity [81]. The systematic removal of heritage buildings and places of worship, venerated for generations, was used as an effective means of humiliation and cultural disintegration in the ongoing ideological struggle with local communities [82] (Figure 72 and 73).

Figure 72. The interior of Al Tahera (Syrian-Orthodox) church located in the far north of the old city of Mosul, Bombed in 2017 (Source: UNESCO).

Figure 73. Ruins of the British cemetery in Mosul, demolished by ISIL (Source: Mosul Eye).

By the end of May 2016, 41 buildings of historical value in Mosul were found to have been either ruined or completely razed. 114 other cases of Islamic period heritage have been confirmed in Nineveh province alone, but the survey is largely incomplete [83]. Religious buildings of all denominations were the primary target of destruction, particularly historical monuments with strong symbolic and interreligious meaning, most venerated by the local people [38]. The most heavily targeted structures in Nineveh province appear to be Shi'a places of worship, but in Mosul itself Sunni mosques, madrasas, mausoleums and shrines dominate the list of destroyed heritage. Further destruction on the Yazidi shrines in Sinjar, Bahzani, Ba'shiqa and others, a cultural eradication that was part of the genocide committed against this unique indigenous religious minority.

4.2.2. Damage assessment

According to the UN-Habitat [84], satellite images show the destruction: around 135 locations in Mosul damaged from June 2014 to September 2016, some of them have been completely wiped out. Out of this number, 86 locations are public buildings including governmental office buildings and educational buildings, while 49 locations are houses. Some buildings in Mosul University, which was used as headquarters of ISIL fighters, were damaged in late 2014 – early 2015. Some houses that belong to police and army officers were rigged. Some neighbourhoods were destroyed by airstrikes in April and May 2015.

The reports of the Mosul municipality observed during the visits to the municipality show that the destruction of the buildings in Mosul was caused by both the ISIL sabotage and the military operations to liberate the city from ISIL. It is reported that more than 60% of the destruction happened by August 2016.

Between 16 June and 8 July 2017, most observed damages occurred in western Mosul (right

bank), where airstrikes had hit residential neighbourhoods. The Old City was attacked harder since June 2017 and additional 5400 severely damaged or completely destroyed houses occurred. Only severely damaged and destroyed buildings could be inspected by the satellite imagery. Thus, the number and the level of damage in the houses is higher (Figure 74).

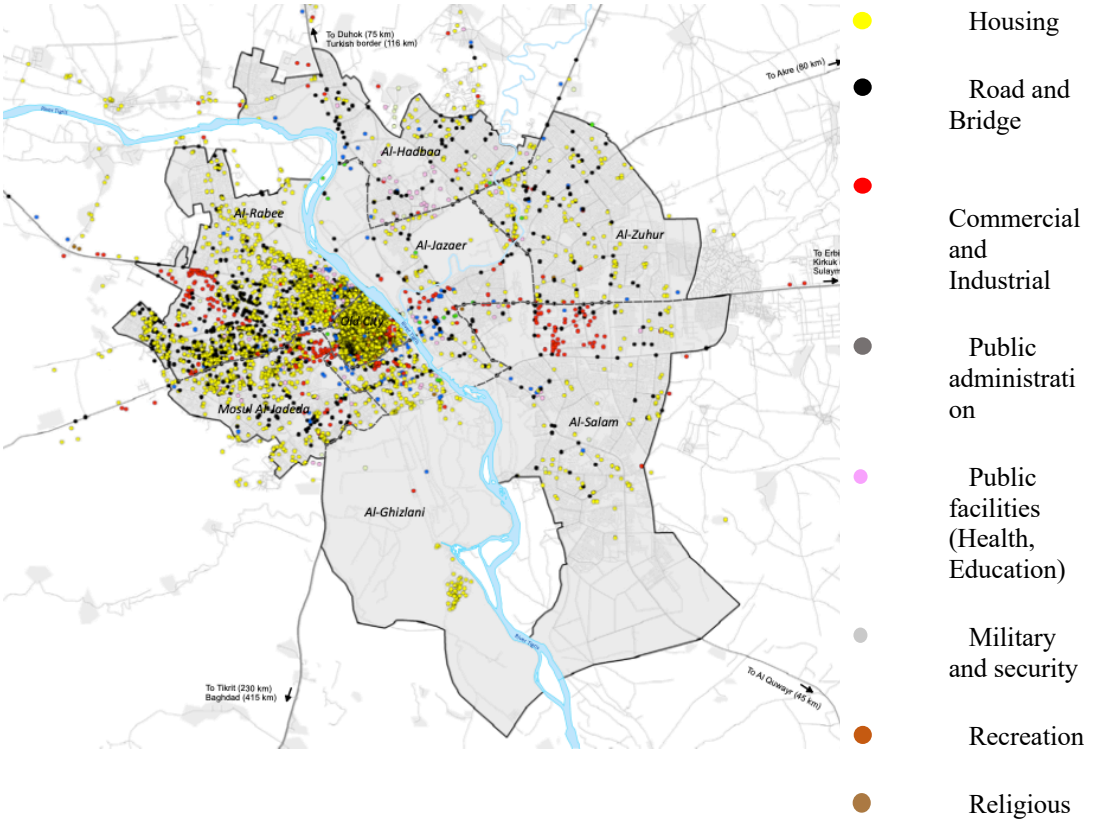

Figure 74. Damaged sites per sector as of July 2017 according to UN-Habitat damage assessment [84].

The reports of Mosul Governorate office indicate that in the last weeks of the operations, the Old City was hit hard. Satellite imagery suggests that over 5000 residential buildings are severely damaged or completely destroyed, and a total of 126 hectare of buildings over the whole duration of the retaking operations. Estimations of the Mosul municipality suggest that there are approximately 16.000 residential buildings in the Old City. This implies that almost one-third of the housing stock is most likely severely damaged or completely destroyed because of the retaking operations (Figure 75).

In August 2017, the Mosul province office and Mosul municipality worked with the others international actors involved in rehabilitation programs started to develop a War Damaged Shelter classification scale to records the degree to which a building site has been damaged or destroyed [40]. Two features define this classification chart; the **heritage value** viewed in conjunction with the **degree of damage** sustained.

Later, according to UNESCO and UN-Habitat [40]: **damage assessment** was defined in five levels, through the identification of primary features of the building. the primary purpose of the database was to produce an overall measure that indicates both the value of a heritage site and the extent to which it has been damaged or destroyed. This classification is agreed upon by development actors working in Mosul.

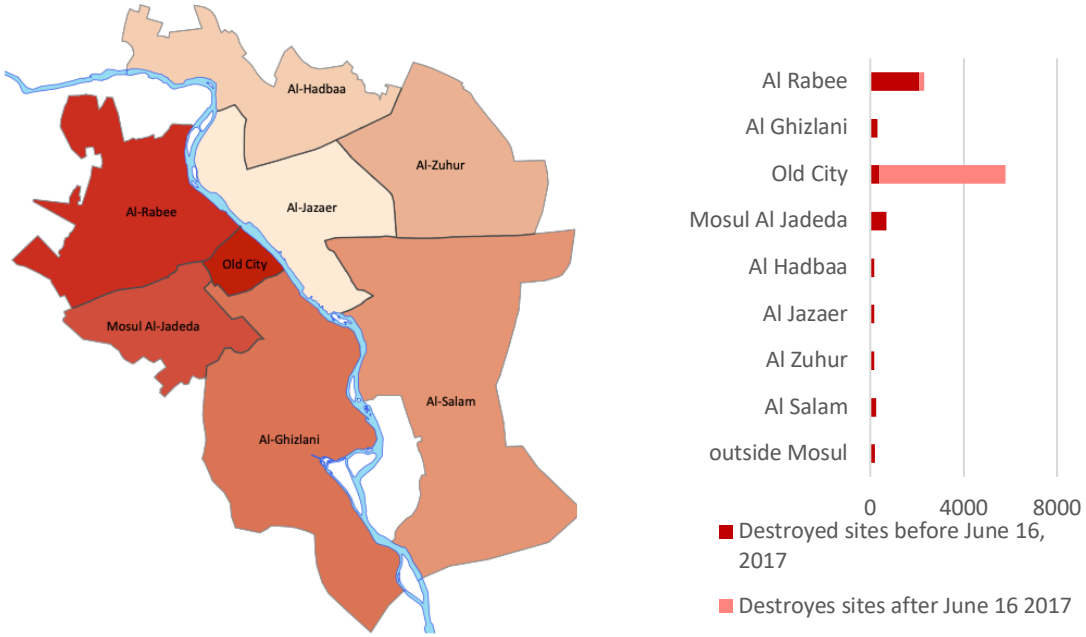

Figure 75. Destroyed sites per municipal sector according to the report of Mosul Municipality (Source: author).

0 Negligible

Walls and loadbearing elements: no damage caused by conflict or damage limited to external finishes or boundary walls.

Roof slab and roof covering: slight cosmetic/external conflict traces to roof or parapets (bullet holes, superficial shell damage).

External windows and doors: slight cosmetic/external conflict traces to roof or parapets (bullet holes, superficial shell damage).

Finishes, water and electricity: slight cosmetic/external conflict traces to roof or parapets (bullet holes, superficial shell damage).

1 Minor

Walls and loadbearing elements: slight superficial cracking with no observable deformation or structural elements or limited mortar and shell perforations to walls.

Roof slab and roof covering: limited mortar and shell perforations to roof or parapets.

External windows and doors: minor damage to windows and frames. External doors missing, or damaged.

Finishes, water and electricity: internal spaces damaged by shells, damage across multiple floors. Fire damage can be repaired.

2 Major

Walls and loadbearing elements: extensive shell perforation, no observable deformation of structural elements.

Roof slab and roof covering: minor damage by shells penetrate roof, but roof internal spaces damaged by shells. Damage across multiple floors. Fire damage can be repaired.

3 Severe

Walls and loadbearing elements: structural damage involving several loadbearing members, significant cracking with observable permanent deformations of the structural elements.

Roof slab and covering: damage by large shells penetrating roof. Engineering solutions required to conduct structural repairs of roof.

External windows and doors: damage irrelevant if structure is compromised.

Finishes, water and electricity: severe fire damage that can be repaired but so widespread that renders the house inhabitable.

Structure is otherwise intact, not buckling.

External windows and doors: damage to window frames, external doors missing or damaged

Finishes, water and electricity.

4 Destroyed

Walls and loadbearing elements: reduced to rubble, complete failure of two or more major structural components, extensive cracking or loss of material with gross local or overall deformations.

Roof slab and roof covering: partial or complete collapse of roof, excessively deflected roof, weakened structure at risk of collapse.

External windows and doors: damage irrelevant if structure is compromised.

Finishes, water and electricity: non-repairable fire damage, affecting structural members.

Measuring historical value: According to UNESCO and UN-Habitat [40]: **Historical value** is defined in four grades, through the identification of significant historical features of the building.

Grade A

High historical value:

The buildings represent example of significant historical, cultural or architectural importance. They have played a central role in local, regional and national identity. They have a documented historical role in the old city that has been recorded from their initial construction through to the present day. They are characterized by a unique aesthetic significance, and they constitute iconic cultural landmarks within the historic fabric of the Old City area.

Grade B

Medium historical value:

Buildings characterized predominantly by their age. Their construction took place in an early historical context and are representative (architectural and culturally) from a specific period of the region's history. They may have a specific relevance to historical events or people. These buildings usually show aesthetic significant architectural elements, and they represent a notable part of the historic

urban fabric but do not embrace any significant communal interest.

Grade C

Low historical value:

Buildings constructed in the recent past.

They exemplify architectural design and construction practices or activities from more recent history and do not have a connection with any specific event or person. These buildings are characterized by aesthetic and structural features that are related top local and regional traditional building techniques and represent the most common element of the historic urban fabric.

Grade D

No historical value:

Buildings that have been recently constructed (circa 20th century or later). They are not related to any specific practice or activity within a historical context. They may only exhibit signs of the recent conflict and associated damage. These buildings do not possess any aesthetically significant or important elements.

By using the above method, each heritage building that was damaged in Iraq from 2003–2011 and entered into the database was assigned a numerical score according to both its 'heritage value' (using the V-Scale) and the extent of the 'heritage destruction'. While these two scales are significant in their own right, the primary purpose of the database was to produce an overall measure that indicates both the value of a heritage site and the extent to which it has been damaged or destroyed (Table 12).

Table 12. Matrix developed by UNESCO and UN-Habitat offices in Mosul merging damage assessment and heritage value. Each value relates to a specific code and type of intervention.

Criteria guiding classification of the buildings in the Old Mosul		**A High**	**B Medium**	**C Low**	**D None**
Damage level	4 Destroyed	A4	B4	C4	D4
	3 Severe	A3	B3	C3	D3
	2 Major	A2	B2	C2	D2
	1 Minor	A1	B1	C1	D1
	0 Negligible	A0	B0	C0	D0

4.3. Estimation of the amount of construction rubble

4.3.1. Methodological approach

The estimation of the construction rubble amount in Mosul is important to make the adequate decisions for a sustainable management. Estimation of construction and demolition rubble generated is a mean in assessing the potentiality for rubble reduction. Furthermore, the quantification of wastes enables a more adequate planning of the construction site and the related logistics in terms of containers and their management. This will provide the necessary information not only on the amount but also on the type and time of waste generations. The first step in implementing waste minimization program is to categorize and estimate the quantity and composition of construction waste generated [85]. Environmental and economic gains are incentives for all actors involved in reconstruction to choose for this prior quantification and planning [75].

The existing studies about amount and characterization of the rubble generated from demolished buildings in an urban scale are fragmentary. There are a few available references about construction rubble quantification methods. All the available methods have low applicability as they are focused on new building construction projects [85]. Rubble quantification and the rubble characterization are based on a good practice of site accounting. In [86], Jalali proposed two approaches for the estimation of construction wastes based on the experience accumulated on waste management:

Global Index Approach: This approach is based on the global data from similar construction types that provides the amount of waste per square meter of construction. The global data are gathered from previous construction works and registered on data files that are used as a global index for a given construction. It is noted that this index can be used also for the quantification

of waste from a region or even from a whole country.

Component Index Approach: This approach provides the amount of waste generated from each construction component that composes the project. The construction component has a specific function in the building and is usually performed by a given professional on the site. Furthermore, it has a unit of its own, for example unit area or volume.

As Jalali mentioned and after testing both methods, the Global Index was chosen to estimate the rubble generated in Mosul, given that it can be used for the quantitation of rubble at a bigger scale.

4.3.2. Data collection

The rubble generated on a given site depends mainly on the construction design, construction process, quality and type of construction materials, available equipment and last, but not least, the skill of the workers [88]. The main data needed are the amount of rubble generated by each type of the houses [86].

The data gathering should be repeated for a given construction activity and the way the measurements are performed and registered must be decided. Based on the experience gathered so far, the rubble generated on site should consider a given Construction Component [87].

Rubble quantification in Mosul city was derived from the basic data collected from Mosul Municipality and the reports provided by UN Environment and UN-Habitat [81] [91] [104]. The UN-Habitat rubble review team conducted a quick architectural assessment to estimate the rubble quantities generates in each municipal sector. Then, these factors were associated to the number of damaged buildings of each category in the classification, as well as to the rubble estimated to be generated from each category.

Six types of houses are defined according to their average size and occupancy. Table 13 shows the houses types and characteristics as they were defined for that assessment. The final column shows the results given by UN-Habitat based on the data and the calculations provided from their fieldwork team.

Once defined, the distribution of each house type relating to each other was identified in each Municipal Sector by UN-Habitat and in consultation with Mosul Municipality (table 14).

In Mosul, the high security limits the movement around the city. Many sites are closed and forbidden to reach. There were streets that were closed, and no photographing was allowed even

with the permission provided by the municipality. For integrity of the missing data in the field visit for damage assessment, the UN agencies and province office in Mosul were contacted whenever needed, along with the available reports from the UN agencies.

Table 13. Distribution of building types within each sector.

	No. of floors	**Total area**	**Typical number of occupants**	**Building material**	**Rubble generation rate (t/100 m^2)**
Small single family	2	100	4	Masonry bricks, concrete blocks, reinforced concrete	80
Common house	2	200	6		100
Apartment villa	2	500	9		120
Apartment complex	3	400	40		140
Commercial buildings	4	400	20		80
Old single family	1	100	8	stone and steel sections	120

Table 14. The distribution of each house type in each Municipal.

Municipal sector	**Building types**					
	Small single-family home	Common house	Large villa	Apartment complex	Old single-family home	Commercial building
Al Hadbaa	10%	65%	10%	10%	0%	5%
Al Zuhur	10%	10%	65%	5%	0%	10%
Al Salam	20%	80%	0%	0%	0%	0%
Al Jazaer	25%	50%	10%	10%	0%	
Al Rabee	10%	40%	50%	0%	0%	0%
Mosul Al Jadeeda	25%	60%	10%	0%	0%	5%
Al Ghizlani	15%	25%	30%	10%	15%	5%

4.3.3. Results

1. Old City

Scale		Floors	Occupants	m^2	Rubble generation (tonnes/100 m^2)
Old single-family house	50%	1	8	100	120
Small single family	10%	2	4	100	80
Common house	20%	2	6	200	100
Large villa	5%	2	9	500	120

	Number of destroyed structures	Total estimated rubble generation
Residential	Destroyed/severe damage – 5529	759480
	partly damaged – 9455	567300
Commercial	111	142080
Public administration	38	97280
Religious	12	14400
		1,580,540 tonnes

2. Al Rabee

Scale		Floors	Occupants	m^2	Rubble generation (tonnes/100 m^2)
Small single family	10%	2	4	100	80
Common house	40%	2	6	200	100
Large villa	50%	2	9	500	120

	Number of destroyed structures	Total estimated rubble generation
Residential	1844	1054400
Commercial	97	124160
Public administration	29	74240
Religious	0	0
		1,252,800 tonnes

3. Mosul Al Jadeeda

		Floors	Occupants	m^2	Rubble generation (tonnes/100m^2)
Small single family	25%	2	4	100	80
Common house	60%	2	6	200	100
Large villa	10%	2	9	500	120

	Number of destroyed structures	Total estimated rubble generation
Residential	424	82400
Commercial	51	65280
Public administration	14	35840
Religious	0	0
		183,520 tons

4. Al Ghizlani

		Floors	Occupants	m^2	Rubble generation (tonnes/100m^2)
Old single-family house	15%	1	8	100	120

Small single family	15%	2	4	100	80
Common house	25%	2	6	200	100
Large villa	30%	2	9	500	120
Apartment complex	10%	3	40	400	140

	Number of destroyed structures	Total estimated rubble generation
Residential	204	70440
Commercial	24	30720
Public administration	25	64000
Religious	02	2400
		167,560 tonnes

5. Al Salam

		Floors	**Occupants**	**m^2**	**Rubble generation (tonnes/100 m^2)**
Small single family	20%	2	4	100	80
Common house	80%	2	6	200	100

	Number of destroyed structures	Total estimated rubble generation
Residential	84	14880
Commercial	55	85280
Public administration	06	15360
Religious	01	1200
		116,720 tonnes

6. Al Jazaer

		Floors	Occupants	m^2	Rubble generation (tonnes/100 m^2)
Small single family	25%	2	4	100	80
Common house	50%	2	6	200	100
Large villa	10%	2	9	500	120
Apartment complex	10%	3	40	400	140

	Number of destroyed structures	Total estimated rubble generation
Residential	55	13920
Commercial	22	28160
Public administration	20	51200
Religious	01	1200
		94,480 tonnes

7. Al Zuhur

		Floors	Occupants	m^2	Rubble generation (tonnes/100 m^2)
Small single family	10%	2	4	100	80
Common house	10%	2	6	200	100
Large villa	65%	2	9	500	120
Apartment complex	5%	3	40	400	140

	Number of destroyed structures	Total estimated rubble generation
Residential	117	51040
Commercial	9	11520
Public administration	6	15360
Religious	01	1200
		79,120 tonnes

8. Al Hadbaa

		Floors	Occupants	m^2	Rubble generation (tonnes/100 m^2)
Small single family	10%	2	4	100	80
Common house	65%	2	6	200	100
Large villa	10%	2	9	500	120
Apartment complex	10%	3	40	400	140

	Number of destroyed structures	Total estimated rubble generation
Residential	75	23000
Commercial	6	7680
Public administration	9	23040
Religious	02	2400
		56,120 tonnes

4.3.4. Results discussion

The quantitative analysis of the rubble generated from the housing sector only in Mosul reveals that the total amount of rubble generated is 3,530,860 tonnes. The results reveal a strong concentration of rubble in west Mosul, approximately 90%, and especially in the Old City. The Old City area in the west bank shares 45%. Al Rabee area also in the west side comes as the second area after the Old City for sharing biggest amount of rubble with 35%.

4.4. Distribution of rubble around Mosul city

The location of the rubble around the city is the key input for a sustainable rubble management in the reconstruction approach. The effect of the conflict on Eastern and Western Mosul are beyond comparison as it is revealed from the quantification results. The recovery of Eastern Mosul is proceeding. The level of destruction in Western Mosul is the greatest and the reconstruction will take years, as the governor of Mosul addressed. Finding suitable solutions to the enormous quantity of rubble generated from the conflict is one of the central issues in the city's stabilization and reconstruction [39].

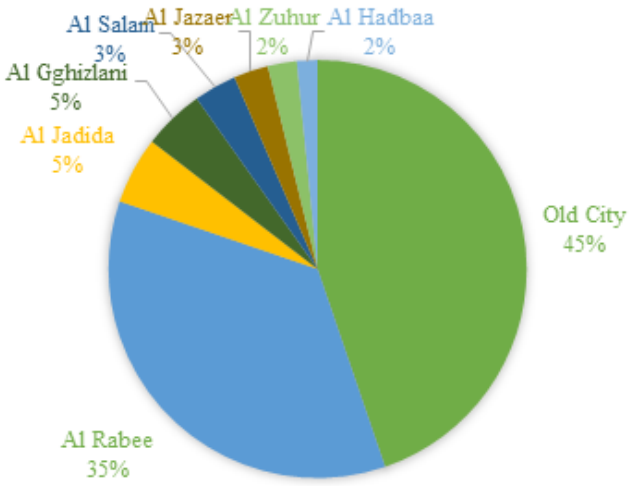

Figure 76. The share of housing destruction in the residential areas in Mosul according to the data collected from the Municipality of Mosul (Source: author).

Mosul city is divided into eight administrative sectors. This division was legislated in 2013 to overcome with urban growth and improve the administrative bureaucracy in Mosul [72]. However, the city is known to consist of two parts, the right bank (Western Mosul) of Tigris River and the left bank (Eastern Mosul). There are 251 neighbourhoods (mahalas) in Mosul, and they are spread along both banks of the river. Connected by five main bridges. The right bank consists of 91 neighbourhoods. The left bank was expanded after the fall of the former regime in 2003, and consists of 160 neighbourhoods. The left bank is known for better security

and public services and contains houses with no historical value [76].

In particular, along the Tigris River, the historic urban fabric has been severely affected, with an estimated 5,000 buildings in the Old City destroyed or severely damaged [79]. 15,000 internally displaced families from the Old City are staying in camps. Over 80% report partial or significant damage to their homes (UN-Habitat 2019) and cite this as a key obstacle to returning. Furthermore, as over half of the above-mentioned IDPs families report that their houses are completely destroyed, and small repairs will be insufficient to cover this caseload [81]. Government and private sector interventions are essential. As an urgent response to the needs of the displaced people, they started to develop self-reconstruction of their homes. While much of this unique architectural heritage has been lost, the historical and cultural soul of the city is still very much present [82]. It is therefore imperative that the reconstruction, restoration and conservation process respects the tangible surviving elements of the historic urban fabric and the traditions and techniques used.

4.4.1. Eastern Mosul

Eastern Mosul was liberated from ISIL in January 2017 by Iraqi Security Forces, and the scope of the damage was relatively limited, as the locations were targeted as separate houses in different locations (Figures 77 and 78). Most of the destruction and damage occurred in the public buildings, 60% of them were reportedly destroyed according to the Municipality of Mosul. The destruction includes public offices, Mosul University and schools. Signs of normal life are returning to Eastern Mosul as the majority of the returnees are settling there.

Figure 77. Eastern Mosul (Source: author).

Figure 78. Satellite photos showing the damage scale in East Mosul before (left) and after (right) the airstrikes in 2016 (Source: earth explorer).

4.4.2. Western Mosul

The destruction in Western Mosul is completely different from that of the Eastern Mosul. The old city is almost completely destroyed, more than 90% of it (Figures 79 and 80). During the field visit in May and June 2019, it was almost empty of its local people, with many military forces and daily attacks were still happening. The old city was also heavily contaminated with explosive bombs and mines. Other than some historical houses that may still be preserved, the Old City and Al Rabee district are severely damaged with approximately 60-70% destroyed houses. Nevertheless, people are gradually returning to Western Mosul starting from Mosul Al Jadida sector, Southwest of the Old City. The returnees of Western Mosul are also targeting the borders of the city that were liberated earlier [66].

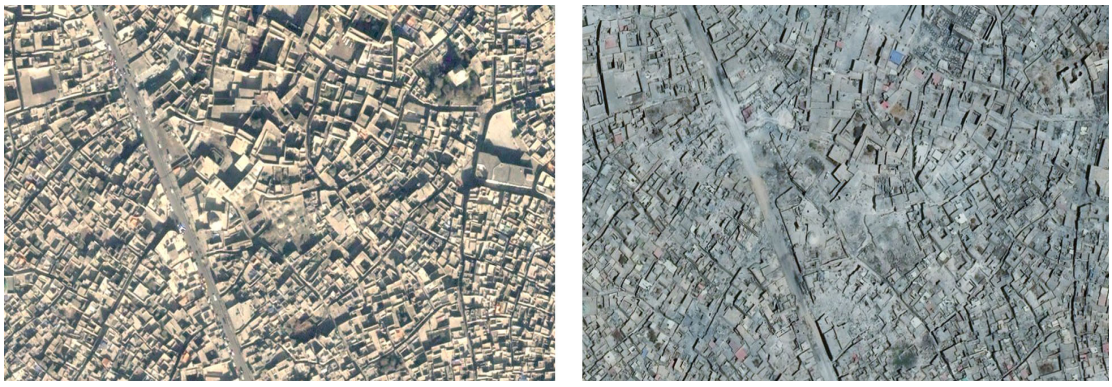

Figure 79. Satellite pictures showing the severe damage of Western Mosul (Source: earth explorer).

Old City

The distinctive traditional architecture and the heritage architectural landmarks with the traditional house in the old city give the Old City its importance, but it is also the most affected neighbourhood in Mosul (Figure 81) [80]. Therefore, there is a priority of focusing on the old city. According to Abdelsattar Al Hibbu, the municipality chief of Mosul, of the 200,000 residents of the Old City, 15000 are IDPs, only 1,000 families have returned – or roughly 5,000 people. Many of those displaced are still living in refugee camps or have piled into East Mosul, putting additional strain on already stretched infrastructure.

Riverfront

The Al Maidan area was largely destroyed during the ousting of ISIL from this stronghold. The area was subsequently cleared by the military and local authorities to allow easier access. A substantial part of the ERW contaminated rubble has been pushed onto the riverbank or into the Tigris River. Parts of Al Maidan should be protected from any further development pending the provision of clear reconstruction guidelines [90].

Figure 80. Western Mosul (Source: author).

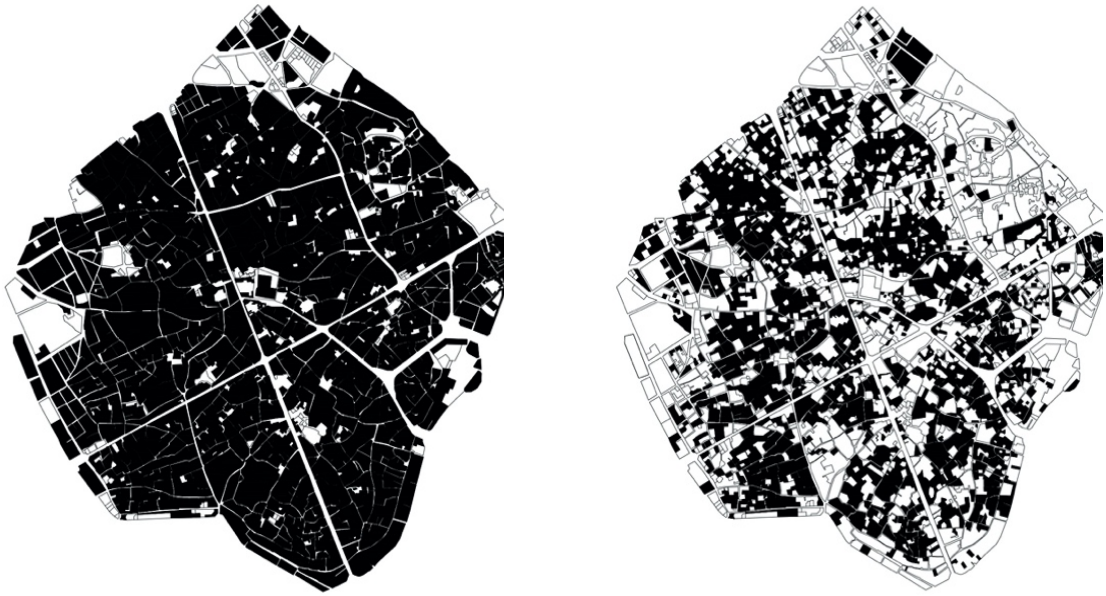

Figure 81. Left) Old City Plan before the conflict; (right) after the conflict showing the scale of destruction. Open spaces are the buildings that are severely or completely destroyed (Source: author).

A stretch of destroyed areas along the Al Maidan riverfront in the Old City was completely cleared in 2017 (Figure 82), with the exception of the residual structure of the Yahya Abu Al Qasim Shrine [91] (Figure 83). While large-scale clearance operations have been temporarily halted, a lack of awareness regarding the value of some damaged buildings may lead residents and other local actors to further demolish and clear residual structures that are sometimes hundreds of years old, inadvertently inflicting further damage on Mosul's cultural heritage [92].

Figure 82. Riverfront in Al Maidan (Source: author).

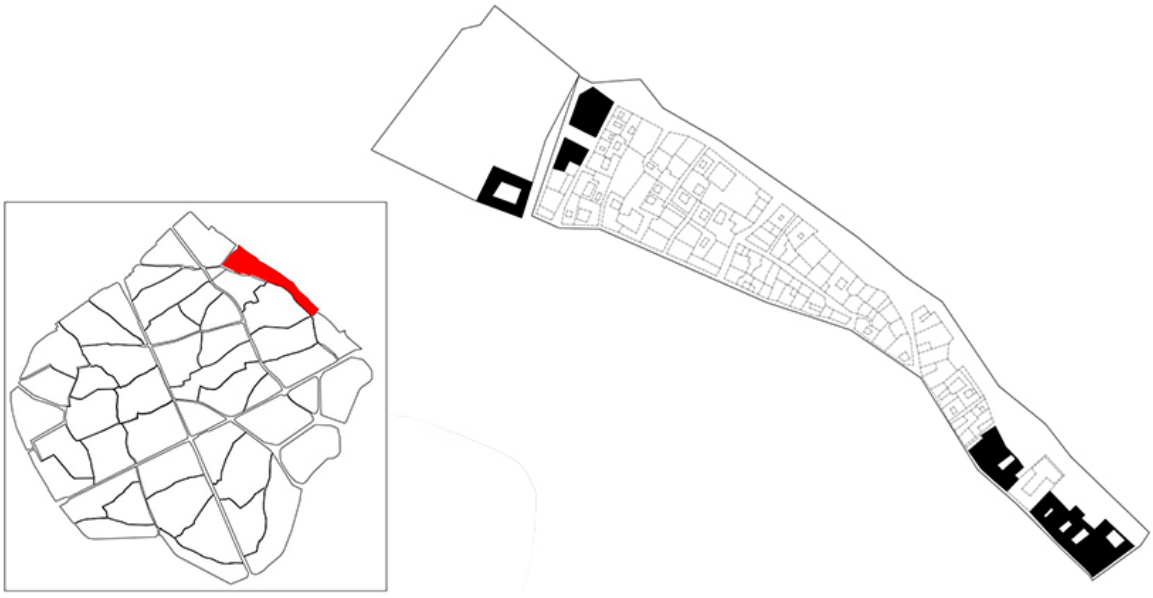

Figure 83. Al Maidan riverfront area. Only the buildings in bold colour are still standing up (Source: author).

Heritage buildings

The heritage city of Mosul lies on the west bank of the Tigris River with some sites also on the east bank. It is situated on slightly higher ground than the surrounding areas. Different heritage buildings are distributed across the city, such as mosques, shrines (of Prophets, Awliya), monasteries, churches, schools, and others. Not all destruction was for religious reasons; some of it was related to political or economic matters, for example Al Kamalyia school, Mujahid Al Din Mosque (Al Kidher), Hammu Al Qadu mosque and Abdal school. They did not contain any tombs, but the strategic location in the Suq or by the river was the reason for their destruction. Similarly, Ajeel Yawer mosque, Tell Afar castle, Sinjar minaret and the police centre were all destroyed for different political reasons.

Because of these destructions, many distinctive architectural features have been lost, for example all Ottoman pencil-shaped minarets (well-known example: Al Qalamya) that appeared at the end of 18th century in the shrines of the Prophets Johan, Gorges and Shith [78]. The conical cupolas that were famous during the Zengid age have been destroyed, except the last small one at Hassan al Bakri Mosque, in addition to countless wonderful Mihrabs and Minbars.

To assist in tracing and preventing trafficking of illicitly excavated and traded artefacts of cultural heritage, the International Council of Museums (ICOM) maintains an Emergency Red List of Iraqi Cultural buildings at Risk (Figure 84).

Figure 84. Locations of the heritage buildings in the Old City that are listed as being at risk (Source: author).

Heritage landmark	Status
1. Shrine and cemetery of Isa Dadah Period: Zengid; Originally a ribat built by Sayf Al Din Ghazi (d. 1149) Location: West bank of the Tigris, Al Shahwan	Destroyed
2. Shrine of Imam Abdulrahman Founder: Badr Al Din Lu'lu' (d. 1259) Period: Atabeg; originally Madrasa Al Izziyya of Izz Al Din Masud ibn Qutbuddin Mawdud (d. 1193) Location: West Mosul, Al Tawalib	Destroyed
3. Tomb of Shaykh Al Shat Founder: Originally a sufi lodge (takiyya) built by Muhammad Efendi Al Afghani (called Shaykh Al Shatt) in the courtyard of the mosque bearing the same name Period: Ottoman (19th century) Location: West bank of the Tigris, Al Shahwan	Destroyed
4. Mosque of Al Umawi	Destroyed
5. Minaret of Al Umawi mosque	Destroyed
6. Primary house of Iraqi	Minor damage
7. Mosque of Imam Ibrahim	Destroyed

Founder: Al Shaykh Ibrahim Al Mahrani Al Jarahi (12th century)
Period: Atabeg
Date of construction: the tomb of founder's wife, Husna Khatun, was built in 498/1104-5; reconstructed as a shrine of Ibrahim ibn Jafar ibn Muhammad ibn Zayn Al Abidin ibn Al Husayn ibn Ali by Badr al-Din Lulu in the 13th century
Location: West Mosul, Ras Al Kur

8. Mosque of Hammo Al Qadu	Destroyed

Founder: Al Hajj Abdallah Chalabi ibn Muhammad ibn Abd al-Qadir
Period: Ottoman
Date of construction: 1298/1880-81; the mosque includes an earlier tomb of Ala Al Din ibn Abd Al Qadir Al Kaylani
Location: West Mosul, Bab Al Tob

9. Catholic church	Minor damage

Period: Founded in the 7th century on the place of an older monastery, reconstructed in 1743 AD and in the 20th century
Location: West Mosul, Al Shifa

10. Al Aghawat Mosque	Minor damage
11. Al Sawwaf khan	Minor damage
12. Nabi Jarjis Mosque	Destroyed

Founder: the modest shrine of Al Nabi Jirjis was reconstructed as a congregational mosque (jami) by Timur Lenk (d. 1405).
Period: Timurid
Date of construction: the first mention of the Shrine of Al Nabi Jirjis is in the year 571/1175-76; the congregational mosque constructed after the arrival of Timur to the town in 796/1393-94
Location: W Mosul, Mahallat Bab Al Nabi

13. Al Basha mosque	Minor damage
14. Al Hadbaa minaret	Destroyed
15. Al Mufti khan	Minor damage
16. Al Nuri Mosque	Minor damage
17. Saida Nifisa shrine	Destroyed
18. Shah Zanan shrine and tomb	Destroyed

Founder: ascribed to Badr Al Din Lulu (d. 1259)
Period: Atabeg
Location: Mahallat Hammam Al Manqusha

State: cemetery ruined, the mosque probably too (not clearly visible in the satellite image)	
19. Al Hagiyat Khan	Minor damage
20. Al Najafi street	Minor damage
21. Khangar Khashab mosque	Minor damage
22. General old police station	Destroyed
23. Al Totonch house museum	Destroyed
24. Al Hatra hawks square	Destroyed
25. Al Saah church	Minor damage
26. Dominican fathers' monastery	Minor damage
27. Monastery of Dominican nuns	Minor damage
28. Khuzam Mosque	Minor damage
29. Ancient Nineveh wall	Destroyed
30. Al Rabiaa mosque	Minor damage
31. Imam Awn Al Din shrines known as Ibn Al Hasan) (I05) Founder: Badr Al Din Lulu (d. 1259) Period: Atabeg Date of construction: 646/1248-49 Location: Mahallat Al Imam Awn Al Din	Destroyed
32. Obeid Aga bath	Minor damage
33. Omar Al Aswad Mosque	Minor damage
34. Al Omariyya mosque Period: Ottoman Location: West Mosul, Bab Al Jadid, opposite the Mosque Al Umariyya	Minor damage
35. Al Abaroqi mosque	Destroyed

The main urban axes

The importance of the urban axes in the Old City of Mosul is the connection of the urban fabric of the old city and especially the two main axes that break into the old area, the Nineveh Street axis and Al Farooq axes (Figure 85). Both axes have become integral part of the surrounding urban fabric and they are also linked to several main streets such as Al Nabi Jarjees and some small important axes such as the street of Al Nuri Mosque and Al Makawi.

A list of heritage buildings, which can be considered an important source for the urban development to the city of Mosul and to strength the sustainability dimension. In addition, the preservation of building heritage in terms of both maintenance and restoration, the importance

of its location within the old urban axis of the city and its role from the point of view of economic activities as well as its strategic location, which makes it versatile throughout the day, must also be considered.

Furthermore, the historic pre-conflict layout of the Old City is a key constituent element of the identity of Mosul and should be retained during reconstruction. Rebuilding according to the pre-conflict layout of roads, streets and alleyways respects the current ownership boundaries and helps to avoid major legal ownership challenges, including housing, land and property rights issues as well as changes in land use designations that could prevent a delay in the reconstruction process and lead to complex compensation procedures.

Figure 85. Destroyed buildings on the main axes in the Old City (Source: author).

4.5. Existing rehabilitation activities in Mosul

After the battle in which Iraqi forces recaptured Mosul from ISIL, the authorities did not have enough equipment to clear the rubble littered across the city as Mosul governor said. Hundreds of Mosul council's vehicles were destroyed in fighting or used by ISIL as suicide bombs [69]. Few have been replaced [93]. Companies hired by the governor on lucrative contracts to make up the shortfall work deliberately slowly, or sometimes do not exist, lawmakers and locals said. Many residents are struggling financially. Families forced to build their own homes go into debt, borrowing from friends and living off charity. Others push into increasingly expensive rented

homes. Foreign-funded projects also suffer delays. “There’s no strategic plan. It’s chaos,” Dr. Muzahim Al Kyatt said.

Poor planning allows mismanagement of reconstruction efforts (Figure 86) and alleged corruption, making recovery slow and random [94]. In this environment, residents fear the remnants of ISIL will again exploit resentment.

Figure 86. Local authorities helped the local people clean some main streets’ rubble (Source: author).

4.5.1. Involvement of the International organizations

It is essential that the reconstruction, restoration, and conservation process respect traditions and techniques used in their original construction. The reconstruction in the Old City should adhere not only to specific rebuilding guidelines developed by UN-Habitat and UNESCO in conjunction with government stakeholders, but also to appropriate international standards and conventions for such processes [95].

Currently, the main actors for housing rehabilitation in Mosul are UNDP, UN-Habitat, UNHCR, UNESCO, Human Appeal, and Norwegian Refugee Council (NRC) (Figures 87, 88 and 89). Many agencies cover damage categories 1 (minor) and 2 (major) to rehabilitate houses to the minimum repair standard.

Figure 87. The Syrian catholic Al Tahera church and the Latin church (Al Saa'a church) are included in UNESCO project to restore heritage sites [96].

Figure 88. An historical house in the Old City currently under rebuilding by UNESCO (Source: author).

Figure 89. UNESCO team has preserved most of the inscriptions and stones of Al Nuri Mosque that was destroyed by ISIL (Source: UNESCO).

4.5.2. Demolition or deconstruction of fragile buildings

Some houses and other types of buildings in Mosul have been destroyed in a way that they are still standing but their structural integrity is compromised. ISIL fighters intentionally destroyed buildings to make them unusable and unsafe, such as by blasting their bearing columns. Therefore, there is a safety problem in these buildings, both for the owners to return there and for the public local people passing by the house. The local authorities in Mosul must work with the post-war design team to provide a guided process for the deconstruction of these houses in order to make benefit of the materials and components that will be generated.

4.5.3. Rubble disposal

Due to a lack of rubble collection sites, public landmarks such as churches and mosques are being used as rubble dumps [75]. This often inflicts further damage on heritage sites and forms a potential safety hazard, as the relocation of rubble makes it difficult to determine which areas have or have not been cleared of ERW.

Many historic buildings in the Old City are currently unprotected from weathering and potential looters.

The unsupervised disposal of rubble jeopardizes the recovery of important landmarks. Valuable historic items, such as pillars, window frames and other decorative elements in Mosulian marble (Al Farsh) or limestone (Al Hillan) are likely to be lost as it is being included with ordinary residential rubble.

Although Mosul suffered heavy damage, it still contains numerous significant surviving historic structures. These buildings are in need of protection from clearance activities until specialized heritage teams can be put in place. The local people are starting to use the rubble for landfill mostly [97]. It is reported by Mosul municipality that the rubble used for landfill is not crushed, that may cause instability of the new construction.

4.5.4. Types of rubble in Mosul

The rubble in Mosul currently is different in each location. In some areas it is kept clean in its original location, in other locations its removed to a disposal site or randomly to a close location. When the rubble is mixed with other wastes at a municipal disposal site, and when the rubble in

its original is used as a disposal site by local people and being mixed with other household waste then the potential opportunities to reuse or recycle the rubble are complicated.

4.5.4.1. Mixed rubble

For rubble that is mixed with non-reusable and non-recyclable items, the cost and effort of separating and repairing it into reusable and recyclable materials will not be appropriate when compared to the benefits [98] (Figure 90). The local people who returned to Mosul are using random sites such as destroyed houses as their household's waste disposals. The mixed rubble with household waste will have limited options such as being used in landfill in the outdoors [75]. In this case, the rubble is assumed to be clear from any hazardous materials and it should not contain large quantities of degradable materials including timber and plastering [99]. These materials degrade over time and make void spaces, which affects the stability [100].

Figure 90. Mixed rubble with household waste in western Mosul (Source: author).

4.5.4.2. Clean rubble

Clean rubble is ready to be separated and repaired for reuse or crushed for recycling applications (figure 91) [94]. The application value of the crushed material when it comes from a clean rubble is often higher because the quality of the recycled material will be the same as natural gravel. Clean rubble is generated mostly during the later phases of rubble management, where rubble is released from structures requiring demolition or explosive ordnance disposal [101].

Figure 91. Example of clean construction rubble in Mosul (Source: author).

4.5.4.3. Available and unreleased rubble

Throughout this research, rubble is referring to include both the available and the unreleased rubble. Available rubble is where it is easy and safe to access it, such as the rubble fallen in the streets and accessible in their original location especially the rubble generated from the houses with destroyed level of damage.

The unreleased rubble indicates the rubble to be generated from other levels of damaged buildings, such as the fragile structures that need to be deconstructed (Figure 92). This kind of rubble also includes the rubble generated from houses with the severe and major damage levels. This case is critical because it emphasises the importance of the ways and actions that need to be done before deciding the rubble management process [96].

Figure 92. The foundations of these buildings were blown up by ISIL (Source: author).

Conclusion and reconstruction challenges

ISIL destructed the heritage buildings in Mosul deliberately. The architectural landmarks that formed a unique historical significance of the city have been targeted. The architectural elements and decorations that refer to specific beliefs or religions were targeted. The development of building classification by UNESCO and UN-Habitat provides directions for the recovery reconstruction of the Old City. Although their gaol was just to give identification to the most important buildings in Mosul and identify their damage level, the classification can provide the reconstruction process with a useful tool for the level of architectural interventions to be proposed.

The quantification of the rubble revealed that the Old City shares the biggest amount of rubble among the other areas in Mosul, as 45% of the rubble generated from the housing sector in west Mosul is in the Old City due to the massive destruction. The destruction in East Mosul is not comparable of West Mosul. The damage in East Mosul was relatively limited and targeted mainly the public buildings. In West Mosul, the destruction of the housing sector was excessive as it shares 90% of the rubble generated from the housing sector.

The study showed that there are partially destroyed buildings in Mosul with fragile structures. These buildings be destructed carefully following the international guidelines instead of demolishing them. In this case, the materials and components generated can be reused in the rebuilding of the same site or in another site. The current rapid self-reconstruction by the locals is an urgent response to their needs of returning. The rubble forms a significant reconstruction obstacle. Rubble clearance in these areas is not supervised and there is no plan to protect the historic building with a high heritage value. The unsupervised disposal of rubble causes further environmental damage and higher transfer costs of rubble to several unplanned disposal spots. Furthermore, many people are not able to afford the cost of repairing the historic buildings, materials, and elements besides the lack of their awareness about the value of these buildings.

The current rebuilding actions by the international organizations are more respectful to the historic value of the buildings. However, they are concentrated on individual public buildings and when they include the residential buildings they work as individual projects related to different organizations with lack of coordination. The projects implemented by these organizations rarely include the houses and when they do include them, they only cover a few selected houses with minor and major damage levels. The governmental neglect of basic needs for housing and services is not a unique product of the post-ISIL era. It is a reflection of successive administrations since 2003.

Recommendations

Finding suitable solutions to the enormous quantity of rubble generated from the conflict is one of the central issues in the city's stabilization and reconstruction.

The unplanned ongoing process demonstrates the need for a public awareness to the environmental aspects due to the hazardous sites and the insufficient rubble management.

In general, emphasis should be placed on optimizing the benefits that can be gained from rubble by:

- Reducing public health risks by removing the rubble from populated areas,
- Employment generation,
- Reusing and recycling the rubble,
- Substituting quarry materials, and
- Minimising waste quantities requiring disposal at a landfill.

It is important to recognize that initial handling of the rubble can have a significant impact on the options available for rubble management [108]. For example, if the rubble is mixed with general waste, then recycling opportunities are considerably reduced since pre-sorting of the rubble would be required [75]. Mixing of rubble with general waste can easily happen if the rubble is left dumped over a period in urban areas where the public will view the rubble pile as a waste pile and add their own wastes to the heap.

Actual options on how to deal with the rubble once generated are varied. Potential alternatives are largely dependent on the quality and location of the rubble as well as potential end use applications, (i.e., market opportunities for the reusable and recycled materials produced) [104] [108]. Often the rubble management option selected will be predominantly local. Where debris management plans and projects are thus brought in by external partners, these local initiatives must be respected and integrated to ensure community benefits and focus [99].

While substantial areas of the Old City have been damaged to such an extent that they will require extensive rubble clearance, they also contain historic structures with a high heritage value. Selective areas need to be immediately protected from further destruction. Clearance in these areas demands supervision by specialized heritage teams authorized by State Board of Antiquities and heritage of Iraq and UNESCO. Unsupervised clearance should cease.

To prevent large-scale theft of historic artefacts, these sites, such as Al Nuri Mosque, require protection by regulating access and closing off specific areas. Proposed locations for heritage

depots are located in close proximity to important areas of the Old City. Homeowners can temporarily store historic architectural elements to be reused for the restoration and reconstruction process.

5. APPLICATION OF REUSE AND RECYCLE DURING THE DESIGN STAGE

The goal of this chapter is to investigate the ways that post-war design can include reused and recycled building materials and elements in the reconstruction process in Mosul, thus reducing the quantities of rubble sent to landfill. This study emphasizes heritage protection of the Old City by reusing the remaining materials and elements.

Achieving these goals would not only reduce the growing pressure on landfill sites, it would also reduce the need to extract new raw materials from the earth. This would reduce the environmental impact of extraction processes. There are compelling reasons for trying to reduce the quantities of rubble materials by increasing the recycling of materials and, whenever possible, exploiting opportunities for reusing components from buildings before becoming simply wasted materials. Furthermore, shifting the balance from recycling to reclamation and reuse can reduce the reprocessing involved and lead to energy savings [103].

Based on evidence collected from the architectural damage assessment, the results and the integrated analysis of the quantitative and qualitative data (Chapter 4), allowed validating the possibilities of applying reuse and recycle in the post-war architectural design approach. The research outcomes indicate environmental, economic, availability and technical factors strongly affect the decision-making process.

The main barriers to reclamation and recycling are unfamiliarity and inertia being unaware of what can be done and how it can be done. This chapter addresses these issues by considering the two key features of reuse and recycling: (1) There must be commitment to reclamation, reuse and recycling by the homeowner and the designer; (2) The design process for using reclaimed goods and recycled materials is entirely different from normal building practice.

5.1. Theoretical background

The main reason for reusing or recycling materials and products is to reduce the impact of the society on the environment [104]. The construction of new buildings and the rehabilitation of old ones, in response to the local people needs for appropriate housing conditions, are already having a great impact on the environment [105]. The destruction caused by the last conflict in Mosul and particularly in the Old City are requiring even more reconstruction activities to meet the urgent needs of the local people. The impact is apparent in different ways including: (1) using non-

renewable natural resources; (2) air pollution from manufacturing new products and materials, and the pollution from the transportation of these products and services; (3) degradation of the natural landscape, quarries, loss of woodland and landfill sites [106].

While the situation in Mosul is urgently in need for a speedy recovery, it also presents a warning sign for the further impact the unplanned rubble management can have on the environment. This challenge is leading to a growing pressure to encourage the reuse and recycling of the materials and the products from the rubble in the reconstruction process.

The last chapter assessing the post-war damage have shown that the rubble continues to be the main challenge for many IDPs to rebuild and return to their houses. Removing the rubble in Mosul for the reuse and recycling activities is faced with several obstacles. First, the existence of the unavailable or unreleased rubble that needs deconstruction activities to be available for future rubble management. Second, the uncontrolled disposal of rubble and mixing it with the general waste of the houses and the existence of high quantities of explosive bombs.

UN Environment have supported a workshop in Al Anbar University in 2018 to discuss the challenges of reducing the quantities of rubble in Mosul and the future of the application of recycling centres in Mosul and the other affected cities in Iraq. The workshop concluded that the seven affected cities in Iraq are sharing similar rubble removal challenges and it suggested that the poor experience of the application of recycling activities in Iraq are the main constraints. In 2020, UN Environment Programme announced that they are collaborating with the International Organization for Migration (IOM) to start an innovative rubble-recycling project for one year in Mosul. However, the project is still not implemented according to the news published online by the UNEP.

Thus, it is important to study the opportunities available on the international literature on the different ways to reduce the quantities of rubble in Mosul and even more on how to reuse the materials more than recycling them from the design stage (in this chapter) to the application stage (in the next chapter).

In the UK, a study in the late 1990s revealed that around two million tonnes of materials and products were being repaired and reused or recycled [103]. The Netherlands, Scandinavian countries and the German-speaking nations already achieved greater reuse and recycling applications than the UK [104]. There are many examples of good reuse and recycling practices in yet other countries. Some materials are more difficult to recycle, and others are being separated by hand or rather by eye. Several techniques have been developed to bring some automation to the process. For example, the colour recognition technique to separate the bricks

and the shape recognition technologies to separate the plastic bottles [85]. Metals are easily separated in the removal process [107].

Reuse and recycling can benefit the local people in Mosul by:

- Avoiding the costs of demolition and reconstruction of their houses by reuse in situ in the cases of major damage levels;
- Decreasing the costs of transporting materials to landfill locations also by reusing them on site;
- Obtaining design permission for reconstructing their houses by matching the new construction with the survived parts of the construction. This applies to the cases in which the houses have a historical value and need to be reserved by minimum architectural interventions.

5.1.1. Reuse

Materials are used in the buildings in two different ways: either as a material in itself, such as glass, or as a product that is made from materials, such as windows. The distinctions are important to avoid the confusion. Bricks, for example, can be separated from the rubble and reused as products, or they can be crushed and used as a recycled material.

The opportunities to reuse materials in the form of products will depend on two main factors:

1. How easily the product can be separated from rubble and the possibility to assess its performance;

2. The nature of the required work or reclamation to improve its performance to the level that makes it ready for the reuse.

5.1.2. Recycling

An essential requirement for recycling is that the material must be as pure, consistent and uncontaminated as possible - e.g., crushed masonry containing no timber or plastics, plastics all of the same chemical type (e.g., polypropylene), or wood chips with no plaster or plastic.

With the exception of crushed aggregate used to make concrete, the recycling of materials does not take place on the construction site. Timber, plastics and metals are all recycled in specialist factories or industrial works outside the construction industry. In the case of recycled materials, no link between the first and second uses is needed. Timber window frames could be recycled as chipboard and used to make kitchen cabinets.

The opportunities to recycle materials depend on two main factors:

1. Whether the material can be separated easily from other materials;

2. Weather the recycled material is suitable to be producing a useful new product.

5.2. Levels of interventions

The most efficient way to deal with the waste in general is not to generate it [108]. The idea of dealing with the materials at the end of their first use as a problem rather than as an opportunity is not helpful either [88]. Providing the context of the life cycle of materials promotes a better understanding of the concepts of ‘waste’, ‘reuse’ and ‘recycling’. Most of the recent practices are applying a linear move of the materials [109] (Figure 93).

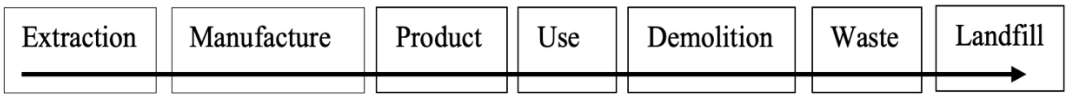

Figure 93. The linear flow (life cycle) of materials (Source: author).

The ideal flow of materials that the practice should tend to aspire is the circular life cycle, if they aim to avoid waste [104] (Figure 94).

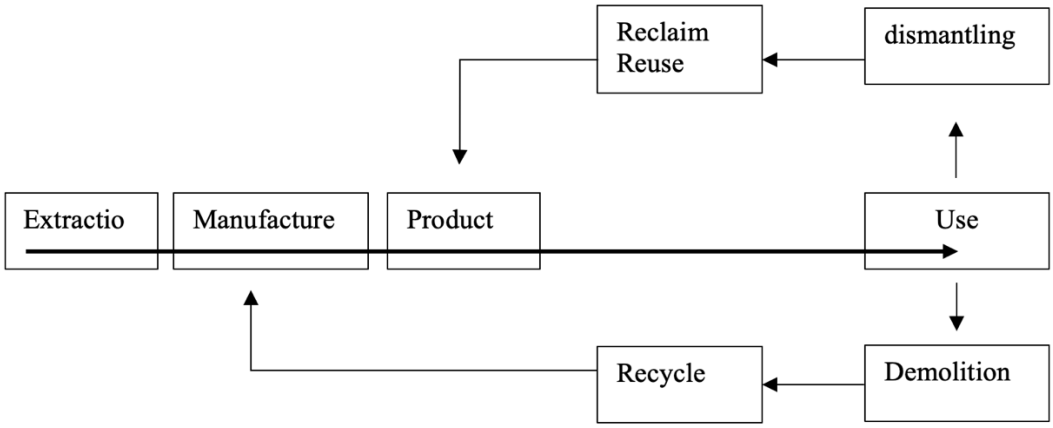

Figure 94. A circular life cycle of materials (Source: author).

In practice, and when applying this theory on the rubble generated from the conflict in Mosul, it is not likely to achieve this ideal if the design team does not consider it during the design process. The houses in the level of severely damaged and completely destructed can be designed to incorporate reuse and recycling. Otherwise, it will be difficult to make reuse and recycle happen.

While reviewing the options available for the application reuse or recycling practices in the houses in Mosul, it will be useful for the design team to have a hierarchy that will make the decision process easier to choose the appropriate option from the environmental point of view. This approach has been suggested by a number of authors [110] [111] [112] [113].

Regarding the reuse and recycling, the opportunities to their applications should be considering the repairing or reclamation practices of the materials and the products as well as the salvage stores for these materials. That will be useful since both previous issues control the availability of the materials for the design team.

The 'recycling protocol' approach invented by the UK salvage firm (Salvo) based on the hierarchy of options: reuse, reclaim, recycle, and destroy [103]. This recycling protocol provides the following priority list especially with dealing with old architectural items. With respect to the built environment, it gives the following priority list of what to do with old architectural items. The architectural antiques are identifies as manufactured products that requires a level of skilled labour involved, such as the decorations and the inscriptions on the gates frames and around the courtyard in the historical houses of the Old City.

1. Reuse the building without demolition or reclamation. If this case is not an option, then:
2. Reclaim the products with minimum repairs by:

Reclaiming the individual products;

Reclaiming whole products such as window frames;

Reusing façade**;**

If reclamation is not an option, then:

3. Recycle and generate a new product or material:

If recycling is not possible, then:

4. Beneficially destroy and recover energy.

The designer team has to define the reasons for which they are aiming to reuse the products and/or use Recycled-Content Building Products (RCBPs) during the design approach. The design team will need to focus on altering the supplies of the new products with the possible and affordable ways of reclaiming the products and using the recycled ones [114].

With this in mind, the design team can engage the deconstruction industry for the cases of the houses

that need to be demolished in Mosul due to their fragile structure resulted from the attacks during the last conflict (chapter 4). The deconstruction of these houses, with a special care in their removal, will help to generate products in good conditions that can be reused. The designers in the post-war reconstruction approach will need to define which materials or products will be reused on site, which to choose from the salvage store (which is from another location), which materials to be recycled and finally, when these are not possible or affordable, which new materials to use (Figure 95).

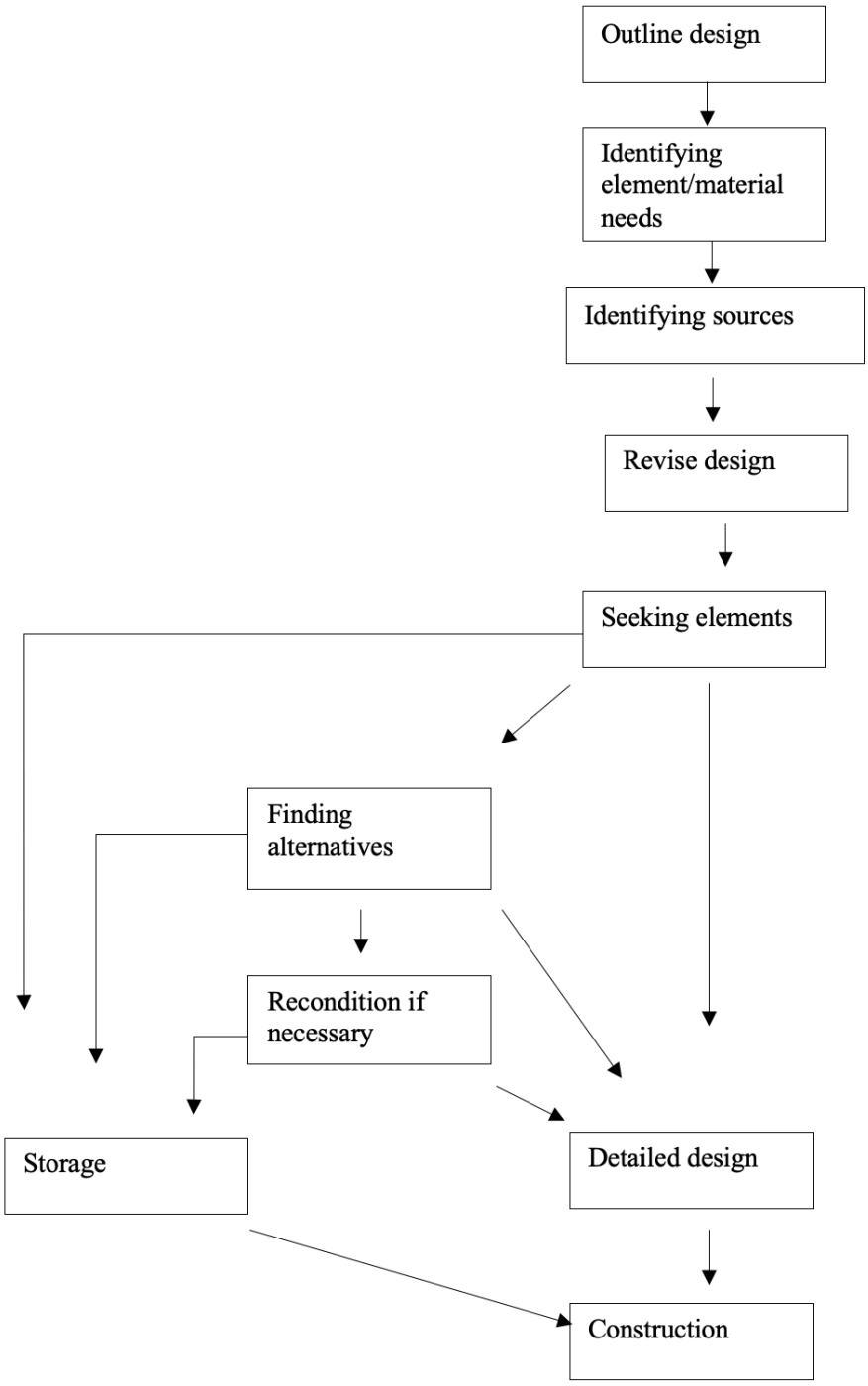

Figure 95. Reclamation, reuse and recycle: designer's view [103].

The design approach required for including reused, reclaimed and recycled products and materials is totally different from the normal design process that includes the using of new materials [114]. It is essential to understand the differences before starting the design approach. The availability of the materials and products controls the options. When deciding the option of reusing the materials and products of a house from its rubble on its original location, it is necessary to address the availability of all materials and products required to rebuild the house. In this case, when some products are missing or not possible to repair or recycle then it is necessary to study the availability of the missing products in salvage stores, meaning using products from different locations.

In normal design cases, the design team first designs the building and then purchases the suitable products and materials. In the case of reusing materials, it is necessary to purchase the materials before the design stage [115] **(**Figures 96 and 97).

When the products are confirmed to be available for reuse, it will then be possible to impose a plan to make them ready for being incorporated in the building. The steps below can be involved in the planning stage [103]:

1. Make a list of materials to be found and define the sources;
2. Draw an outline design;
3. Start setting out the types and quantities of the required materials;
4. Identify the condition of materials available;
5. Prepare approximate costs for the repairs required to make the materials ready for reuse;
6. Prepare the schematic design of the building;
7. Arrange the reclamation of the materials;
8. Prepare a detailed design when the products are ready for reuse.

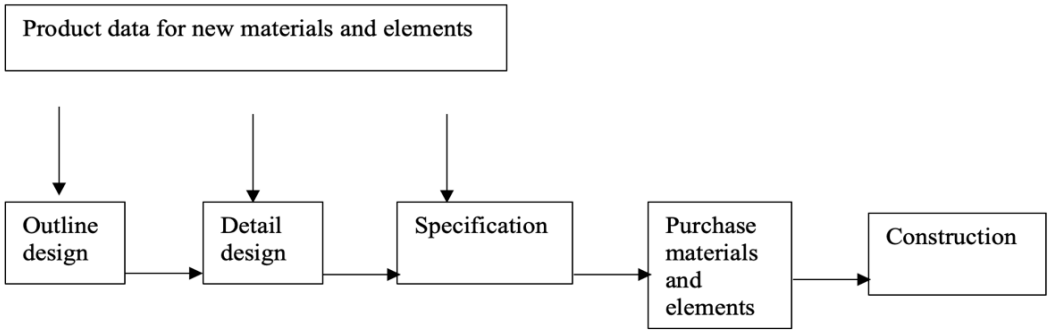

Figure 96. Normal design (Source: author).

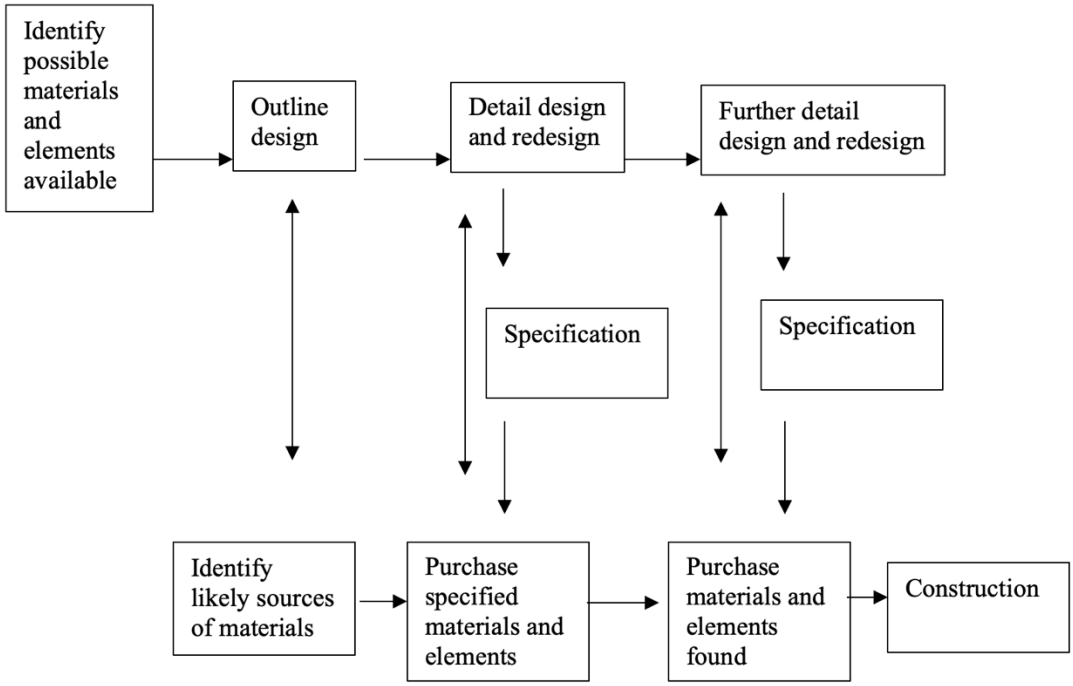

Figure 97. Design with reclaimed materials and elements [103].

Considering the damage assessment in Mosul (chapter 4), the identification of the damaged features in the five defined levels of destruction show that the building envelope is the most exposed part of the buildings to the bullets and the exploded blasts. It is the only part that experienced a level of damage from the negligible to the destruction level of damage. That is why the materials used in the building envelope are of primary concern when considering the reuse and recycling practices in Mosul.

The loadbearing walls in the masonry houses in the Old City serve as a part of the structure as well as the building's envelope. There is a percentage of modern houses in the Old City where the function of the structure and envelope are greatly separated. In both cases, the envelope performs distinct functions and these must all be considered when reusing a façade or roof, or using reclaimed or recycled-content materials, just as when using new materials and components.

The building envelope is the most visible part of a building. As much as this characteristic gives the building envelope the most exposure to the conflict, it also gives the importance in determining the general character of the city. A great consideration is given to the façade when the local authorities give the design permission. Most local authorities provide guidance for building designers on suitable and appropriate materials and types of construction. For the historical houses in the Old City, therefore, an important reason for reusing the materials might be to ensure the permission of rebuilding the house.

Another reason on why to reuse the materials and elements of the building envelope is the large mass of materials used. In the loadbearing masonry buildings, the façade and the structure are one, and therefore their reuse will avoid sending large quantities of materials to landfill sites.

As with the design and construction of any building envelope, the performance of the old façade as part of the new building envelope will require careful consideration of the various issues outlined above.

The retention of masonry façades is now a well- established practice and further details are beyond the scope of this thesis.

The methods of construction used in many types of roofs and building façades, both traditional and modern, are such that the components can be removed during demolition with little or no damage and be reclaimed to make them suitable for reuse. This is especially true of roofing tiles and slates, and brick and stone used in façades for which there is nowadays a buoyant market. Architectural salvage firms tend to specialize on certain sectors of the market.

The materials most likely to be salvaged during demolition are those that are no longer made, such as old bricks and roof tiles, and those that can easily be salvaged for reuse, such as bricks laid using lime mortar rather than modern, high-strength cement mortars.

Modern cladding systems for building façades comprise high-value elements such as granite or less costly metal sheet. Most of these could, in principle, be carefully removed from buildings during demolition and then reused. In practice, relatively little is reclaimed at present and a change in the attitudes of building owners, designers, building firms and demolition contractors will be needed before this situation changes. Such changes are, however, possible only 30 years or so ago hardly any roofing tiles or bricks were recycled; today there is a thriving market.

Apart from the use of reclaimed building materials such as tiles and bricks, a growing number of products for use in constructing the building envelope are available. These incorporate various ‘waste’ materials such as polymers and crushed ceramic materials used as aggregates for concrete products.

5.3. Politic challenges of reconstruction in Mosul

Officials, administrators, and civil society leaders across all political persuasions are pessimistic about the future of reconstruction in Mosul. The assignment of blame in this state of fairs depends on political affiliation.

Reconstruction funds are controlled by several government agencies that do not coordinate closely with each other. Most of the local government officials and observers stated that the reconstruction agencies including the Reconstruction Fund, the service provision federal ministries, and the governor's office operate in Mosul without coordinating with each other and with the local provincial council.

During the fieldwork visit to Mosul, Dr Muzahim Al kayatt, president of Nineveh University and the committee responsible for the national effort to restore services in Nineveh province, said during the interview that "Reconstruction effort is fragmented and there is no clear vision and aim among the implementing parties. For instance, the central government ministries implement projects without coordinating with the local government and the local provincial council. This has meant that Baghdad authorities, who are less informed on the needs and the priorities of Nineveh, have determined which projects are prioritized and where."

The government is not the only actor involved in reconstruction. UNDP officials emphasize that the media's fixation on government corruption and failure in Mosul has resulted in a poor narrative towards all reconstruction actors, including those representing the international community. One UNDP official noted that Mosul city team has rebuilt all the water treatment plants and electrical substations, 3 maternity hospitals, 144 schools, 40 colleges at Mosul University, and 9 police stations across Mosul from scratch, including the police headquarters. As for housing, they have completed over 2000 houses, with the aim of completing 15,000 in total.

This is not to say that UNDP and the other major international organizations involved in reconstruction, such as the International Organization for Migration (IOM), can minimize the pervasiveness of politics and corruption and the impact this has on projects.

This dynamic forced UNDP to seek approvals by other means: "There are a couple of cases when we had at least 30 projects on his desk for months, so we just went to Mahdi Al Allaq, the chief of staff (in the Prime Minister's Office), and he just basically signed them for us and sent a letter to Agub saying this is hereby approved." When the governor finally received formal charges of corruption and was forced to spend time in Baghdad, this period away enabled international actors to push more projects through via agreements with the directorates. However, even while away, the governor tried to pressure the local director generals to refuse compliance without his approval.

There was a distinct difference in the level of interference between Mosul city and the surrounding smaller towns and rural areas comprising most of the province's geographic area.

The UNDP teams in these areas noted far less interest on the part of the governor, mostly working with the directorates for approvals and secondarily the local mayors.

The major problem facing reconstruction in the rural areas is the degree of government neglect. Many rebuilt schools, for instance, are standing empty, and the government has shown no signs of re-opening them for students. They also have to contend with the politicization of aid from the international community, particularly the United States, which is often more concerned with directing aid towards minority populations such as the Christians rather than achieving holistic humanitarian development. One official reflected, “This policy of favouritism doesn’t help anyone, not even the Christians. Nothing exists in isolation, so if you want to fix a water network, it is going to cut across different areas, and it is like a tree, so you have to start at the bottom to find the root and follow it. Therefore, if you say you are only going to work in the Christian towns, you are basically against the technical aspect. They are interconnected. And the same thing goes with the water and the electricity grid” [39].

Any announcements of new infrastructure projects, job programs, or reform agendas must be viewed in light of a long-standing pattern of incompletion [102]. Projects are announced near elections and/or in response to political unrest but then ultimately fall to the wayside [100]. Regardless of whomever holds the position of governor or controls the directorates, all of these major governmental projects are routed through a local bureaucracy that is co-opted by functionaries beholden to political parties, thereby injecting nearly limitless blockages into the process. A coherent reconstruction program in Mosul simply cannot be managed under such conditions and the same holds true across Iraq. The protestors who took to the streets in Baghdad during October of 2019 were all too aware of the structural flaws in the post- 2003 governance system, prompting their demands for a new political order.

Conclusions

This study reveals the possibility to apply reuse and recycling practices in the reconstruction of Mosul by considering the existing materials and products to be reused or recycled before starting the design. It reveals that in order to incorporate the reuse practice in rebuilding the houses, it is essential to manage the rubble in a systematic way that allows the design team to choose the availability and suitability of certain materials in a certain house according to its historical value and its damage level.

The study shows that practicing reuse and recycle, besides the environmental benefits, can help to reduce the transportation of rubble to disposal sites. Instead, each house can keep its materials

and products that the design team decides to reuse or move them to the closest house where they can be reused, according to the design decision.

The practice of designing with reuse and recycle will be applied specifically for the houses that require the reconstruction level of intervention.

Recommendations

Many countries now are having national policies to regulate the sustainability in the construction industry. These policies are concentrated on the reduction of the waste by increasing the level of reusing and recycling materials [116].

Local authorities can focus on two aspects of environmental impact relating to the use of materials:

1. Reducing extraction of new materials: reusing products and materials reduces the need for primary materials and thus, reduces the resources needed to make primary materials;
2. Reducing materials sent to landfill: reusing products and materials also takes material out of the waste stream before sending it to landfill.

There is a growing interest by local authorities in many countries to incorporate environmental criteria during the awarding of design permission to a building project proposal. Authorities currently issue guidance for design teams on better practice in sustainable construction in the UK, for example [104]. This way of guiding the design teams can encourage the application of reusing and recycling materials during the design process. In this case, the design team is not obligated to follow the guidance. However, there are authorities that publish a sustainability checklist to be submitted by the design team and the resulted score may affect the decision to provide the design team with the permission [94] [104].

6. DESIGN GUIDANCE: VALUE-BASED DESIGN APPROACH

The present research explores the role of architectural design in the post-war reconstruction process considering the historical significance of the houses and the post-war housing challenges. The goal was to explore an architectural design guidance that can establish control over the unguided rebuilding of the houses.

The results presented, based on evidence collected from the observational fieldwork and the integrated analysis of quantitative and qualitative data, allowed the research to validate and set out the ongoing reconstruction activities' impact on the architecture of the houses and the future post-war architectural design. The research finds out that the degree of the historical value of the houses and the degree of their architectural interventions must be linked.

Through the case of Mosul, the Old City was analysed. The details of the local architectural materials and design techniques used in the Old City were identified and the historical significance was selected as the main indicator of the design (chapter 1 and 2). The post-war housing challenges were explored as well as the rehabilitation of different temporary housing shelters by the local people who returned to the city and the ongoing reconstruction actions by different international organizations (chapter 3). Those ongoing reconstruction activities were analysed as how they affect the previous described historical buildings and the future reconstruction process. Quantification, characterization, and distribution of rubble was assessed (chapter 4). The quantitative analysis revealed that the total amount of constructional rubble generated from the housing sector is 3,530,860 tonnes. The study also revealed a strong concentration of rubble in west Mosul, approximately 90%, the Old City area in west Mosul shares 45% of that. The goal was to ensure that the post-war design will integrate harmoniously with the existing local architecture in the Old City by prioritizing the reuse of original materials from the rubble and respecting the original design of the houses. collecting the information available in the international literature (chapter 5) combined with an inventory of materials and building elements collected from the findings of the previous chapters, and given that the Old City has a significant historical importance and heritage value, the research came up with the proposal of architectural design principles and suggested interventions, presented in this chapter, focused on the houses of the Old City.

The guiding design principles can be incorporated into the future reconstruction process, supervised by the local authorities' policies, and implemented by the local people and the international agencies. The research encourages the discussion of moving from a unified intuitive design approach to a value-based design approach regarding the historical value of

individual houses. Each house has its own historical value and damage level that needs to be addressed when considering the opportunities of reclamation, reusing, or recycling in the post-war architectural design stage. This approach also guarantees the urban cohesion and value of the historical old city of Mosul.

This chapter is divided into three main parts: (1) the methodological approach from which the design guidance is derived and the presentation of the design approach; (2) the principles of the design approach as references for the proposed architectural interventions; (3) architectural interventions.

Keywords: Design, guidance, houses, design approach, priority actions.

6.1. Postwar housing design guidance: Methodology proposal for the old city

The preservation of the historical houses and their architectural characteristics in the Old city is challenging due to the urgent needs of the returnees and the IDPs in the camps. As addressed in the damage analysis in chapter 4, the areas that contain historical houses were targeted and have been severely destroyed. Thus, they will need extensive rubble management before starting the reconstruction of the houses. According to the UN-Habitat and UNESCO reports there are at least 335 historical houses out of 15,000 houses in Old City [117] [66]. Comparing the data available given in these reports with the observational field visits, the research outlines the areas (blocks) which contain historical houses (Figure 98).

Figure 98. Areas with historical houses (Source: author).

According to the research outcome in chapter 4, most of the ongoing rebuilding activities in the Old City are small projects implemented by different actors including the international organizations and some local people who returned. However, in large areas of the Old City, no

returns have been taking place as the basic services and the livelihood opportunities are not available [103]. Therefore, empowering the local people from the Old City by providing them with the skills and tools to contribute individually and collectively in the reconstruction process is essential. As a major potential for preserving the historic elements lay in their hands. In addition to raising awareness to local people, it is essential that the local authorities, the different international organizations and the UN agencies increase the coordination among them. Thus, the research developed the post-war architectural solutions in a way that can be controlled and supervised by the local authorities and executed by local people.

The guidance proposed in this chapter is derived from the direct observation of local residential architecture, academics, local people and authorities, international organizations and from the results of analysing the post-war architectural damage. This helped to confront and enrich the theoretical concepts with realistic data from the ground and added data to the post-war reconstruction plan. The principles for architectural reconstruction of houses are focused on developing the design and solutions for the interventions. The structural performance of the houses will be assessed by the structural engineers and detailed data will need to be obtained about each house before deciding the level of intervention needed for it.

6.1.1. Value-based design

In order to provide a useful tool for administrating control over the different proposed design principles and to make the process of deciding the level of intervention to be coordinated, the research guidance is based on categorising the houses in the Old City. The design guidance is approaching the houses through a Value-based design, as the historical value is the main criteria guiding the architectural interventions. This value-based design approach coordinates the post-war architectural design around the classification of the houses according to their historical value and the existing damage scale of the houses and later to be executed through coordination between the local authorities, international actors and local people.

The classification conducted by UNESCO and UN-Habitat (addressed in chapter 4) is chosen because it provides additional depth to the reconstruction plan. It is tailored to the context of the Old City of Mosul and provides a useful sustainable tool for the reconstruction plan. In this classification, each code is related to a specific historical value and its damage level (figure 99). The historical values of the houses are identified in four categories: high; medium; low; none. The damage levels are divided into five categories: negligible, minor, major, severe and destroyed. The resulted codes or types of the houses, (figure 100), will be used to define the

potential reconstruction design needed and the potential actor (local authorities, international organizations or local people) that needs to be involved and their way of assistance.

CRITERIA GUIDING INTERVENTIONS IN OLD MOSUL		ARCHITECTURAL/HISTORICAL VALUE			
		A HIGH (LISTED)	B MEDIUM (HISTORIC - VERNACULAR)	C LOW (TRADITIONAL)	D NONE (MODERN)
DAMAGE LEVEL	4 DESTROYED	A4	B4	C4	D4
	3 SEVERE	A3	B3	C3	D3
	2 MAJOR	A2	B2	C2	D2
	1 MINOR	A1	B1	C1	D1
	0 NEGLIGIBLE	A0	B0	C0	D0

Figure 99. Classification developed by UNESCO and UN-Habitat to merge damage level and historical value. Each code is related to a specific type of architectural intervention [40].

Figure 100. Application of the classification of the houses on a group of houses from the riverfront in Al Maidan area to Nabi Jarjis Street with varying historical values and damage levels (Source: author).

The research proposes ten key design tracks, driven by this classification, envisioned as the basis for the post-war architectural design approach. The houses with high historical value (A) and medium historical value (B) are considered in the same design procedure and categorized in five design principles according to their damage level: (1) A0, B0; (2) A1, B1; (3) A2, B2; (4) A3, B3; (5) A4, B4. In the other hand, the houses with low historical value (C) and no

historical value (D) are considered in the same design procedure and categorized in five design principles according to their damage level: (1) C0, D0; (2) C1, D1; (3) C2, D2; (4) C3, D3; (5) C4, D4.

Table 15. The ten key design tracks proposed in the value-based design.

	Houses with historic value	**Houses with no historic value**
Negligible damage	**A0, B0**	**C0, D0**
Minor damage	**A1, B1**	**C1, D1**
Major damage	**A2, B2**	**C2, D2**
Severe damage	**A3, B3**	**C3, D3**
Destroyed	**A4, B4**	**C4, D4**

As explained before, the proposed value-based design approaches the classification of the houses in two ways differentiated in the priorities of the principles explained in (7.2.1) according to their historical value. Both ways take different design principles, as the original design and the building materials are different for both.

The first category (A and B) includes the houses that are designed traditionally (identified in chapter 2). The value-based design proposes the minimum interventions in this case to preserve the architectural design and building materials whenever possible and therefore the reuse of building materials is prioritised in this category. These buildings are characterized by aesthetic and structural features that are related to local and regional traditional building techniques and represent the most common element of the historic urban fabric.

As for the second category (C and D), includes the houses constructed in the recent past. The architectural design and construction techniques applied do not have a connection with any historical event or architectural heritage. The value-based design prioritizes improving their design and make it compatible with the local design in the first category whenever possible, thus, more recycled building products can be used in this category.

The proposed design approach in this research suggests that the focus can start from the houses with high and medium historical values (categories A and B). The approach can be replicated and scaled up to other categories of the houses, based on priority. After applying the classification on the houses of the Old City, Value-based design selected team can use it to decide the suitable way to intervene each case depending on the level of physical damage intersected with the historical value of each house in the block.

The main actors who are currently implementing different individual projects separately on the ground, can intervene directly in a joined partnership as the application of the classification on each block provides the opportunity for a systematic management of rubble. By making use of the analytical classification and applying it to the design process for each category in the Old City, insights in the precise reconstruction needs per category allow for specifically tailored projects and targeted architectural design. Local people (returnees) to participate in the reconstruction process can get the required assistance according to their house category. A committee that consists of representatives from local authorities and the international organizations can study, supervise and provide technical assistance when required.

6.1.2. Prioritizing design criteria

The degree and extension of the architectural intervention involves the implication of the structural, social, and economic aspects [115]. These aspects must be taken into consideration. To ensure that the intervention levels are based on adequate decisions, they will be decided based on principles.

One of the main reference documents is the Venice Chart [110], which was prepared by UNESCO-ICOMOS Documentation Centre, has adopted the following seven principles in the rehabilitation of architectural heritage:

1. Guarantee of structural safety
2. Respect for the cultural value of the building
3. Minimum intervention
4. Reversibility of the intervention
5. Integration of the whole building
6. Compatibility of the materials
7. Minimum cost.

Sometimes these principles contradict with each other [116]. In each specific case, compromises between those principles will be necessary. For the case of Mosul, it is subjected to the historical value of the house. For example, in many cases, the historical value will conflict with the structural performance and the minimum cost. In each specific case, even in the same category of the houses, compromises will be important. Taking in mind these principles will help the designer to make the adequate decision.

The compromising process will be different in the first category of the houses from the second category, in some cases, as both categories are different in their historical value. In categories

A and B, the houses that the research is seeking to preserve as much as possible, respecting the historical value with the minimum intervention will be prioritized. In the categories C and D, minimum cost and integration with the local architecture will be prioritized. It gives a balanced opportunity between saving the remaining of the historic houses in the first category and improve the contemporary houses designs and their building materials, thus, design them back to be integrated with the local architecture.

Applying the previous theory to the categorized houses in the Old City allowed the research to establish the following **principles for the post-war design guidance according to the level of intervention** (Table 16, 17, 18, 19 and 20):

1. A0, B0, C0, D0: When the house is generally in a good condition only minimum interventions are required, ***minimum repair*** level of intervention will be applied to prevent further damage. This case applies when the physical condition of an element or a material on the building envelope usually requires additional work [161]. For the houses with a historical value, where this work will require skilled people, the cost will be higher than the houses with no historical value.

2. A1, B1, C1, D1: The damage is minor in this case, it is required to reclaim damaged elements and it needs to involve minor interventions, ***repair*** level of intervention will be applied. For the houses with a historical value, character-defining features will be repaired then reused rather than replaced. The repaired elements can be reused in the location. In the houses with no historical value, the elements can be replaced if the cost is less in that case. Recycled elements can be used in the category (C, D) when the cost is less than repairing the original ones. The new elements will be made from recycling materials compatible with the local materials.

3. A2, B2, C2, D2: The intervention hierarchy will require ***rehabilitation*** when the historical house requires replacement of an entire architectural feature with a new one. Because the level of damage does not allow for repairing to be an option. This level of intervention does not include structural rehabilitation. For the category (A, B), designing and constructing a new feature based on the historical documentation will help to reproduce the element accurately. If the historical documentation is not enough to design the new feature or in case the materials are not found, then a new design is recommended. The new design should be clearly differentiated to avoid a fake historical look. Although it is preferred to use the same material in the new design, alternative material is acceptable. In the category (C, D), avoiding demolition and reconstruction costs by reuse in situ will be preferred but the replacement will be with a recycled material as long as the cost is less.

4. A3, B3, C3, D3: The houses with severe damage to their structural elements will require interventions in the level of ***structural rehabilitation***. The interventions will include the completion of the structural elements and the rehabilitation of partitions and facades. For the category (A, B), after assessing the actual condition of each house, collected data about the safety of the building, and deciding the solutions, information about the building's past and its design techniques is important for the architect (chapter 1 and 2). The category (C, D) of the houses do not have the local architectural design techniques, and therefore it is an opportunity to take in mind an integrated design that respects the local architecture when rebuilding the new elements, when rebuilding the kissing structural parts. ***Deconstruction*** can be an option in some cases for these categories of the houses especially for the category (C, D). This case can be decided in coordination among the design team, local authorities and the owner of the house.

5. A4, B4, C4, D4: Houses that are destroyed, in the case of historic houses (category A, B), will be subjected to two different interventions:

a) ***No reconstruction***, this kind of intervention aims at leaving some destroyed houses unbuilt to decrease the density of houses in the historic urban fabric, to create public spaces and memorizing areas. The local authorities will decide a few selected destroyed houses' remains to be preserved. This case can be decided in coordination among the design team, local authorities and the owner of the house.
b) ***Reconstruction***, destroyed houses will be re-built on their original site. This level of intervention starts from the design process to choosing building materials. The design in this case will be based on the design process addressed in chapter 5. For the category (A, B), the design will consider reusing the original building materials and elements found in the rubble of the same house or from other houses, whenever suitable. Recycled materials can also be used to replace the original materials as explained in level 3. For category (C, D), it is a good opportunity to improve the design and create a new design integrated with the local architecture and its design techniques. Recycled materials and building products will be prioritized.

Following these principles, it is important to mention that if the elements or items of a house cannot be reused in the same house, they can be reused in another house with the same historical characteristics. Usually, those elements will need to be reclaimed to make them suitable for use in different required level of repair. Thus, providing salvage stores in the Old City is necessary to save those items until the architects choose them to be used in another location. As an example, in one of the projects that UNESCO is undertaking its reconstruction in the Old City of Mosul, they selected valuable elements from the location of the building to be separated from its rubble and reclaimed to be ready for reuse during its reconstruction (Figure 101). The local

authorities in Mosul can use this strategy for the reconstruction plan of the houses in the Old City.

Storage locations can be arranged to cover the period of reconstruction in the Old City. In the case of reuse and recycling, the availability of the elements in salvage stores will affect the decision of the design team during the design process in level 5 (b). The salvage stores can be in different types, according to the importance of the items separated from rubble.

Figure 101. UNESCO stored some items from the rubble of one of the heritage buildings in Mosul (Source: UNESCO).

The classification of the houses will also help to make the process of rubble separation and categorization of the salvage stores. As the rubble of houses in category (A, B) will contain historic items and local materials that are preferred to be reused with minimum intervention and the rubble of houses in category (C, D) will have items that can be recycled whenever it is recommended after the cost analysis. The stores will be ranging from the high value architectural elements which will be found in the rubble of houses from category (A, B) such as distinctive elements, ornaments and features that refer to special historic time or the elements that can no longer be made in the Old City, to low value items which will be in the rubble of houses in category (C, D).

Table 16. Value-based design approach for the Negligible damage level.

Damage details	**House category** (Historical value/ damage level)	**Value-based design**		
		Architectural intervention level	Prioritizing design criteria	Further architectural design interventions' priorities
Slight traces on external walls	A0, B0	Rehabilitation with: -Minimum intervention.	Respect for the historical value of the building.	Leave the marks bare in selected houses. Or Conservation of the marks on the walls
	C0, D0		Integration with local architecture. Minimum cost.	Cover the marks

Traces on the ornaments and inscriptions on the gate	A0, B0		Respect for the historical value of the building.	Repair of cast stone with using mortar aggregate from the same house's category' to match the historic unit.

Table 17. Value-based design approach for the Minor damage level.

Damage details	**House category** (Historical value/ damage level)	**Value-based design**		
		Architectural intervention level	Prioritizing design criteria	Further architectural design interventions' priorities
Limited mortar perforations on walls/roof	A1, B1	Rehabilitation with: -Minor intervention -Minimum Repair	Respect for the historical value of the building. Compatibility of the materials.	Integration between the new mortar and the original one. The new mortar will be made from recycling the materials used in the production of the original mortar instead of using new raw materials
	C1, D1	Rehabilitation	Minimum cost.	
Minor damage to windows and external doors and their frames.	A1, B1	Minimum Repair	Respect for the historical value of the building.	Most types of windows and doors will be reclaimed and reused in their location.
	C1, D1	-Repair -Replace with recycled elements	Minimum cost.	
Limited damage to internal walls.	A1, B1	Rehabilitation with: -Minimum intervention.	Respect for the historical value. Compatibility of the materials.	Integration between the new mortar and the original one. The new mortar be made from recycling the materials used in the production of the original mortar instead of using new raw materials
	C1, D1		Minimum cost.	

Table 18. Value-based design approach for the Major damage level.

Damage details	**House category** (Historical value/ damage level)	**Value-based design**		
		Architectural intervention level	Prioritizing design criteria	Further architectural design interventions' priorities
Extensive shell perforation on walls	A2, B2	Rehabilitation with: Repair Reuse Replacement	Respect for the historical value. Integration of the whole building. Compatibility of the materials.	Stone of the same location can be reused after cleaning it from old mortar. If the stone on the location is missing, then stone from salvage stores can be used.
	C2, D2	Rehabilitation with: Replacement	Integration with local architecture. Minimum cost.	In this category where the houses are built using concrete blocks, the blocks will be made from recycling the old ones.
Internal spaces damaged	A2, B2	Rehabilitation with: Repair Reuse Replacement	Respect for the historical value. Compatibility of the materials.	Stone of the same location can be reused after cleaning it from old mortar. If the stone on the location is missing, then stone from salvage stores can be used.
	C2, D2	Rehabilitation with: Replacement	Integration with local architecture. Minimum cost.	The blocks will be made from recycling the old ones.

Table 19. Value-based design approach for the Severe damage level.

Damage details	**House category** (Historical value/ damage level)	**Value-based design**		
		Architectural intervention level	Prioritizing design criteria	Further architectural design interventions' priorities
Structural damage involving walls and roof. Doors and windows damage	A3, B3	Structural rehabilitation	Respect for the historical value. Compatibility of the materials.	Repairing and reusing the original materials. Reusing materials and elements from salvage stores Using new materials made from recycled materials of the same houses' category.
	C3, D3	Structural rehabilitation	Integration with local architecture. Minimum cost.	Using new materials made from recycled materials of the same houses' category.
		Deconstruction	Minimum cost	Decrease the density of houses in the Old City Create urban spaces. Generate different elements and materials. reuse and/or recycle of the generated materials and components in other houses.

Table 20. Value-based design approach for the Destroyed damage level.

Damage details	**House category** (Historical value/ damage level)	**Value-based design**		
		Architectural intervention level	Prioritizing design criteria	Further architectural design interventions' priorities
Structure is reduced to rubble	A4, B4	No reconstruction	Respecting the remaining of the historical building.	Decrease the density of houses in the Old City Create urban spaces
		Reconstruction	Respecting the historical original building.	Architectural design respecting the original design and involving the reuse and recycled materials from the design stage (following chapter 5) Choosing building materials and components from the rubble in the house location and salvage stores to reuse and/or new materials and components made from recycled materials.
	C4, D4	No reconstruction	Minimum cost	Decrease the density of houses in the Old City Create urban spaces.
		Reconstruction	Integration with local architecture. Minimum cost.	Architectural design integrated with local architectural design (in category A, B) and involving the reuse and recycled materials from the design stage (following chapter 5) Choosing building materials and components salvage stores to reuse and/or new materials made from recycled rubble.

6.1.3. Reuse and recycling practices

The Value-based post-war design approach ensures that the reconstruction process respects not only the noticeable surviving elements of the historic urban fabric, but the traditions and techniques used in their original construction. With this in mind, key intervention of this design approach is the application of appropriate reuse and recycle practices to the classified houses.

The use of appropriate materials and designs where practically feasible is essential to build the proposed design principles and the revitalization of the Old City. Traditional building techniques are fully understood and employed throughout the process. Based on the value-based design's methodological approach and principles, the decision on the intervention level for each case and priorities for reusing or recycling the surviving elements and materials within the Old City will be accurate and practical.

Negligible damage: A0, B0, C0, D0

Damage ***Interventions***

1. Slight traces from bullets left perforations on the walls and the stonework of the ornaments and inscriptions on external walls.	***Category (A, B):*** The holes caused by bullets on the external walls of selected historical houses will be maintained bare for keeping the evidence of this period in the historical memory. In other selected houses the historical value will be emphasized by conserving the marks made where the walls were breached [200]. The conservation work will include using lime mortar compatible with the original one used in the Old City (Al Noura) in colour and appearance. It is not recommended to apply paint or other coatings to masonry that has been historically unpainted or uncoated to create a new appearance or use new colours that are inappropriate to the historic houses. ***Category (C, D):*** It is an opportunity to unite the appearance of the contemporary houses in this category and differentiate them from the historical houses in category (A, B), by covering the traces on the walls and paint them in a uniform colour (off-white colour is recommended). Regarding the decorations in this category of contemporary houses, they are not usually applied. In some cases, the Local marble and limestone (Al Hillan) kept in use for the decorative elements. When the decorations of these category of houses exist and they have traces left from the conflict, the decision to is either to repair them when they are made from local limestone or remove them when they are representing foreign features, instead of repair.
2. Traces on the ornaments and inscriptions on the gate (entrance of the house/Al Bab).	***Category (A, B):*** as identified in chapter 2 the decorative features in the entrances of traditional houses made of local marble (Al Farsh) are important features in defining the overall historic character of the houses and they must be emphasized during the design stage. The architectural historical values of the gate are embodied, among other things, in the inscriptions appearing on its facades.

These values will be reinforced by the conservation of the inscriptions and ornaments by documenting the inscription field, its state of preservation and analysis, restoring a uniform colour to the stone and highlighting the written letters in order to improve their legibility.

Deeper traces, damaged corners and occasional fragments are repairable conditions that do not involve the replacement of the stone [103]. Small repairs to damaged stones (masonry unites) will be using mortar that matches the original material. The same methods used for repairing the stone masonry are applicable for repairing the historic cast stone [106]. For successful repairs on cast stone, the aggregate size and the mortar colour must match the historic unit [161]. Crushed stone from the rubble of category (A, B), which is similar to the traditional aggregate, is necessary to obtain an appropriate repair to the historic element.

Minor damage: A1 B1, C1, D1

Damage	***Interventions***
1. limited mortar and shell perforations to walls and/or roof.	The new mortar must be compatible with the original one to achieve similar physical properties, appearance, and external colour. The ideal access of these standards requires that the new mortar be made from recycling the materials used in the production of the original mortar instead of using new raw materials. The binder material of gypsum-lime and aggregate material of sand are the main components of the original mortar in the Old City [117]. The integration between the new mortar and the original ones considers one of the most important issues that should receive crucial concern. Cleaning and repainting must be decided after inspecting painted walls to determine if it is necessary. The repainting will be with colours that are historically appropriate to the houses. Avoid using new colours for painting the historic houses (Category A, B). For category (C, D), it is recommended to use a unified

colour. To differentiate the houses in category (A, B) they must be painted using limewash paint in traditional brown colour and the houses in Category (C, D) must be painted in off-white.

For both categories, it is not allowed to use finishes in aluminium, plastic panels, tiles. The external walls shall be finished with stone, brick, or plaster.

2. Minor damage to windows and their frames. External doors missing or damaged. Traces on the ornaments and inscriptions on the gate

Retaining the original windows and doors will influence the character of the house and its historical value for the houses in category (A, B). They need to be physically exanimated to identify the problems and the intervention level required. In addition, it is important to identify each window or door's location before the assessment to organize required components to be repaired or replaced. It is recommended by Heritage conservationists to repair traditional windows and doors, and "to replace them only when absolutely necessary" [118].

In minor damages, most types of windows and doors will be reclaimed in their location, when only painting is required or replacing specific components with recycling same materials. The missing components can be found in the salvage stores.

Traditional wooden and metal-framed windows in category (A, B) when in need of repair, they can be removed, repaired, and returned to their original place [118], unlike vinyl ones that require complete replacement. In addition, studies have shown that repaired historical windows and doors will last two times longer than vinyl ones and the cost is less.

Besides the benefits of reusing the missing components, repairing the windows and doors in the Old City will help to employ local people and encourage the reuse of salvaged elements rather than newly producing them.

In other cases where the frame of the entrance is damaged and parts of it are still in good status, it can be moved to salvage storage, as

	some parts can be reused in other houses where suitable. *Marble (Al Farsh):* These values will be reinforced by the conservation of the inscriptions and ornaments by documenting the inscription field, its state of preservation and analysis, restoring a uniform colour to the stone and highlighting the written letters in order to improve their legibility.
3. Limited damage to internal walls.	Similar principles apply in the internal walls minor damage as the ones used in external wall minor damage.

Major damage: A2, B2, C2, D2

Damage	***Interventions***
1. Walls have extensive shell perforation, no deformation to structural elements.	The opportunity to reuse masonry depends very much on the ease with which the individual bricks or stones can be separated and cleaned [140]. Lime mortar also bonds very lightly to the brick or stone. This has the advantage (for reuse) that individual stones or bricks can be separated with relative ease and without causing damage. Both strong-back and stick cladding systems can be refurbished in situ to some degree. Such materials and special items now quickly find their way into the architectural salvage yards located throughout many countries. The challenge will always be to find masonry of the required type (age, material, colour, size, quantity etc.) to match the materials of the original construction. To repair the missing parts on the walls, the stone in the same location can be reused after cleaning it from old mortar. If the stone on the location is missing or has been removed from the location before, the design team can use stone from the salvage stores. The main reason why masonry materials and components would be reused from a different location is to match the materials used in an old building when being repaired or restored or when an extension is being built. Many planning

	authorities are strict about the use of construction materials in conservation areas or for the repair of buildings important to the local or national heritage. Great care is needed to match the colour, size and age of bricks and stone.
2. Internal spaces damaged by shells, damage across multiple floors.	(C, D) in this category where the houses are built using concrete blocks, the blocks will be made from recycling the old ones. Modern cement mortar hardens very quickly (days) and becomes brittle when hard. The bond between the cement mortar and the bricks or blocks is very strong sometimes stronger than the bricks or blocks themselves and so it is relatively difficult to separate individual bricks or blocks [119]. According to the type of building, a masonry partition wall may be painted, finished with wet plaster or faced with a dry lining of plasterboard that, in turn, may be finished with wet plaster [118]. Masonry and partition walls can be removed and rebuilt in a new location to suit changes in internal layout. Masonry partition walls can be constructed of concrete block made with recycled aggregate. The ceilings of domestic and other small buildings are likely to be formed using the same technique as for partition walls.

Severe damage: A3, B3, C3, D3

In the Principles of the Value-based design (7.2.2), the decision of the design team in these categories of houses will be 1) structural rehabilitation of some selected houses and 2) deconstruction of other selected houses. The following architectural interventions for the reuse and recycling of materials are included for the case of **structural rehabilitation**.

Damage	***Interventions***
1. Structural damage involving walls and roof.	If the bricks obtained by following the recycling procedure are not sufficient to complete the future interventions, it is required to manufacture alternative bricks. The ideal achievement of these criteria necessitates the new brick materials to be from the same source of original building materials.

Aesthetic and appearance criteria of new brick samples do not only refer to colour but also shape and dimensions, as well as methods of arranging the bricks in the building. Regarding the colour of the new bricks, it is possible to add pigments or artificial colours to clay-raw material, and during the baking process, a group of brick samples will be produced in different colours [117].

Although bricks are usually made from virgin clay, it is possible to make bricks with recycled content using a variety of post-industrial waste materials, namely colliery spoil, dredged silt, Pulverized Fuel Ash (PFA), blast-furnace slag and sewage sludge [106].

The stone generated from severe and destroyed damage level can be salvaged to be reused later in different applications.

Masonry partition walls can be constructed of concrete block made with recycled aggregate. Timber studwork can be made using timber salvaged from the demolition of a building.

Masonry partition walls can be constructed using bricks or blocks reclaimed from another building. This may be more practical than for exposed masonry in the external wall as partition walls are usually faced or plastered. Hence, reclaimed bricks with some visible damage, adhering mortar or remaining paintwork can be used.

Rigid panels of partition walls will most likely be damaged beyond reuse.

Timber studwork, however, can be removed with little damage and thus is likely to be available for reuse in a new partition wall.

2. Doors and windows damage

The comparison between the life cycle cost analysis of a maintained wooden window and a vinyl replacement has proven that repairing your heritage window is more cost effective and environmental-friendly.

Destroyed: A4, B4, C4, D4

With the consideration of the damage details provided in UNESCO's classification to define the destroyed houses:

1. the structure is reduced to rubble, complete extensive cracking or loss of material, overall deformation
2. Partial or complete collapse of roof, weakened structure at risk of collapse
3. Deflected roof

Damage of doors and windows
Non repairable fire damage, affecting structural members.

In the **Principles of the Value-based design** (6.1.2.)**,** the decision of the design team in these categories of houses will be 1) **no reconstruction** of some selected houses and 2) **reconstruction** of other selected houses. The architectural interventions for the case of reconstruction are provided in chapter 5. The architectural design process with the application of reuse and recycled materials is discussed. The rubble generated from the destroyed houses will be reclaimed and stored to be reused later in the same location or in other site, according to the decision of the design team.

FINAL CONCLUSIONS AND FUTURE DEVELOPEMENTS

Although Iraq have been in political and economic conflicts for the last three decades, the conflict against the Islamic State in Iraq and Syria, caused significant heritage destruction comparing to the conflicts before. ISIL deliberately attacked heritage buildings in the seven provinces that they occupied in Iraq. The largest scale of destruction was in Nineveh. Mosul, the centre of Nineveh, was occupied by ISIL for the longest period, specifically the Old City area of Mosul. ISIL hiding in the Old city led to massive airstrikes from the Iraqi military forces backed by the international air forces, to liberate the city.

The destruction of the houses in old city led to a humanitarian crisis and heritage loss. The local people who lost their houses flee to other cities in Iraq or in areas around Mosul. Some people retuned back after the announcement of the liberation of Mosul. Others stayed as IDPs in their host cities. The research revealed that both groups are in urgent need for housing solutions. Years after the liberation of Mosul and there are still no governmental plans for the reconstruction of the Old City. The research found that there are currently two main actors implementing the existing rebuilding activities:

1. First, the local people who returned back to their homes, who are rebuilding in such way just to cover their emergency needs. The research showed that the self-reconstruction of the returnees is unguided causing more damage to the historical value of the houses in the Old City in different ways, such as: using inappropriate material, inappropriate rubble management and loss of significant architectural elements. They are not aware of the importance of some materials and elements found in the rubble of their homes. In other cases when they cannot afford to remove the rubble and rebuild their houses, they choose to build new houses in informal or illegal areas around Mosul. Which led to the increase of unregulated illegal areas. The research also investigated the different ways that the IDPs are seeking to upgrade their temporary housing solutions in the host cities within and out of the camps.
2. Second the international agencies mainly UNDP, UN-Habitat, UNHCR, UNESCO, Human Appeal, and Norwegian Refugee Council (NRC). They are implementing projects in a more respectful way to the historical value of the buildings. However, these agencies are limited in their rebuilding targets. They mainly focus on the public buildings especially mosques and churches and a few selected historical houses. They lack coordination among themselves and between them and the local authorities in Mosul such as Mosul municipality and the committee responsible for the national effort to restore services in Nineveh province.

The research gaol was to develop an architectural design guidance that can coordinate the current rebuilding activities based on two principles: 1) respect the historical value of the houses; and 2) avoid further damage to the environment. Assessing the previous post-war self-reconstruction challenges and finding out the displacement is prolonged with no comprehensive governmental plan for the reconstruction, in one hand. In the other hand, the research found that self-reconstruction by the local people can achieve an active framework for rapid reconstruction in case it was supervised and assisted by the international agencies. The research revealed a design guidance that can be supervised by the local authorities to create the coordination among the actors (local people and international agencies).

The methodological approach adopted revealed to be sufficient. The field visits to Mosul allowed to fill the gap in collecting the necessary data. The observational fieldwork provided insights regarding the urgency of the reconstruction, local people self-reconstruction challenges, the involvement of the international agencies in the current rebuilding actions and a realistic assessment of the housing damage scale. These outcomes can feed future housing reconstruction policies in Mosul. The main innovation was the proposal of a methodological approach to the reconstruction of the houses in the Old City.

The study of the historical context of the region and the traditional architecture in Mosul resulted in categorizing the houses with significant historical values. The analysis of the compact layout of the Old City enhanced the understanding of the rubble generated and the importance of the salvage stores to separate the rubble generated from the heritage buildings and mixed with the rubble of the housing sector. Understanding the characteristics of the traditional house in the Old City will contribute to the characterization of the rubble generated from them, the level of intervention required, and appropriate decisions for the reuse of the architectural elements and materials found in their rubble. It was also important to study the architectural characteristics of the traditional house to contribute to the reconstruction of the houses in the categories A4 and B4, and the houses in categories A3 and B3 in case the design team decides to deconstruct and reconstruct them.

Actions required to be taken by the local authorities and the main actors for the implementation of the value-based design approach

- Specialised heritage damage team should be appointed to apply the classification on the ground. A design team should be selected by the responsible local authority to make the architectural design decision, the intervention level needed and the compromising of the principles for each house design.

- The design team must identify heritage elements to be mover to the salvage store sites before the rubble clearing activities in selected areas in the old city. The houses that are severely damaged from the categories A and B need to be protected immediately from further unguided rubble clearance actions and the loss of their surviving elements.
- The design team need to examine the historical value of individual surviving element in detail. To be stored accordingly in salvage stores.Instructions should be issued to protect selected houses from further damage by preventing the clearance of the houses until the supervising teams can be present.
- The houses that have been already cleared from rubble should be protected from unsupervised reconstruction by issuing instructions to put temporarily all self-reconstruction activities on hold, until the application of the classification on ground and issuing the decision of the design team for the intervention level of each house.
- Further guidelines should be published by the design team to recommend the use of materials, house design, paint colour, window and door types according to the historical value of the house.
- Selected blocks that have a significant number of historical houses need additional guidance for their reconstruction. The accesses to the historical houses need to be limited until they are reconstructed to protect them.
- The houses should be cleared from the explosive ordnance before clearing the rubble. The local people should obtain official approval for the rubble clearance and the reconstruction after the review of the design team. The approval will include taking the responsibility of the materials within the rubble (category A, B). The design team need to work with structural team before the decision of the intervention level required for each house.
- Salvage stores should be selected ahead of the rubble clearance. The historic architectural elements can be stored there to be reused later. A wide awareness campaign is required regarding the importance of the Old City's historical significance.
- Issue a local order that makes adherence to the guidance mandatory for obtaining rubble clearance and reconstruction approval within the Old City.
- Establish facilities that represent a centre for traditional construction skills training, information and provide workshops. These facilities can provide an environment in which local people can get assistance from each other and from the international agencies' experts in their self-reconstruction endeavours.

Future developments

The design guidance proposed in this research is derived from confronting the collected data with observational visits to Mosul. The visits to Mosul, at the time of this research, were limited due to the complicated security issues and the research could gather enough data and

observational visits to apply the classification of the houses on one block of the houses in Al Maidan area. Future studies are necessary to apply the classification on every block of the Old City.

The proposed architectural interventions levels for each house historical value and damage level revealed to be effective to achieve a rapid self-reconstruction approach. Each intervention level will require further design guidance tailored to the context of the Old City. Further studies are necessary for design decisions needed for the intervention levels. For example, the design guidance suggested two options for the destroyed house, reconstruction and no reconstruction, the study will select areas in the Old City where it is recommended for no reconstruction.

The present study allowed starting a database regarding the design guidance tailored to the Old City. Future works may select other cities to apply the same methodology for controlling the unguided reconstruction activities and speed the housing reconstruction. Global Index Approach revealed to be fit for the quantification of rubble generated in urban scale. It can be applied to the future works to estimate the rubble generated from the other sectors or from the housing sector in another city.

The study of the ethnicity background in Mosul revealed to be important in the reconstruction process, since the houses of the local people were targeted according to their beliefs. Future works may investigate further the impact of that on the current housing challenges of the targeted groups.

Future works may study the environmental benefits of the application of this design guidance in the Old City and the estimated reduction of the carbon emissions. Future works may also study the different options for recycling with the local materials in the Old City.

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