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Using Three- Dimensional Modeling Techniques in Digital Preservation of Urban Plans for the Old Walled City of Shibam Hadramawt

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ABSTRACT: *Historic cities have great importance in our time because they represent a cultural, social and urban wealth for societies. Where historical cities gain their importance through the values and principles that are reflected on the reality of the city, its personality, its social and topographic components and its planning and urban form. The traditional methods and paths of preservation have taken long periods of time and have been affected by the political and economic situation of the country which until our current situation, still living a period of instability. The study object is to create a vision for a preservation digital platform of the historical city of Shibam, Hadramawt using 3D modeling techniques. The study importance is, using 3D modeling techniques and a set of metadata associated with each graphic object of historical urban elements would help in digital preservation. The research followed the descriptive inductive approach in studying the theoretical concepts and the practical approach in creating the digital platform for the three-dimensional modeling technologies.*

Keywords: *3D modeling techniques, historical cities, digital preservation, urban plans.*

I. Introduction

The current era has specialized in developing many techniques, applications and programs for modeling buildings and cities in three dimensions, but these technologies lack the steps to be used in embodying historical cities and their urban plans. Where three-dimensional modeling techniques can be directed to study and analyze urban plans of those historical cities in order to document and preserve them digitally in order to manage their urban plans and assist in making future conservation decisions. The city of Shibam Hadramawt is considered one of the most historical Yemeni cities that still retains its historical urban characteristics despite the torrents and floods that threaten it at different periods. This may require modern methods of preservation in dealing with it based on digital technologies. So, the historical city of Shibam Hadramawt was chosen to create a digital platform for it that includes steps and stages of using 3D modeling techniques in digitally preserving the urban plans of the city and linking their metadata with a set of attached files, then making an analysis and simulation of those plans.

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II. The problem

The research problem is based on the adoption of conservation projects in Yemen on traditional methods and techniques, which are subject to continuous neglect as a result of their high material costs, especially in the current political situation in the country and the lack of a tendency to use modern digital technologies in preservation.

III. The significance

The research gains its importance in that the three-dimensional modeling techniques are one of the modern methods used in digital preservation by managing and archiving urban data for geographic information systems, which contributes to build a spatial database linking three-dimensional spatial data and a set of descriptive data associated with each graphic object of historical urban elements.

IV. The objective

The main objective of this research is to create a digital platform for the process of digital preservation of the urban plans and their condition in the historical city of Shibam Hadramawt, using 3D modeling techniques, in order to direct future conservation projects in it, and to reconstruct the historical buildings, zones and areas according to their importance.

V. The methodology

The research consists of two main parts sequentially to achieve its goal. The first part of the research is based on the descriptive inductive approach (theoretical framework). The second part of the research is based on the applied approach (practical framework) as follows:

A. Theoretical framework: by collecting basic information and creating a database of the research's topics.

B. Practical framework: by following the applied approach in the work of the digital platform.

VI. The First Part: The Theoretical Framework

6.1. 3D Modeling:

There are many talked about modeling with its various concepts, as the term modeling appeared in the eighties of the twentieth century after the beginning of the spread of computers [1]. The concept of modeling was adopted initially at Harvard University in the late nineties of the last century. Garland[2] (1999) defined three-dimensional modeling as a phrase about converting two-dimensional maps and data into a three-dimensional image or a model. As well as Reddy[3] (1997) defined it as (the process of translating the mathematical representation of any three-dimensional surface of the body by means of specialized software and the output is called the three-dimensional model), and these models can be represented manually Or semi-manual or automatic depending on the type of hardware and software used in addition to the characteristics of the body to be modeled. These three-dimensional models are formed by collecting a number of points or shapes within the three-dimensional space and are linked with each other by a number of engineering relationships. Modeling was also defined by Çöltekin[4] (2006) (the use of computers to represent things that may be inanimate objects or living organisms and simulate the operations that they perform). Çöltekin explained that computer models have a high scientific value because it allows someone to study the response of the system or the object to be tested under conditions that cannot easily and safely experience in real situations. Models can also allow researchers to study the functioning and behavior of the system and what can happen when one of the different individual components of the system is modified. Mao[5] (2011) defined the three-dimensional model as (a simplified descriptive representation of a complex reality). Chen[6] (2013) explained that modeling is widely concerned with the tools and concepts necessary to form three-dimensional models that are based mainly on a set of architectural and structural information for all the elements that make up the body or the object. In short, he defined modeling as (the digital representation of the building's physical and functional characteristics to

form the most accurate and effective model for the building in its current constructive state). This definition is very similar to the definitions of Reddy and Çöltekin.

So, modeling can be defined as the representation and embodiment of objects in a three-dimensional image within the computer environment of a specific area or physical elements, after performing a number of complex harmonic mathematical and engineering operations, identifying the characteristics of that region or element, and modeling them at a specific level of detail, which helps to understand the areas and elements that has been modeled for people who have not seen it yet directly (face to face).

Figure (1): Digital models part of the land showing elevation, depression, levels, and type of terrain[8]

6.2. Types of 3D modeling:

6.2.1. Modeling according to the accuracy scale[7] :

There are many three-dimensional modeling types classified according to the scale of accuracy and to the level of detail, as they are classified according to the scale of accuracy as follows:

A. Models with a small scale of accuracy: such as digital models of terrain, contour lines showing elevation and depression, and general levels of the earth in its various forms, such as leveling lines and the matrix formula used in topographic analysis, such as calculating slopes, sight lines, and others. Figure (1).

B. Models with an average accuracy scale: They are at the level of cities in their representation. They are used in city planning and design, and in rapid response operations to emergencies. Figure(2) .

C. Models with a large scale of accuracy: They are at the level of buildings and rooms. They are used in decoration design, and in some analyzes and video games.

Figure (2): Medium-scale models that are at the city level in their representation and used in city planning[9]

6.2.2. Modeling by level of detail:

The modeling was divided according to the Level of Detail (LOD) into five levels, as in figure (3), and they are shown as follows:[8]

Figure (3): Biljecki's division of modeling according to Level of Detail[11]

1. Level 0 of detail (LOD 0) is represented by the small-scale models that are at the regional level and are also called two and a half dimensions (2.5 D) models.
2. Level 1 of detail (LOD 1) is represented by medium-scale models which allow to represent buildings as blocks according to their heights without any external details of the building.
3. Level 2 of detail (LOD 2) is also represented by models with a medium scale of details, which is the same as the previous level, in addition to the exterior fabric of buildings and the roof structure.
4. Level 3 of Detail (LOD 3) which is a medium-scale model as well, and it is the same as the previous level, in addition to that the buildings are represented with the smallest external details on the facades.
5. Level 4 of detail (LOD 4) is represented by large-scale models that are concerned with the interior design of buildings, and modeling of objects in them.

6.3. Digital preservation in historic cities:

In the current era, wars and natural or industrial disasters occupy the attention of global organizations and institutions responsible for preservation. In turn, these organizations direct the different societies to preserve and sustain various levels and fields, such as the urban, architectural, cultural, social, heritage and various

archeological fields. Therefore, conservation is considered the motto of the twenty-first century for the sustainability of humanity and its affiliated societies. From this point of view, urban preservation and sustainability in cities, especially historical cities, are among the most important goals pursued by developed countries because those cities and historical regions constitute economic importance and an important cultural and social heritage for their affiliated societies in particular and humanity in general. The methods of traditional preservation represent the overall scene of the reality of the historical city, and in some cases, it may result in a scene that is not related to the reality of the historical city [12]9. But in recent years digital urban preservation systems have become widely used in the ranges of historical regions and cities, due to the possibility of digital urban preservation mechanisms of archiving, analyzing and arranging data, which in turn expands in preparing, arranging and managing future plans. Trillo10[13] and others (2020) indicated that digital urban preservation as (the process that includes all procedures and methods which provide for the heritage to remain in a three-dimensional digital computer image for the longest possible period to play a role in the life of the community that coexists with it In the future). Mohamed [14] (2017) explained that digital urban preservation as (the managing and planning using modern technological technologies based on plans and a digital database similar to reality with optimal utilization of natural and human-made resources in order to conform to the requirements and needs of the future, and how to exploit and manage them). Pointing out that this concept is concerned with the management of digital urban preservation, which differs somewhat from the definition of Trillo and Francesca [15]11 (2018) clarified that digital urban preservation means (the procedures and actions that are taken to prevent damage and extend the life of urban heritage digitally using modern technology). Francesca also indicated that the process of the digital preservation of historical cities must be done in a correct manner, based on the criteria for digital preservation, without falsifying the historical value. This process includes many disciplines and includes a team of specialists, such as architects, archaeologists, economists, engineers, historians, surveyors, building contractors, planners and specialized consultants. The focus here is on what they contain of important buildings, distinctive urban facilities, urban fabric, historical planning and heritage values using modern technology. Digital preservation includes the urban, social, economic, cultural and environmental aspects. It also includes the general visual image of the historical urban areas. According to Fadli and AlSaeed (2019), it falls within the methods of dealing with historical urban areas and affects other methods of dealing, as in figure (4). Where methods of dealing with historical urban areas differ according to the problems they are exposed to, and digital preservation is considered one of the methods of architectural and urban preservation, as in Figure.(5)

Figure (4): Methods of architectural and urban preservation [16]

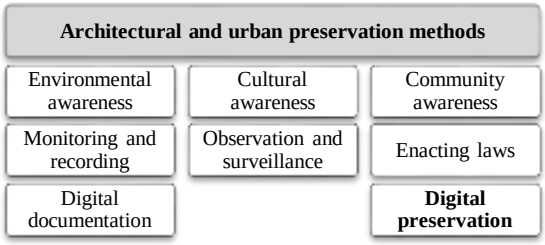

Figure (5): Methods of dealing with historical urban areas where the digital preservation is among those dealings [17].

[13] [12]

6.4. Steps of the digital urban preservation process:

The steps of digital urban preservation are numerous and vary according to the project and the historical region for which the urban preservation process is in progress. Three different models will be presented here to demonstrate the steps of digital urban

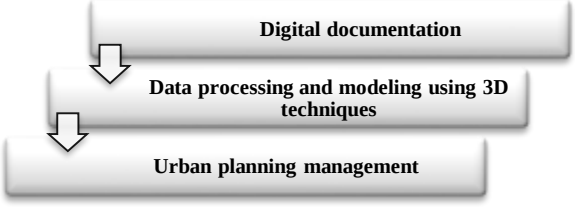

Figure (6): The main steps of digital urban preservation process [19].

preservation [18]14. The steps are generally divided into several main steps shown in figure (6) and figure (7). They could be summarized as follows:

1. Digital Documentation: This stage monitors, describes and records historical models visually and digitally through conducting a comprehensive field survey, in addition to relying on literature, sources, information, and documents that provide us with complete information about the original state of urban plans in the historic city and its various elements.

2. Data processing and modeling using 3D technologies: where the information from the previous step is taken and used as a database for 3D technologies to be able to perform the correct modeling and representation process.

3. Urban plans management: This process is associated with 3D technologies and depends on the outcome of the information and data generated from it.

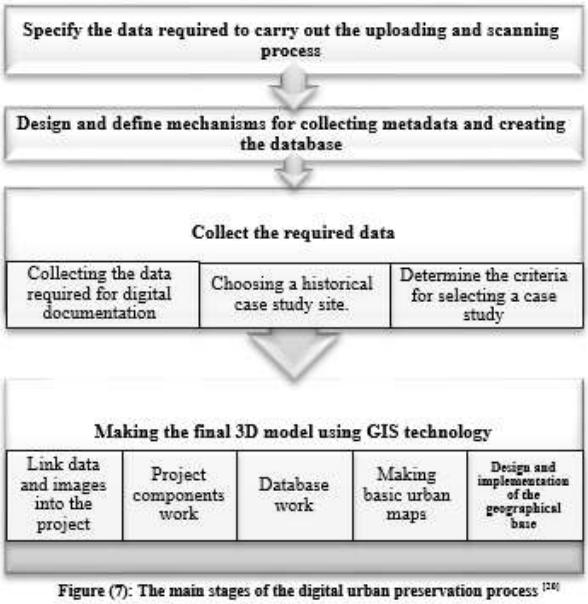

Figure (7): The main stages of the digital urban preservation process [20]

VII. The second part: the practical framewor:

7.1. The city of Shibam Hadramawt:[15] [21]

Yemen has a unique architectural diversity as a result of the topographic diversity and cultural richness. It is located between latitudes [20 degrees] north and [12 degrees] south, and longitudes [41 degrees] east and [45 degrees] west, forming the southwestern part of the Arabian Peninsula. Yemen administratively consists of twenty-one governorates, as in figure (8). Hadramawt governorate is the largest, with an area of 155,376 km2.

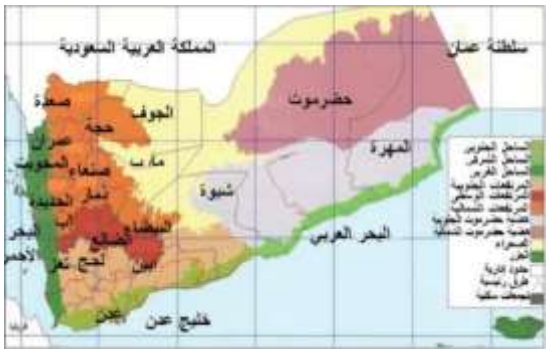

Figure (8): Map of Yemen and its governorates [22].

7.2. The city location[16] : [23]

Shibam is one of the 29 districts of Hadramawt Governorate, where the city of Shibam is located at 48º and 38º east of Greenwich and 15º and 57º north of the equator in the middle of Hadramawt Valley within the Shibam directorate in Hadramawt governorate, as in figure (9). The city is located directly to the north from the course of the main valley, and on an earthen mound whose height does not exceed 10 meters, where the valley has carved its western and southern edges. As for its height above sea level, it reaches 600-700 meters. The main regional road of the valley passes next to the city. The area of the city is approximately 7.7 hectares. A mountain range ranging between 200-300m in height overlooks the city from the south.

Figure (9): Location of the city of Shibam in Wadi Hadhramaut. [24]

7.3. The Digital Preservation Platform:

The city of Shibam Hadramawt is considered one of the most important historical cities in Yemen and the Arabian Peninsula. The process of documenting and preserving this historical city is one of the most important priorities of the UNESCO World Organization, given its great importance to the global cultural and civilizational heritage.

However, these traditional documentation and preservation processes suffer from many aspects of shortcomings, especially in the current era, so there was a need to take an advantage of modern technologies and advanced techniques to preserve that human heritage formed in the historical city of Shibam Hadramawt and its urban components. The mechanisms of documentation and digital urban preservation are considered one of the best methods due its importance for raising urban data of historical cities in archiving, managing and analyzing data, preparing future plans for urban plans and directing decision-makers with regard to preserving the historic city. The digital urban preservation system for the historic city of Shibam Hadramawt translates into creating a platform for 3D modeling techniques and 3D geographic information systems.

7.4. Steps and stages of creating a digital platform:

These steps consist of six main steps, the first of which is the calibration and correction of the maps that will be included in the platform using GPS technologies after we have the urban information and data for the historical city of Shibam Hadramawt documented digitally (providing reliable metadata digitally, providing various urban plans digitally, providing digital architectural plans for selected models. providing realistic digital photographs, providing a digital block model for urban plans (LOD=1), providing a general digital model for the city (LOD=3), providing detailed digital architectural models for the selected models with a detail ratio (LOD=3-4). These buildings were selected especially because of the large availability of its architectural data relative to other buildings. Then it is transferred to the next step, which is to enter it into the digital urban documentation and preservation platform by linking all of what was mentioned to each other through three-dimensional modeling techniques (Revit, AutoCAD, Lumion, laser scanning, GPS) and in the platform of (GIS). The above and other metadata may be included through two programs (FileMaker, BIM) in a two-dimensional image only, and these two programs specialized in managing information and data. After That, certain analyzes of the urban plans are made based on the actual reality and three-dimensional modeling techniques. The mechanism of these stages can be systematically as shown in figure (10). The stages that will be followed to create a platform for documentation and digital preservation of the historical city of Shibam Hadramawt are detailed as in figure (11).

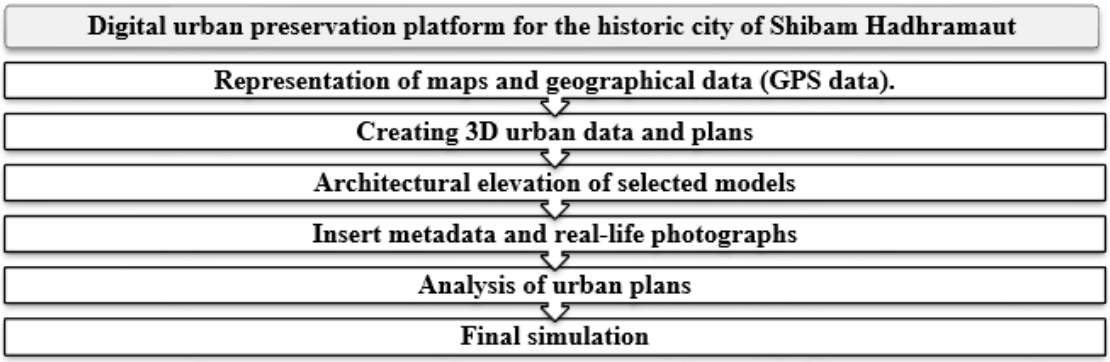

Figure (10): Stages and steps of the digital preservation platform for the historic city of Shibam Hadhramaut, source: researcher

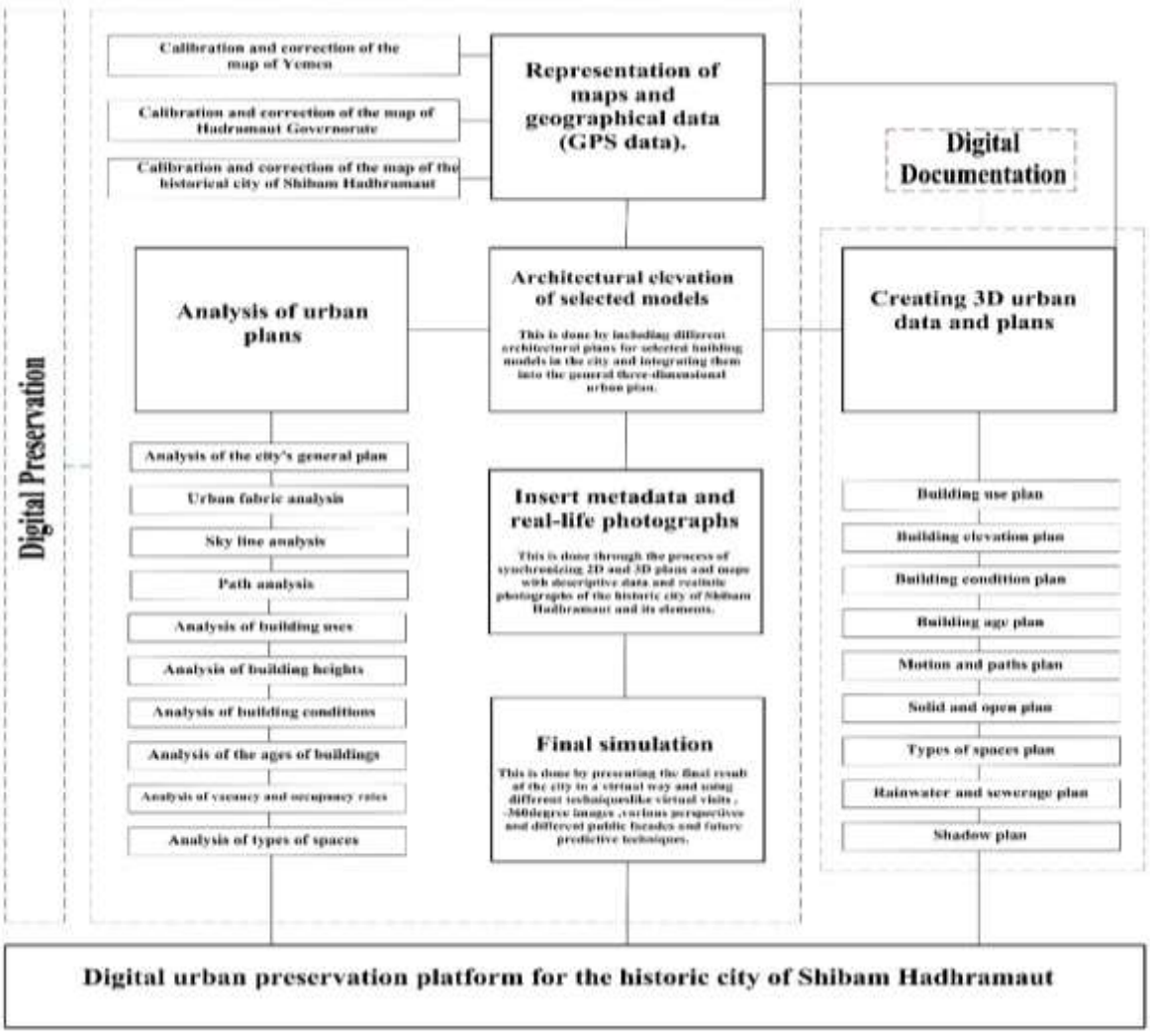

Figure (11): Detail of the stages and steps of the digital preservation platform for the historic city of Shibam Hadhramaut. Source: Researcher

7.4.1. Representation of maps and geographical data:

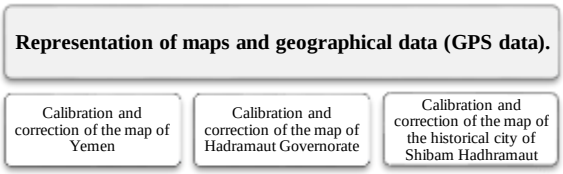

Figure (12): Stages of representing maps and geographical data for the historic city of Shibam Hadhramaut, source: researcher

This step is considered the first stage in the use of 3D modeling techniques to create a digital preservation platform for the historical city of Shibam Hadramawt. This stage is divided into three sections or main stages shown in figure (12). These sections are the calibration and correction of the map of the Republic of Yemen, because the study case is located in it, and then the calibration and correction of the map of Hadramawt Governorate, because the study case is one of the cities belonging to the governorate, and finally the calibration and correction of the map of the historical city of Shibam Hadramawt , which is considered the case study for this research.

A. Calibration and correction of the map of Yemen:

Where this step inserts the map of the Republic of Yemen into one of the three-dimensional geographic information systems (ArcGIS) with high accuracy, and then the calibration and correction operations of the map take place. These operations are based on the GCS system, which is a system affiliated with GPS coordinates data, and the GCS system calibrates and corrects according to the degrees of longitude of the globe, to obtain a final corrected and calibrated map of the actual location of Yemen on the globe within the three-dimensional geographic information systems data that can be worked on, and urban elements and data can be included in it in a three-dimensional image as shown in figure(13) .

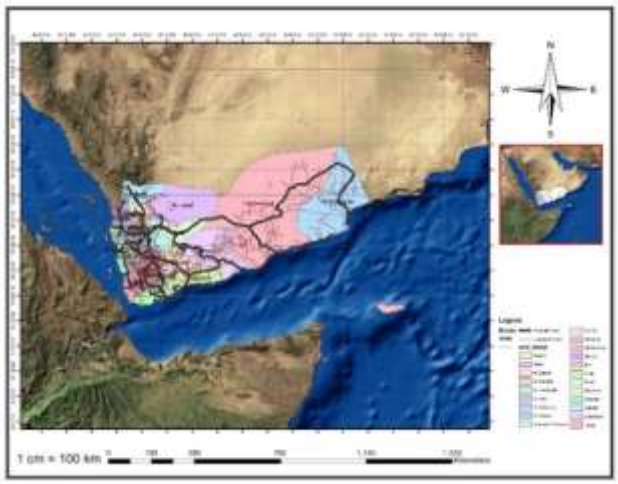

Figure (13): Final corrected and calibrated map of Yemen's actual location within 3D geographic information systems data. Source: Researcher

B. Calibration and correction of the map of Hadramawt Governorate:

Where this step inserts the map of Hadramawt Governorate of the Republic of Yemen into one of the three-dimensional geographic information systems (ArcGIS) with high accuracy, and then calibration and correction operations for the map are performed. These operations are based on the GCS system, which is a system affiliated with GPS coordinates data. GCS is calibrated and corrected according to the degrees of longitude of the globe. Since Hadramawt Governorate is located between longitudes 46° and 52°N, i.e. east of Greenwich and north of the equator, A final corrected and calibrated map of the actual location of Hadramawt Governorate in Yemen will be obtained within the 3D GIS data that include urban elements and data in a three-dimensional image, as shown in figure(14) .

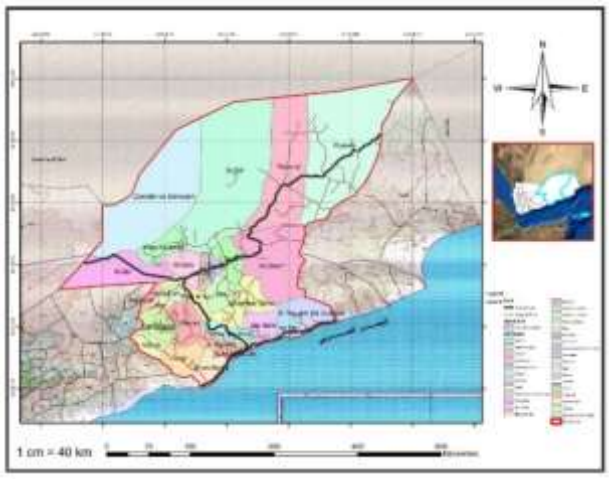

Figure (14): Final corrected and calibrated map of the actual location of Hadramaut Governorate in Yemen within 3D geographic information systems data. Source: Researcher

C. Calibration and Correction of the Map of the Historical City of Shibam Hadramawt:

Where this step inserts the map of the historical city of Shibam Hadramawt into one of the three-dimensional geographic information systems (ArcGIS) with high accuracy, and then calibration and correction operations are performed for the map. These operations are based on the UTM system, which is a system affiliated with GPS coordinates data, The UTM system calibrates and corrects according to the degrees of longitude of the globe after converting them into a corrected numerical coefficient based on entering the percentage of error in the sphericity of the earth in flat maps. The UTM system specializes in close-up maps that contain many urban and architectural details, so it should be worked on in the case of historical cities, as in figure (15) which shows the

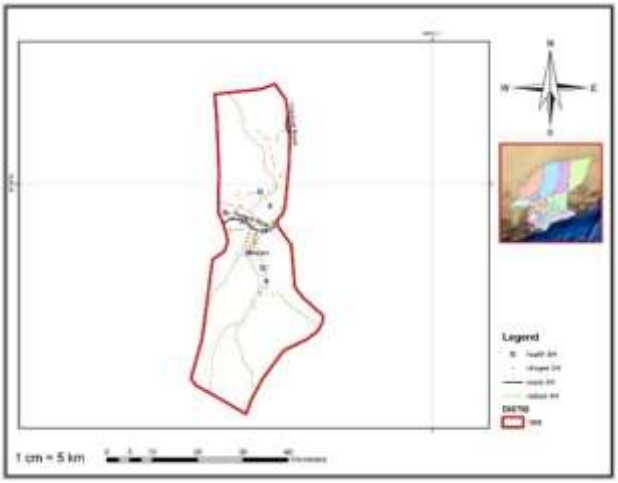

Figure (15): A final corrected and calibrated map of the actual historical location of the city of Shibam Hadhramawt in the Shibam District of Hadhramawt Governorate within 3D geographic information systems data. Source: Researcher

historical city of Shibam Hadramawt within the three-dimensional geographic information systems data. It can be worked on and the urban elements and data can be included in a three-dimensional image.

7.4.2. Creating 3D urban data and plans:

This step is the second stage in the use of 3D modeling techniques to create a digital preservation platform for the historical city of Shibam Hadramawt , as the digital documentation of the actual urban data and plans for the historical city of Shibam Hadramawt is the main element in this stage, which in turn affects the comprehensive digital urban preservation system and the platform for the city. This stage is divided into nine main sections shown in figure (16). These sections are the three-dimensional construction processes for the plans of buildings' uses, heights, states and ages. In addition to the plans of movement, paths, solid and open spaces, types of voids, and finally rainwater and sewage sewers.

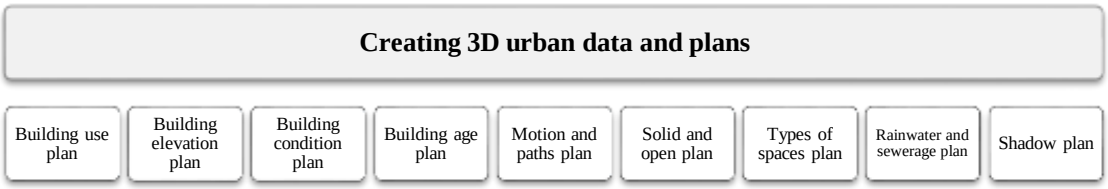

Figure (16): Sections of creating data and three-dimensional urban plans for the historic city of Shibam Hadhramaut, source: researcher

At this stage, the various urban plans for the historical city of Shibam Hadramawt are created in a three-dimensional images, as in figure (17) (18) (19) (20). These plans are created based on modeling processes (creating and working in a two-dimensional and three-dimensional image with the available paper data and the data of the traditional creating of the city) using REVIT and ArcGIS programs and GPS technologies to provide the required coordinates, the element within the three-dimensional space and finally the scale using the implicit partial media models of the urban elements in the main plan.

Figure (17): The process of creating three-dimensional urban plans for the uses of buildings for the historic city of Shibam Hadhramaut, source: researcher

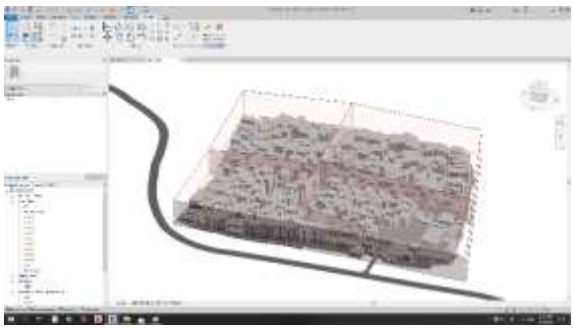

Figure (18): The process of creating three-dimensional urban plans for building's heights for the historic city of Shibam Hadhramaut, source: researcher

Figure (19): The process of creating three-dimensional urban plans for building's conditions for the historic city of Shibam Hadhramaut, source: researcher

Figure (20): The process of creating three-dimensional urban plans for the types of spaces in the historic city of Shibam Hadhramaut. Source: Researcher

7.4.3.The architectural bulding of models:

This step is the third stage in the use of 3D modeling techniques to create a digital preservation platform for the historical city of Shibam Hadramawt This stage is concerned the inclusion of different architectural plans for selected building models (22 buildings) in the historical city of Shibam Hadramawt and their integration into the general 3D urban plan. The German-Yemeni project for urban development in the city of Shibam **GTZ** [25] presented the program of historical houses in Shibam to document the buildings in the city to raise about 30 houses, and some of these models were used as in figure (21). After that the buildings of those sectors were numbered into serial numbers, as the buildings of those sectors exceed 450 buildings.

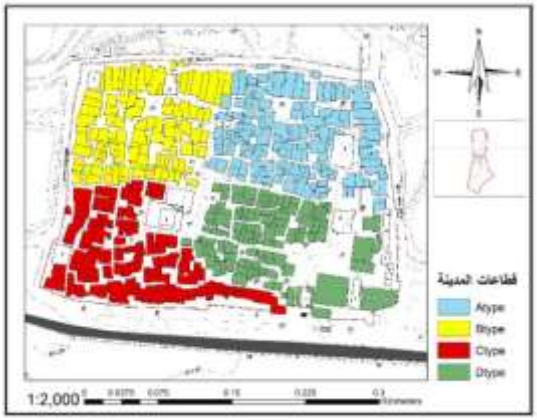

Figure (21): Division of the historical city of Shibam Hadhramaut into four sectors. Source: Researcher

7.4.4. Insert metadata and images:

This step is the fourth stage in the use of 3D modeling techniques to create a digital preservation platform for the historical city of Shibam Hadramawt. This stage is concerned with the process of creating and synchronizing metadata and images. After that, linking them with plans and 2&3-dimensional maps of the urban elements in the historical city of Shibam. There are multiple methods of linking in systems Three-dimensional geographic information, but it is mainly built within tables in which most of the descriptive data are included, as in figure (22).

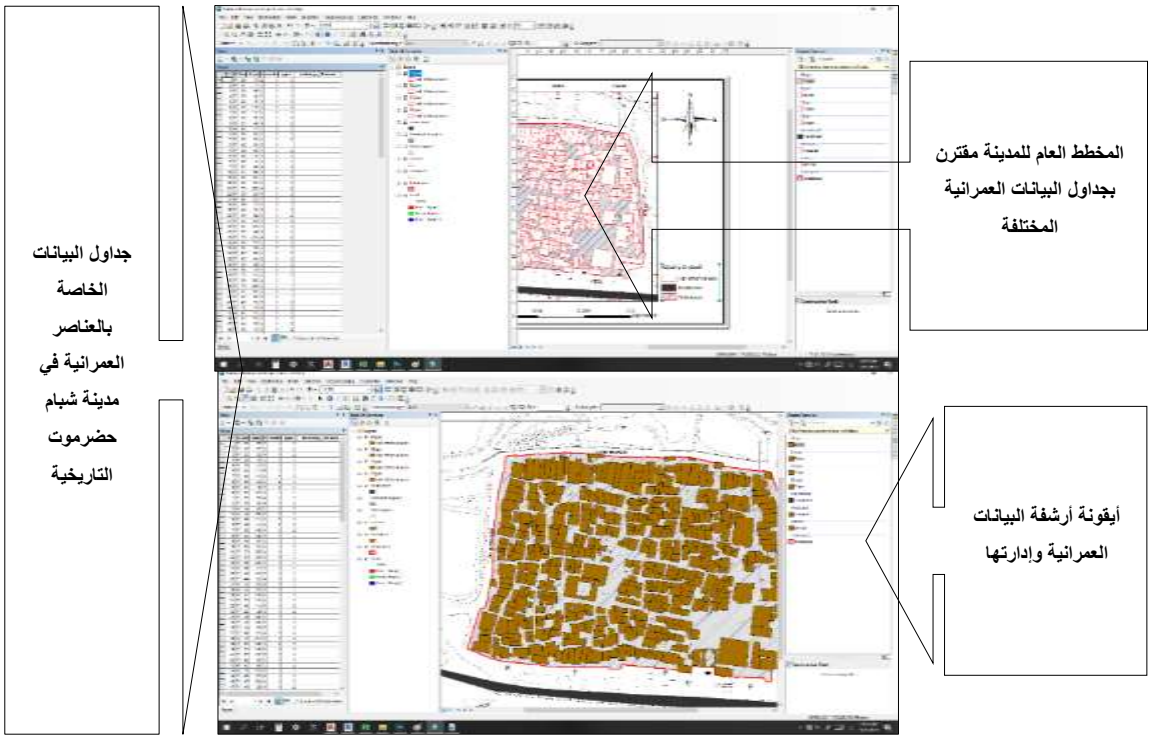

Figure (22): Descriptive data and linking it to different tables. Source: Researcher

It is possible to include many lists of data types and mold them in the tables commensurate with the quality of the modeled urban elements, unlese linking them with letters and words or to a group of numbers, as in figure .(23)

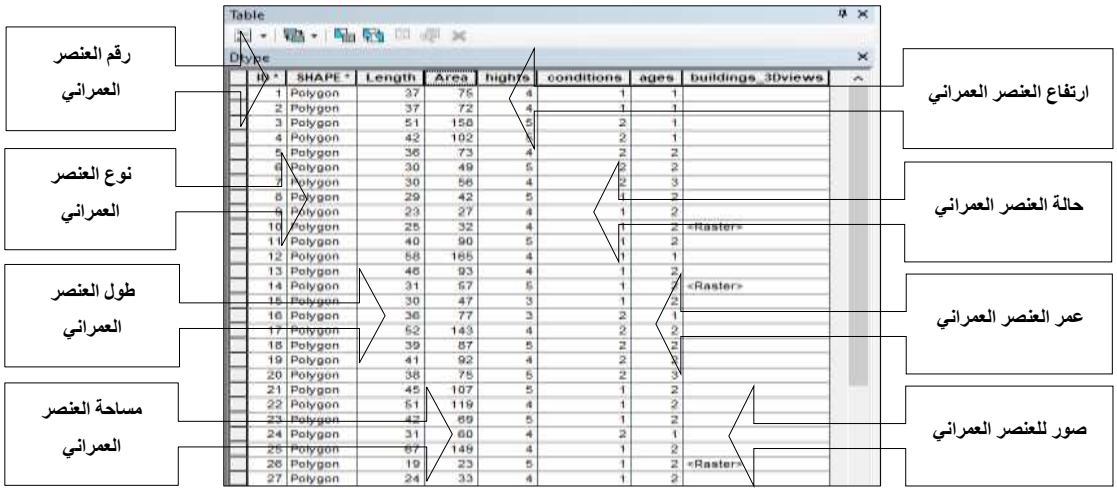

Figure (23): Lists of data tables in the three-dimensional information systems of the historic city of Shibam Hadhramaut, source: researcher

It is also possible to include many types of realistic and modeled images, and link them to their urban elements in the historical city of Shibam Hadramawt within one of the many characteristics of the tables, as in figure(24) .

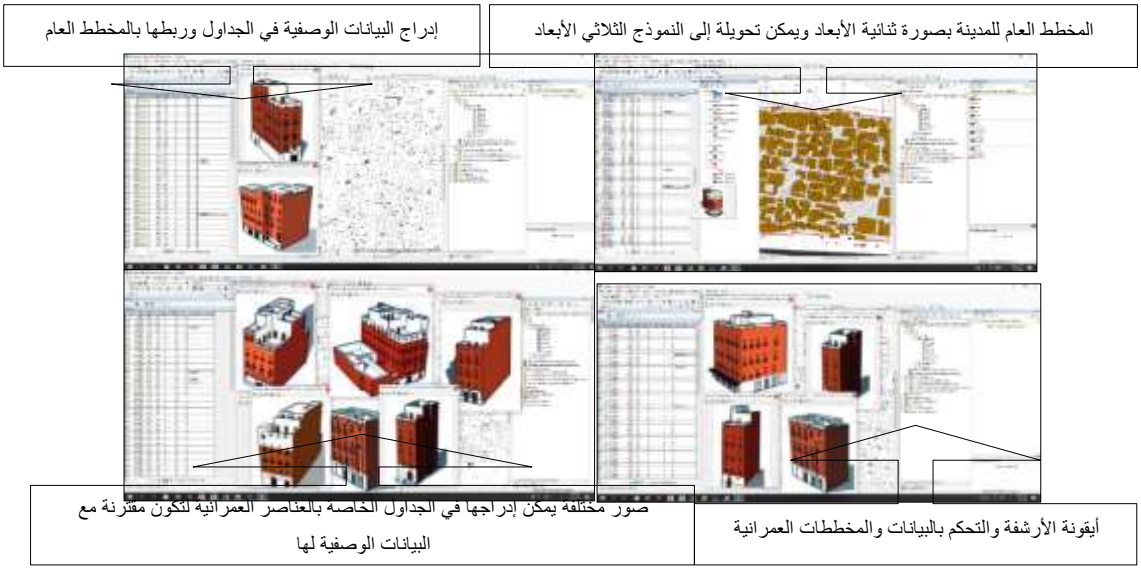

Figure (24): Linking images to urban elements within data tables in 3D geographic systems. Source: Researcher

7.4.5.Analyzes of the 3D urban plans:

This step is considered the fifth stage in the use of 3D modeling techniques to create a digital preservation platform for the historical city of Shibam Hadramawt. As the system for digital preservation of actual urban data and plans for the historical city of Shibam contributes to conduct many analyzes that can be included within the digital preservation platform by taking advantage of the technical and spatial characteristics of the three-dimensional systems (ArcGIS) to perform different analyzes of the historical city of Shibam Hadramawt and its

urban plans like shade analysis, sky line analysis, vacancy and spelling ratio analysis, building age analysis, building condition analysis and building height analysis.

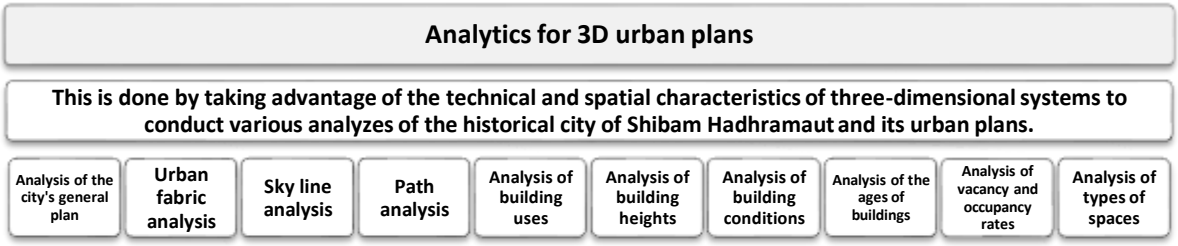

Figure (25): Types of analyzes of three-dimensional urban plans in the historic city of Shibam Hadhramaut, source: researcher

A. Analysis of the general plan of the historical city of Shibam Hadramawt:

The city is divided into four sectors by two vertical axes from north to south, and a horizontal axis from east to west. Most of the service buildings are gathered in the southeastern part of the city where the main gate of the city is located. The service buildings are gathered around the largest squares of the city such as the palace, mosque, school, market and some government's buildings. Public service shops which are buildings with limited heights are located through a series of narrow streets in the interior of the city ranges and neighborhoods that enjoy some privacy. The buildings of sector A, according to three-dimensional modeling techniques, occupy an area estimated at about 13,330 square meters out of the total area of the city, which is estimated at about 82,000 m^2, and the number of buildings in this sector is about 141 with an average area of 94 m^2, figure (26) shows a graph of these analyses.The buildings of Sector B, according to 3D modeling techniques, occupy an area estimated at about 11,386 square meters of the total area of the city, and the number of buildings in this sector is about 101 buildings, with an average area of 112 square meters. The total area of the city, and the number of buildings in this sector is about 109 buildings with an average area of 97 square meters. Table (1) shows the total occupancy area for each sector.

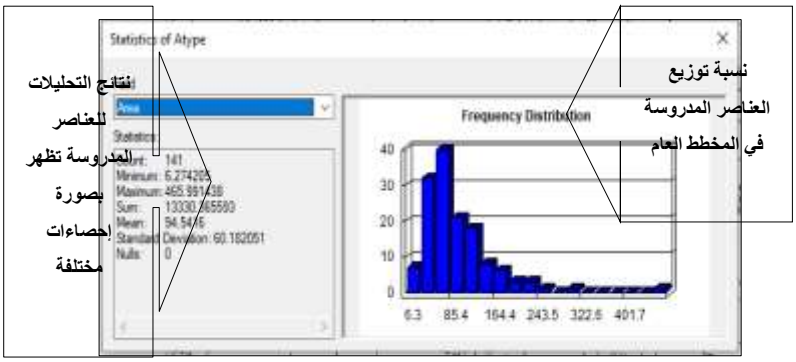

Figure (26): A diagram of sector A of the historic city of Shibam Hadhramaut, source: researcher

Table (1): Occupancy rate of buildings in the sectors of the historic city of Shibam Hadramaut, Source: Researcher based on GIS techniques

Sector name	The area of the sector's buildings in square meters
A	13330
B	13386
C	10666
D	10683
Total	48065

B. Skyline Analysis of the Historical City of Shibam Hadramawt:

The high building blocks in the city's outer facades dominate the sky line in it, and these towers draw a gradual line up and down on the horizon line. The scene is an extension towards the top, and the aesthetics of the sky line are evident in the southern facade of the city, where there are the tallest buildings in terms of height. Horizontal gradient ascends from east to west in formal harmony and rhythmic repetition, ascending to the highest point, then returning to descending, then to relative stability, as in figure (27).

Figure (27): Skyline of the Historical City of Shibam Hadramawt, source: researcher

C. Analysis of Vacancy and Filling Percentages in the Historical City of Shibam, Hadramawt:

The vacancy plan (solid and open) of the historical city of Shibam Hadramawt shows that the percentage of filling in buildings is rather large in some sectors of the city relative to the general plan. Using analysis by 3D modeling techniques shows that the area of the solid part or filling in the city is estimated at about 50067 square meters, i.e. 61% of the total area of the city, while the area of the open or vacant part in the city is estimated at about 31,785 square meters, i.e. 39% of the total area of the city.

D. Analysis of Building Uses for the Historical City of Shibam Hadramawt:

The uses of buildings vary in the historical city of Shibam Hadramawt, and differ from one region to another, as in figure (28). The residential use of buildings dominates in the western and northern sides of the city, and the commercial use of buildings is concentrated in the central region of the city, also the uses of governmental, educational, health and industrial buildings are concentrated in the southeastern part of the city at the main entrance to it. Using three-dimensional analysis systems shows that the area of the residential part ranges from about 43482 square meters, or about 53% of the total master plan for the city of Shibam Hadramawt , and the commercial use ranges from an area of 2283 square meters, or about 3% of the total master plan, while it ranges the area of the religious part (mosques) 3182 square meters, which is approximately 4% of the total master plan of the city, as the diagram shows in figure (29). The services part

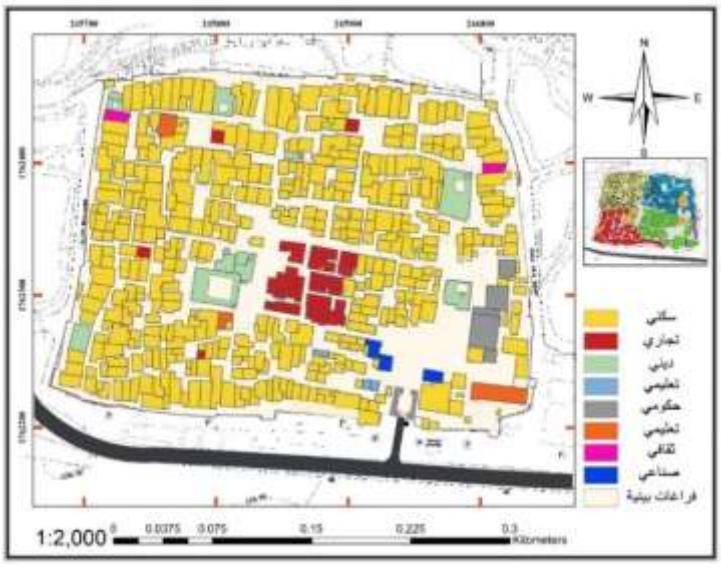

Figure (28): The building uses plan for the historic city of Shibam Hadhramaut, source: researcher

(governmental, industrial, educational, health and cultural) ranges around 1120 square meters, or about 1% of the total master plan. Finally, the houses usage spaces occupy approximately 39% of the master plan with an area of 31,785 square meters, table (2) shows the areas of building uses in the city of Shibam Hadramawt. So, it can be said that the historical city of Shibam Hadramawt is mainly intended for housing, meaning that it is a residential city, not a commercial one, or was established for religious and other reasons.

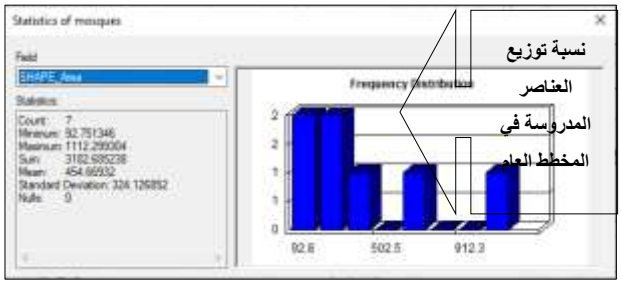

Figure (29): A diagram of the mosques of the historic city of Shibam Hadhramaut, source: researcher

Table (2): Areas of building uses in the historic city of Shibam Hadramaut, Source: Researcher, based on GIS techniques

Usage	Area in square meters.	Percentage
residential	43482	%53
commercial	2283	%3
religious	3182	%4
Services	1120	%1
Interstitial spaces	31785	%39
the total	81852	%100

7.4.6. Final simulation:

This step is considered the last stage in the use of 3D modeling techniques to create a digital preservation platform for the historical city of Shibam Hadramawt. The digital preservation system for actual urban data and plans for the historical city of Shibam Hadramawt contributes to the production of a semi-real final simulation of the studied area by reviewing the final result of the historical city of Shibam Hadramawt in a virtual way using various techniques, including virtual visits, 360-degree images, many prespectives types, and various interfaces. The REVIT program and the LUMION program and some utilities were used in ArcGIS systems, as after modeling operations with a detail ratio of LOD = 1 (as at this stage simple details were included in the general model of the city such as the block model of buildings and other urban elements without the presence of architectural details such as doors, windows, decorations, etc.) as in figure (30). Carrying out various cutting operations for the block model in the city with a detail ratio of LOD = 2, as in figure (31) (where attention was paid at this stage to the real heights of buildings and in the construction of window and door openings), these cutting operations contribute to increas the architectural details and urbanism in the three-dimensional model of the historical city of Shibam Hadramawt. Then the cladding operations to detail of the shown city with a ratio LOD = 3-4, as in figure (32) (where most of the urban details of the city are shown here such as buildings, traffic paths and other elements in addition for some of the architectural details of those buildings such as windows, doors, etc., and then cladding these models with construction materials that are close to the realistic construction materials in the historic city).

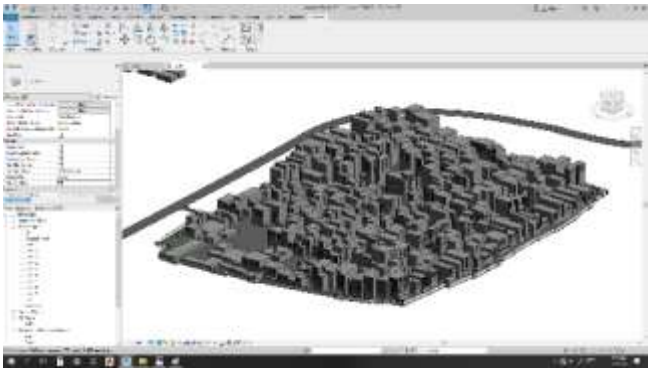

Figure (30): Modeling processes for the historical city of Shibam Hadramawt with a detail ratio of LOD=1. Source: Researcher

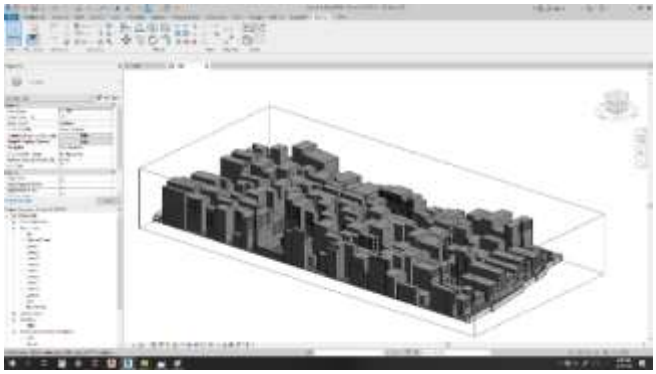

Figure (31): Cutting operations for a model of the historical city of Shibam Hadhramawt with a detail ratio of LOD=2. Source: Researcher

Figure (32): The cladding and detailing processes for the model of the historical city of Shibam Hadhramaut with a detail ratio of LOD = 3-4. Source: Researcher

Different mechanisms can also be made to show the details of the city's model, including general projections that correspond to reality, as in figure (33), as we ll as isometric perspectives with various vanishing points, as in figure (34).

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Figure (33): The general location of the historical city of Shibam Hadhramaut model, source: researcher

Figure (34): ISO-metric perspectives with various vanishing points for the model of the historic city of Shibam Hadhramaut. Source: Researcher

It is also possible to create images with the feature of 360 degrees for the interior views of the squares of the city model, as in figure (35), and images with a bird's eye 360 degrees for the model of the city, as in figure (36).

Figure (35): 360° images of internal perspectives from the squares' sectors of the historic city of Shibam Hadhramaut, Source: Researcher

Figure (36): Al-Tair's Eye 360-degree images of a model of the historic city of Shibam Hadhramaut. Source: Researcher

Finally, many videos and visits can be produced using VR technology, i.e. virtual reality, as in figure (37), which is supported by AI technology (artificial intelligence) that can not be shown in the scope of the search in writing or in pictures, but it could be displayed in another way (videos or VR glasses and devises).

Figure (37): VR automated working system for the historical city of Shibam Hadhramaut, source: researcher

VIII. Results

1. The term of 3D modeling deals with the representation and rendering of objects in a 3D image within the computer environment of a specific area or physical elements through many mathematical and engineering operations.
2. The most important problem of traditional documentation is the long periods of time required by the stages of traditional documentation. In addition to the fact that, traditional documentation processes often face obstacles due to the high cost of field survey work, and the noncontrolled time and cost of data and information collection. Moreover, the obstacles related to how could we deal with the high amount of information that have multiplicity of sources and parties who dealt with them.
3. The use of modern technology in digital documentation and three-dimensional modeling techniques in the process of collecting, storing and processing data is characterized by a low cost to match the size of the expected benefit due to the availability of many material needs, as it is possible to take advantage of the availability in this field related to the opportunities that were not easy to obtain on the previous traditional documentation techniques.
4. One of the most important problems that faced most of the previous documentation and preservation projects for the city of Shibam Hadramawt is the weakness of linking the descriptive data to the general plan of the historic city, in addition to neglecting the urban aspect in some projects or addressing it in a simple and superficial manner, without conducting any digitization or analysis of the urban data for the general plan of the historical city.
5. The process of preserving historical cities takes place according to several stages (documentation, study and analysis, observation, dealing method, reports, follow-up). The digital urban documentation is the first

and the most important stage that must be developed before the rest of the previous stages in the process of preserving historical cities because of this stage influence the subsequent stages.

6. The concept of digital preservation in historical cities means the processes of archiving, managing and analyzing urban digital data that were collected within mechanisms steps in the digital platform, which can be accessed by a number of users (planners, urbanists, architects, archaeologists, administrators, civilians... etc.). Also, the digital urban preservation has many characteristics and steps, as well as many effects, benefits, and advantages for decision makers, managing urban plans in historical cities, and preparing and directing future plans.
7. The digital platform for the urban plans of the historical city of Shibam Hadramawt is based on two basic principles: digital documentation and digital preservation. Where the principle of digital documentation is the process of creating three-dimensional data and urban plans for the historical city of Shibam Hadramawt, and this process can be represented by other detailed processes, including three-dimensional creation of plans for buildings' uses, heights, states, and ages. The principle of digital preservation is represented in five main operations, which are the representation of maps and geographical data, the architectural elevation of selected models, in addition to the inclusion of descriptive data and realistic photographs, analyzes of urban plans, and finally simulation the final model of the actual historical city.
8. The digital urban documentation and preservation platform is considered one of the best and most important methods for creating, uploading, archiving, managing and analyzing urban data of the historical city of Shibam Hadramawt, and guiding decision-makers to preserve the historical city and its surrounding areas.
9. The digital urban documentation and preservation platform is created from a set of three-dimensional modeling techniques, and from three-dimensional geographic information systems, where this platform is comprehensive of the historical city and its four sectors. It is specific to urban plans and data related to the elements of these plans in the current period, and these data can be added and updated in the future as needed.
10. Among the most important outputs of the final simulation using three-dimensional modeling techniques for the model of the historical city of Shibam Hadramawt are the public facades of the city, the general projections that correspond to reality, as well as isometric perspectives with different vanishing points, 360-degree images of perspectives from squares belonging to the city model, 360-degree images for the model of the city in the bird eye vision, and many videos and virtual visits with the technology of virtual reality (VR) and artificial intelligence (AI), which contribute significantly to supporting the field of tourism and media promotion .

IX. Recommendations

1. The urban engineer should have geographic knowledge and scientific background when using the 3D modeling techniques of the historical city of Shibam Hadramawt.
2. The appropriate geographical system must be chosen when carrying out the process of correcting and calibrating urban plans and satellite images of the model of the historical city of Shibam Hadramawt as follows:

A/ Using the GCS system: to obtain calibrated maps using the cycling system in case the work area is large, such as the studies dedicated to vast provinces and regions.

B/ Using the UTM system: to obtain calibrated maps with a system of units in the event that the work area is relatively small, such as the studies dedicated to cities and lands that require high accuracy in raising and embodying geographical coordinates.

3. To give realism to the model of the resulting historical city of Shibam Hadramawt , it is necessary to export the model before displaying it within the virtual reality activities to programs, such as Lumion, 3D Max, Maya, Revit, or similar programs, to add a suitable environment for working in three dimensions, such as trees and elements of public site brushes.

4. To obtain a two-dimensional document for the model of the resulting historical city of Shibam Hadramawt , the three-dimensional model (with realistic dimensions and proportions) must be exported to engineering drawing programs, such as Revit, ArcGIS, AutoCAD, Vector or similar programs, to be able to obtain an understandable digital copy that can be dealt with easily by many professional users.
5. Decision makers are highly recommended to be guided in preparing future preservation plans for Yemeni historical cities, using the digital preservation platform for urban plans for historical cities.
6. It is obligatory to modify and develop the digital preservation platform for urban plans in the historic city in a manner commensurate with the type of the studied project and the final objectives of that project.

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