Digital Applications in Archaeology and Cultural Heritage 21 (2021) e00189

Contents lists available at ScienceDirect

Digital Applications in Archaeology and Cultural Heritage

journal homepage: www.elsevier.com/locate/daach

Applying digital methods for documenting heritage building in Old Jeddah: A case study of Hazzazi House

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ARTICLE INFO

Keywords:
Heritage houses
Terrestrial laser scanning
Historic Jeddah
Digital documentation
and photogrammetry

ABSTRACT

There are multiple methods available for documenting heritage buildings that have significant cultural importance in the society. However, selection of a particular method varies from one technique to another according to the requirements of documenting the heritage buildings. Generally, most organizations depend on financial supports to be able to begin their project in documenting particular buildings. Terrestrial Laser Scanning (TLS) systems are widely used for detailing 3-dimensioanl data captured from an object (i.e., historical buildings in particular). In this study, TLS system has been selected to carry out the surveying and architectural documentation process of the Hazzazi House as a case study. This research aims to provide the architects and professionals with a complete capture of architectural heritage sites via combined terrestrial laser scanner and traditional survey methodology to document the heritage houses in old Jeddah in order to overcome financial shortages while obtaining quality resolution at the same time. Specifically, the presented methodology assists in producing comprehensive architectural documentation of heritage houses in the area of historic Jeddah with the required quality and lower financial burden. This method may be applicable in similar cases in the Middle Eastern countries to set up conservation strategies of old heritage buildings across the region.

1. Introduction

Passing down the characteristics of historical structures to the following generations in a healthy way without compromising the deterioration is a critical job (Bozkurt and Demirkale 2019; Harun 2011). Kingdom of Saudi Arabia (KSA), represented by the Saudi Commission for Tourism & National Heritage (SCTH), strives to introduce the rich cultural heritage as a regions through preserving several historical buildings, landmarks, and monuments before the world (Belarem et al., 2018; Jeddah Chamber, 2017). This orientation and perspective represent the country's historical ornate architectural culture and assist in transforming these areas into a cultural and economic hub for the KSA residents, visitors, researchers, and others who are interested to know about the Arabian Peninsula's architectural heritage. Jeddah is one of the cities in KSA, which has a heritage site recognized by The United Nations Educational, Scientific and Cultural Organization (UNESCO). Consequently, Jeddah is considered as one of the several main cities in the Middle East along with the economic gateway for the KSA (Hanan et al., 2015; Jeddah Chamber, 2017). The city is located along the Red Sea coastal plain (Ameur, 2016). Moreover, the city is well known as the Bride of the Red Sea and it is one of the most popular tourism destinations and economic centers in the KSA (Abdulaal, 2012). Furthermore, the city is the second-largest in the kingdom and acts as the main port hub of Umrah and Hajj (i.e., the pilgrimage of Muslim religion) (Jeddah Chamber, 2016–2017) (Jeddah Municipality, 2019).

Currently, data and research that endeavours to document heritage buildings varies. Examples of this type of research have attempted to encompass the work that has demonstrated the need to use building information modelling after recognising the advantages exist in the architecture and engineering fields (Sztwiertnia et al., 2019). Relevant works present a general outline for the utilisation of Building Information Modelling (BIM) processes with regard to architectural heritage (Chokhachian, 2014; De Luca, 2014; Diara and Rinaudo, 2018). These research consist of three levels concerning the Level of Development (LOD) to consider higher level details (Baik, 2017; Baik et al., 2015). However, BIM is still necessary for documenting architectural heritage.

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https://doi.org/10.1016/j.daach.2021.e00189
Received 20 May 2020; Received in revised form 26 April 2021; Accepted 7 May 2021
2212-0548/

Fig. 1. Jeddah historical map.

Moreover, the need to use three-dimensional laser scanning has become essential in order to increase the accuracy of architectural heritage documentation.

Restoring and preserving heritage buildings are issues that demand sophisticated technology, which is dependent on available information, types of machinery, and innovations (Gonizzi Barsanti et al., 2017; Harun, 2011). This task can be impacted upon by a number of problems, such as negligence, abandonment, maintenance, and a lack of architectural studies with regard to most buildings (Diara and Rinaudo, 2018; López et al., 2018; Murphy et al., 2011; Murphy et al., 2013; Rocha et al., 2020; Sztwiertnia et al., 2019). Finding solutions to deal with these problems and complete the task depends on the issues the specialists encounter while notarising the phases or steps during the research. These obstacles demand a deep examination in order to determine a definitive answer to help overcome them. The steps prior to the restoration phase involve the developing of the architectural and study documentation. Most of the heritage houses in Jeddah city have various issues; one of these issues involves the technical and digital notarisation from the primary to the advanced and more complicated steps (Baik, 2017; Baik et al, 2013, 2015; López et al., 2018; Rocha et al., 2020).

One of the critical examples is considered in the research study conducted by Baik (Baik, 2017; Baik et al., 2013). In this study it is critically discussed that the difficulties with stratifying BIM into existing construction is considered more appropriate for heritage buildings. Baik's research relates to an examination of one of the houses in Historical Jeddah Districts, in KSA named as Zainal House (Baik, 2017; Baik et al, 2013, 2015). This heritage building has exceptional architectural façades and there was a demand to analyse Zainal House's structure, components, and design in detail (Baik, 2017). In this research, BIM has been utilised due to the fact that it operates through the use of a digital database and three-dimensional laser scanning of the building, which is then transferred into the point-cloud system as digital data. Further attempts were revealed in a study conducted by Grussenmeyer et al. (Grussenmeyer et al., 2008; Murtiyoso and Grussenmeyer, 2017), who examined different documentation methods suitable for cultural heritage recording purposes. These methods encompassed: tachometer, photogrammetry and terrestrial laser scanning. These initiatives compared the three technologies via applying them in to the medieval castle of Haut-Andlau (Alsace, France)(Murtiyoso and Grussenmeyer, 2017). This castle's architecture was a result of distinct styles, which were completed over several centuries. The scientific article also discussed the advantages and disadvantages of these different methods and technologies, examined via the documentation of the castle. Furthermore, Murphy et al. (Murphy et al., 2011; Murphy et al., 2013) conducted research concentrating on Historic Building Information Modelling – concerning adding intelligence to laser and image-based surveys of European classical

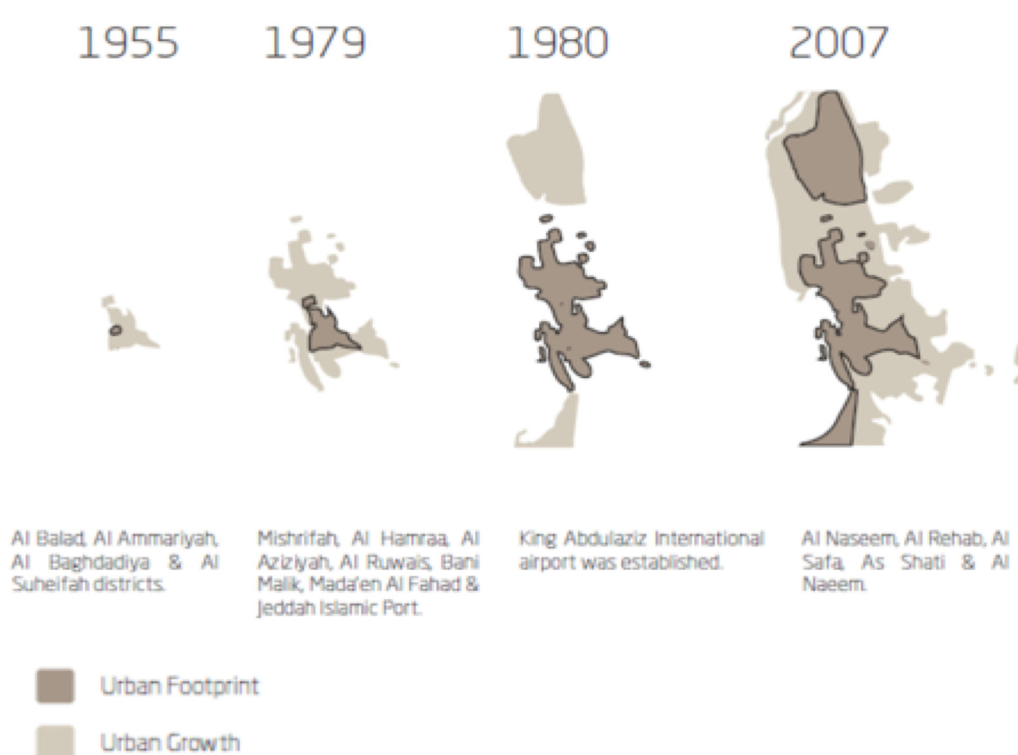

Fig. 2. Evolution of Jeddah city.

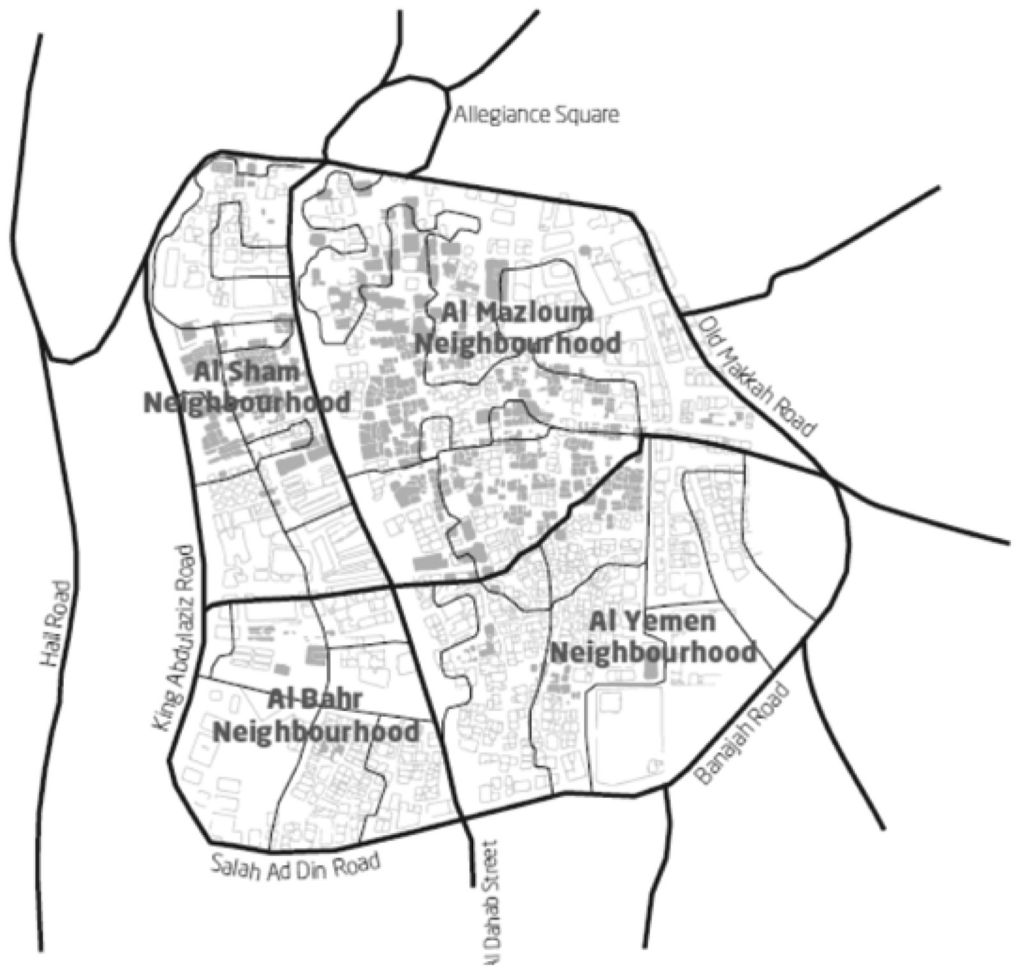

Fig. 3. Old Jeddah city neighbourhood.

architecture. The research papers discussed the Historic Building Information Modelling (HBIM) process, which was used to collect the survey data via terrestrial laser scanner combined with digital photo modelling. Consequently, the research results discussed methods of overcoming the issues that might appear while converting the data through the BIM ArchiCAD software. Also, this research presented the final HBIM three-dimensional model, including the details that could assist others in analysing and conserving historical objects, structures, and environments. Several other researchers focused on exploring the open sources of software, such as DBMS, CAD, and Servers, in order for them to be applied to cultural heritage buildings (Dell'Unto et al., 2016; Bustillo et al., 2015; Diara and Rinaudo 2018; Lezzerini et al., 2016; Murphy, M. et al., 2011; Murphy et al., 2013). Additionally, this would allow for the generation of a HBIM open source integration. Furthermore, Barsantia et al. (Barsanti et al., 2014; Gonizzi Barsanti et al., 2017) conducted research concerning the documentation and preservation of cultural heritage buildings. Their research asserted that the 3-D modelling process would be ideal for recording traditional buildings. Furthermore, these research aimed to identify the difficulties and problems that occurred through analysing some of the available methodologies; such as segment three-dimensional point cloud or mesh (Georgantas et al., 2012; Gonizzi Barsanti et al., 2017; Hanan et al., 2015; López et al., 2018; Murphy, M. et al., 2011; Rocha et al., 2020; Rodríguez-Gonzálvez et al., 2017). Furthermore, LiDAR and BIM technologies were used in understanding the deformation of building structures in case of historical buildings (Yaagoubi and Miky, 2018). Additionally, semantically enriched historical spatial database (SHE-SDB) method was employed in few cases for preserving the monuments and heritage structures (Yaagoubi et al., 2019). However, most of the research outcomes considered not suitable in terms of low cost while preserving the quality of the resolution. In this study, we opted to use the TLS systems with the assistance of traditional survey techniques in order to minimize costs without negotiating the quality of the optimal resolution.

As a result, this research focused on the various technical issues documenters had experienced while working on the Hazazai heritage building in the historical areas of Jeddah city. Each issue encountered from the first day of the survey and the actual documentation of the house required a special process in order to solve the problems, especially concerning any technological aspects. In this project, the team was able to find a practical solution in order to push the documentation forward. One problem the researchers were confronted by was placing the registration points without removing them for at least 4 days until the documenting was finalized. Moreover, sourcing the appropriate location to place the TLS, transferring the TLS into the higher floors and rooms were lacking a good amount of air and light. Furthermore, there were problems with TLS batteries. Additionally, permissions were needed to enter various buildings around the Hazzazi House in order to gain more points clouds, target registration from the laser scanning files, laser scanning blinds spots, the software transfer of the laser scanning file directly into the model, redrawing the architectural and structural components, and other similar technical issues. However, this present research paper would explain all the required methods for successfully completing the

Fig. 4. Al Mazloum neighbourhood.

Fig. 5. Al-Hazzazi house location in the Al Mazloum neighbourhood in Old Jeddah.

Fig. 6. Modelling process through multiple steps.

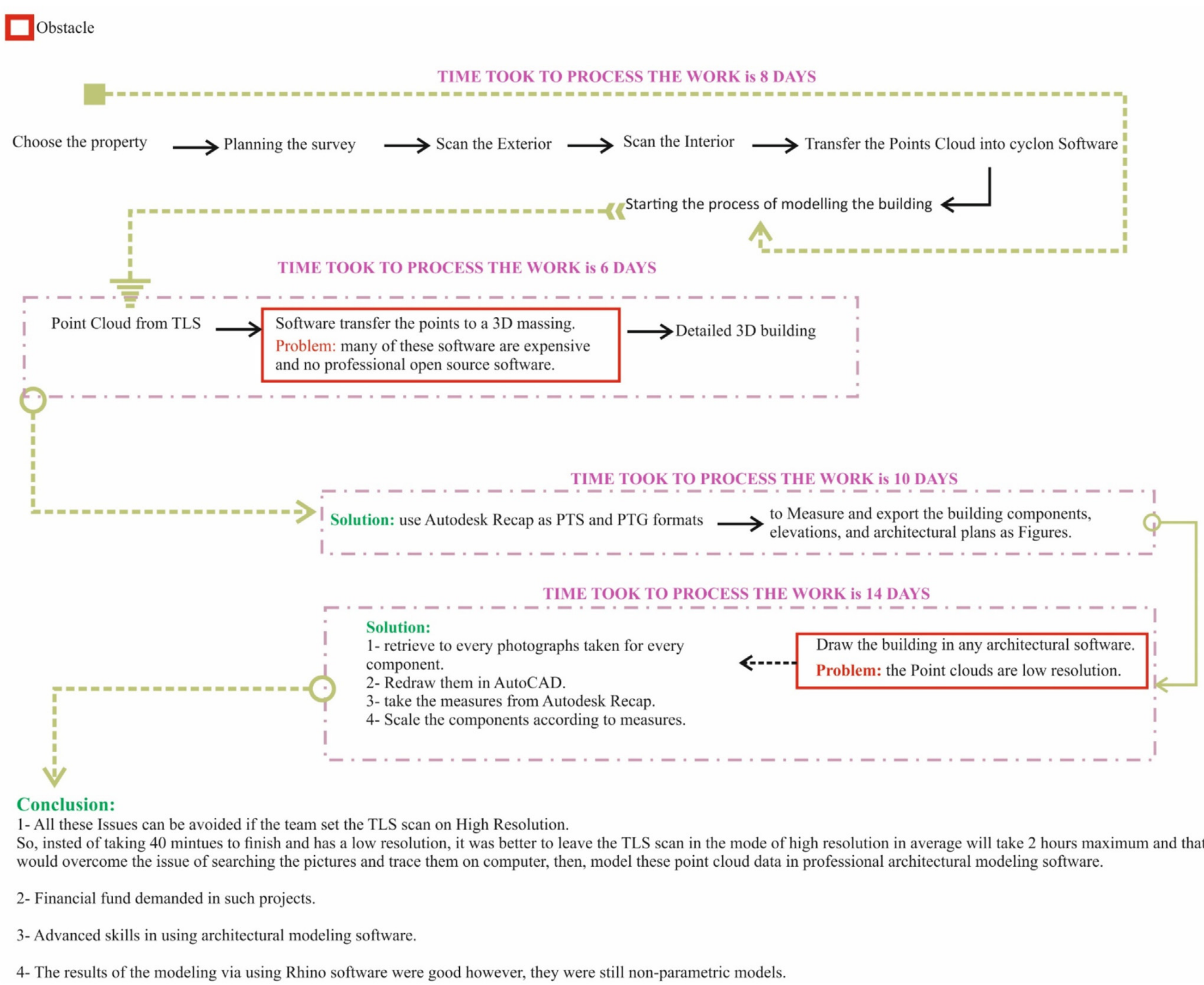

Fig. 7. Schematic diagram of the methods employed in this study.

Fig. 8. TLS in front of Hazzazi House.

project and the procedures in detail to document the historical building.

2. Study area

Hazzazi House is one of the heritage buildings in Old Jeddah, KSA. Hazzazi house is situated on the eastern side of Bab Jadid (the New Gate) in Al-Sham neighbourhood. This house has stood for more than 100 years (Baik et al., 2013). The main reason that the researchers have choosen this house is the strategic location mainly because the house is next to the famous Al-Baiah Roundabout, Alshurbatly house, and other significant premises consider essential to the historical Jeddah region (Baik, 2017; Baik et al., 2013; Jeddah Chamber, 2017). Moreover, the inheritors have seemed happy to allow the researcher's and the team to investigate the house's condition. Simultaneously, it is important to have permission to use of the most high-end sophisticated technology in order to document the house, and subsequently rebuild it. Note that the survey has been carried out via TLS. Subsequently, a three-dimensional (3-D) model has been generated including the house's architectural and structural details (see Fig. 1).

After 1946, Jeddah began to experience the benefits of Saudi oil exports (Nejat et al., 2015). In 1947, the old city walls were demolished, preparing the city for its first phase of expansion. In the following eight years, from 1948 to 1956, Jeddah experienced a remarkable rate of growth. This period was characterized by rapid population increase, supported by government investment in roads, piped network installations, new houses, and major urban infrastructures (Al-Filali and Gallarotti, 2012; Alrashed and Asif, 2014; Alshehri et al., 2013). It was made possible by the first oil boom in this particular time period. During this period, the city grew by ten times in size, from 300 to 3,300 ha (Belarem et al., 2018; Jeddah Chamber 2017; Aljoufiea et al., 2012) (see Fig. 2).

Additionally, Jeddah is situated on the west coast of the KSA beside the red sea. Its history was way back before Islam, whereby the city was elevated when it was transformed into a port for Makkah City at the time of Caliph Othman bin Afan (May Allah be pleased with him), in 26H/647AD (Aljoufiea et al., 2012; AlQahtany and Abubakar, 2020; Azzam and Belhaj Ali, 2019; Harris et al., 2014). Old Jeddah is composed of four parts; the Al-Sham, Al Mazloum, Al Bahr and Al Yamen neighbourhoods. The urban pattern is comprised of houses, merchandise quarters, Mosques and other types of buildings, penetrated by small open courts, yards and zigzagging alleyways.

Hazzazi house is located in historical Jeddah. It is considered to be situated in the Al-Sham neighbourhood by the inhabitants of historical Jeddah. After an insight research and observation of Jeddah municipality's maps, the researchers have determined that the house is actually located in the Al Mazloum Neighbourhood. Hazzazi house has been categorized by the administration of preserving historical Jeddah as one

Fig. 9. Targets placed next to each other.

Fig. 10. Targets placed on the house's facades.

Fig. 11. Example of the registration process.

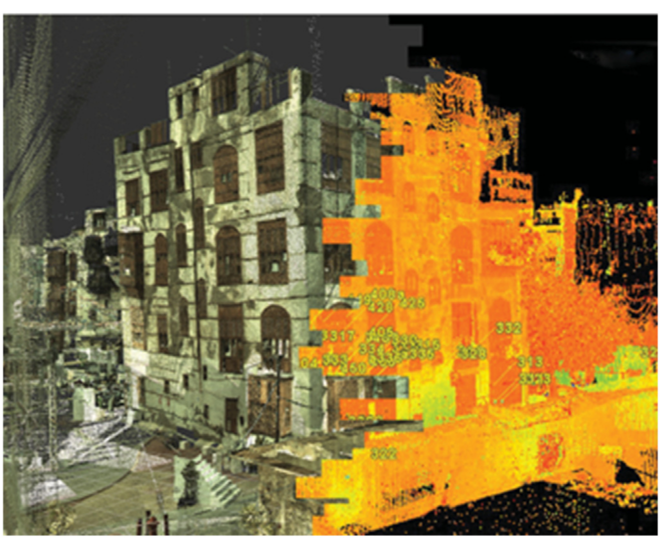

Fig. 12. Hazzazi House in point cloud phase.

of the first-rate buildings in terms of historical significance (Jeddah Chamber, 2017). There have been adjustments made in the past in order to rent the house (see Figs. 3–5).

Hazzazi house is still remained as one of Jeddah's historic buildings, however, there are other houses in the Al-Mazloum neighbourhood with similar characteristics. Therefore, three houses have been chosen in order to make a comparison with Hazzazi house, which are: (i) Al Shurbatli house that is very close to Hazzazi house and is one of the houses that has previously been restored; (ii) Ba Eshen house that is located a away from Hazzazi house and it is one of the houses that has been reused and now functioning as a museum; and (iii) Al Shafe'I house that is one of the oldest houses in old Jeddah and has built in 1800AD.

Hazzazi house is named after the last family that lived there, who are one of the long-established families of Jeddah. They have owned the house since 1296 H, 1875. The house is composed of four levels, including three serviced lounges with three entrances on the ground floor, while the first, second, third and fourth floors are all comprised of private rooms, and the roof has a further three bedrooms. With its olden history, Hazzazi house has been categorized by the administration responsible for preserving historical Jeddah as one of the first-rate buildings in terms of historical significance. However, adjustments have been made in order to rent the house out at later time.

3. Methods

3.1. Justification of the methods adopted in this case study

In the very first place, it is important to know the issues of employing the specific methods we have adopted in order to document the information. Several literatures have suggested that application of a single method for documenting the heritage buildings may have several challenges. Among these challenges, (i) digitization (i.e., transforming available analogue data into computer systems); (ii) meta data indexing (e.g., managing the data in a scientific fashion by adopting a simple but efficient technique); (iii) managing the intellectual property rights; and (iv) diverse business models are prominent.(Campanaro et al., 2016; Evens and Hauttekeete, 2011; Gomes et al., 2014; Hanan et al., 2015; Kim and Muller, 2011; Pocobelli et al., 2018; Zhao et al., 2016). However, the results obtained from adopted methods such as; Lidar, Satellite imageries; UAV (Unmanned Aerial Vehicles), Photogrammetry, and Scanning through multispectral sensors in documenting the heritage sites and buildings are not comprehensive for a single case. As a result, in this case study approach, we have adopted to utilize several methods and documented the building in a scientific fashion with minimal costs involved in the project.

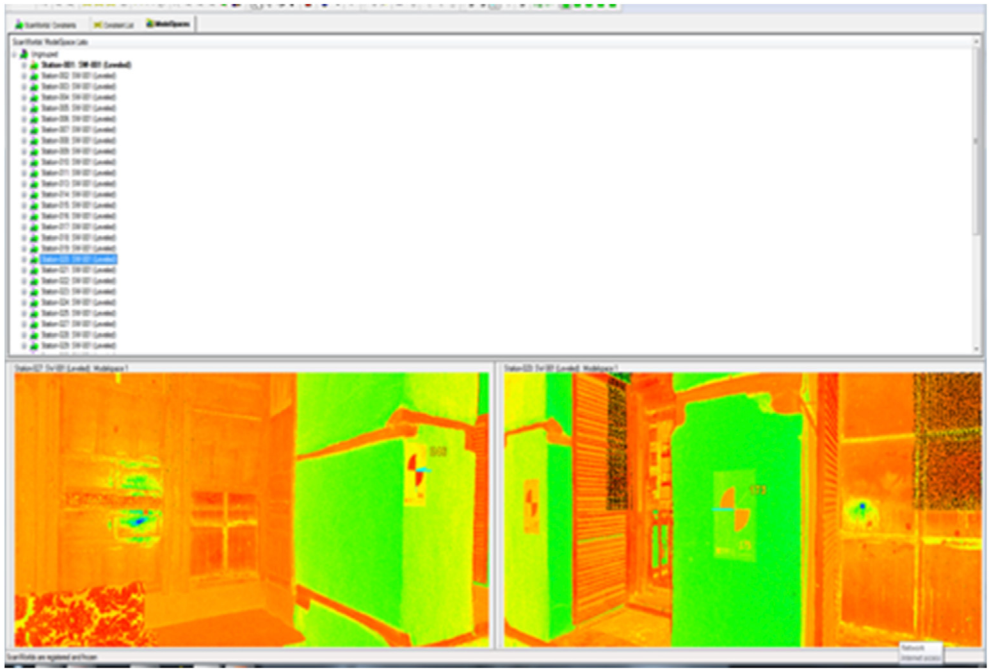

Fig. 13. Hazzazi house registration.

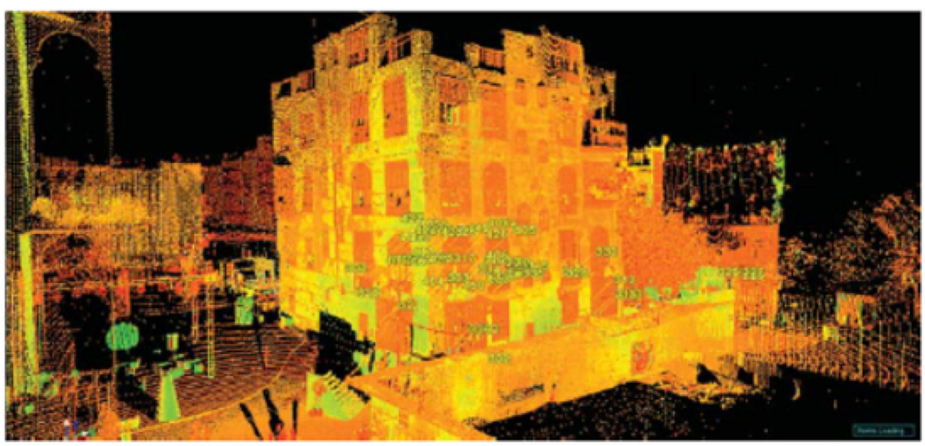

Fig. 14. The Completion of the registration processes.

Fig. 15. The buildings appearance after adding the colours. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

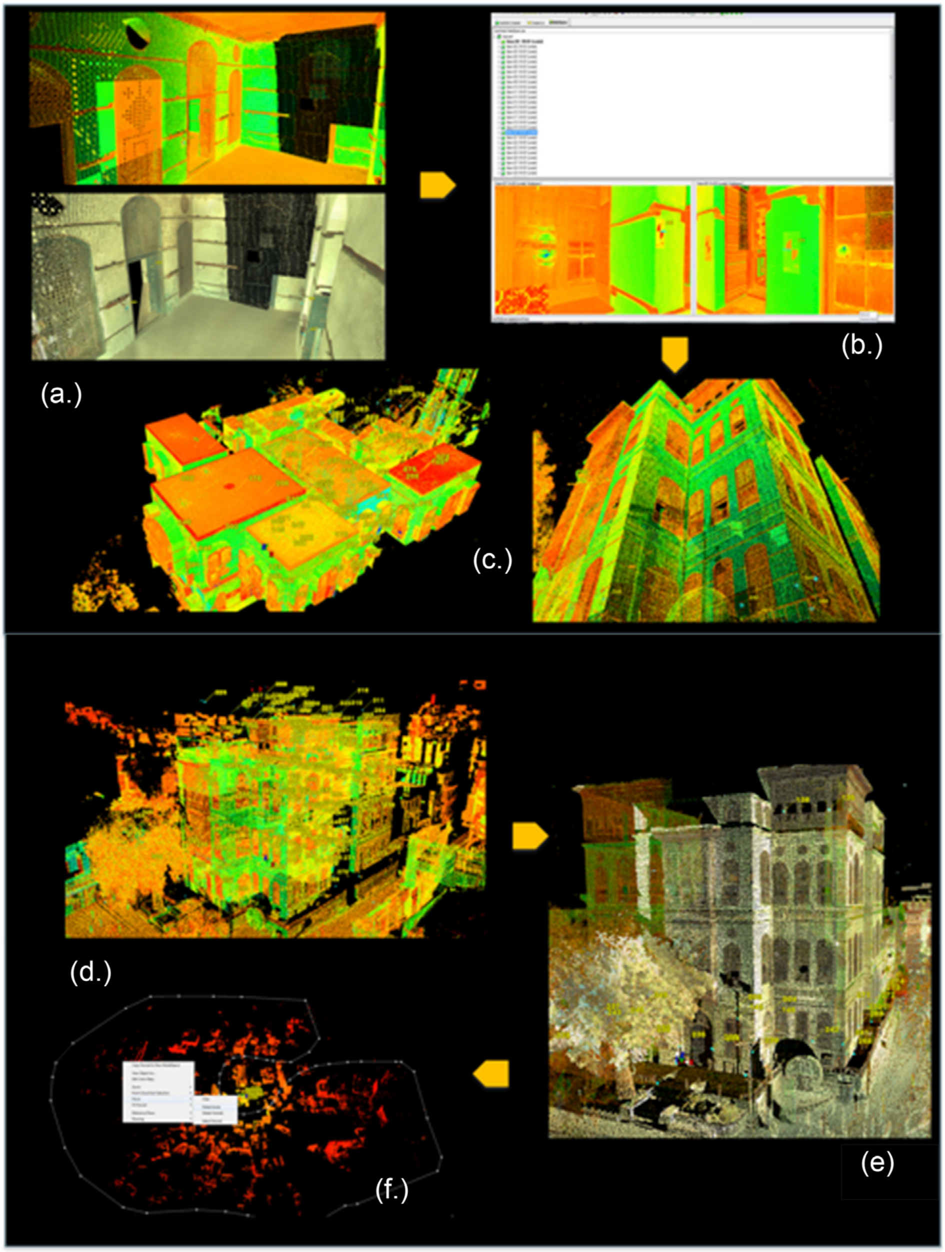

Fig. 16. Point Cloud Data Processing for Hazzazi House. (a.) Point cloud with/without image texture map. (b.) Registration of the scans' point cloud. (c.) The results of the registration. (d.) The results of the registration for all the scans. (e.) Applying the image texture map. (f.) Cleaning the noise.

Moreover, using these methods for the Heritage buildings in Jeddah seem a great opportunity to evaluate the effectiveness of these methods. And, to discover how suitable are these method with a high level of component's details, and complicated structure such as the Hijazi style.

Note that, it is always a daunting task to acquire funding from government sources in order to assist the stakeholders associated in preserving heritage buildings in KSA. However, we have received the in-kind support from King Abdulaziz University's department of architecture for using laboratory instruments. Consequently, we have received supports from volunteer organizations in order to conduct the survey at different weather conditions.

In case of this particular Hazzazi House project, we organized the methods into five main stages. The *first* phase began with collecting all of the data from the College of Architecture and Planning at King Abdelaziz University, available online resources, and from the inherited owner of the house. The *second* phase was organising the data in order to ascertain their validity and cautiously selecting them for the research before starting on-site stage. The *third* phase was using the terrestrial laser scanning to scan the house from all of the various elevations. The *fourth* phase was utilising the TLS scan files as a reference to draw up the plans and elevations. The *final* phase was to produce a documented house that was able to be used for redesigning the house from an architectural, structural, and interior design perspectives. Therefore, this will enable the inheritors to preserve the house and utilize it to an optimum way.

3.1.1. 3-D modelling phase

The modelling process of heritage monuments such as the one in this project requires a suitable amount of time to obtain a precise result and achieve a perfect execution plan. This process is referred to as HBIM, which refers to Heritage Building Information Modelling. In this stage, 3-D data is accurately gathered and converted into 3-D digital data, and subsequently transformed into a 3-D model for it to be designed in line with the accurate pre-existing building. Nowadays, using information from traditional surveys in the BIM process doesn't garner ideal results.

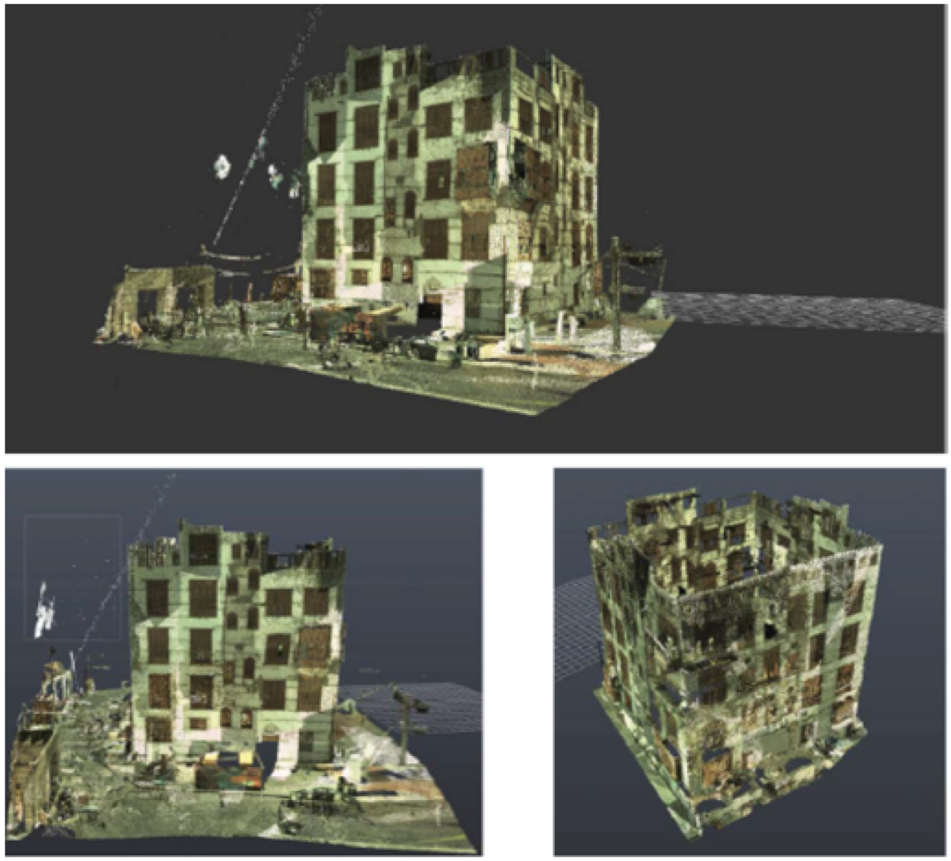

Fig. 17. Examples after adding the colours. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

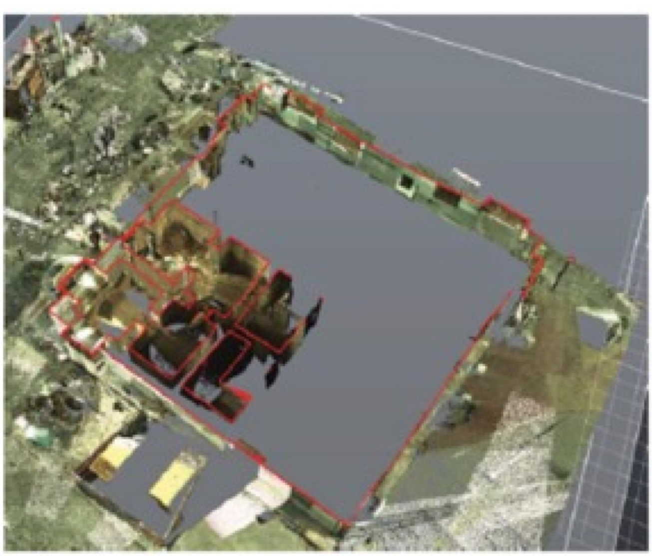

Fig. 18. Slicing step for Hazzazi House and outcomes.

The reason for this is due to the use of non-parametric methods, such as a CAD programme, to create the 2-D survey drawings. As a result, the work process and displaying techniques requires a paradigm shift from the industry leaders (Baik, 2017; Rocha et al., 2020; Sztwiertnia et al., 2019).

The process of HBIM modelling demonstrates the HBIM objects' construction, which means the components and parts of the heritage building, including the features and relationships, are both non-geometric and geometric. Based on Volk et al. (2014), the data quality through the deployed technique and the provided LOD are thought to be influenced by the preceding data capture, processing, and recognition methods if the HBIM "is modelled on the basis of previously captured building information." Yet, HBIM has no standing in the case of LOD. In fact, BIM provides a large amount of detail gathered via advanced technologies, such as laser scanning, and therefore this requires significant time and cost. Hence, this is an obstacle for people who attempt to create their own standards through "as-built" BIM modelling.

3.1.2. 3-D manual modelling

Generally, 3-D digital modelling occurs in order to represent a building that doesn't exist as yet in reality. However, the goal in the case of modelling existing structures such as heritage buildings is to present them as they are in the real world. Currently, the procedure is predominantly manual, and it is acknowledged by many experts and studies to be time consuming, subjective, uninteresting, and requires more skill (Baik, 2017; López et al., 2018; Sztwiertnia et al., 2019; De Luca 2014). We can describe the procedure of the manual method as the generation of 2-D CAD plans, removing the LIDAR data demands of the user so as to employ them as an instructor in the BIM applications. This result will thus shape the geometry successfully, demanding a huge amount of knowledge in order to understand the scene, as well as increasing the rich semantic information that promotes BIM as an effective procedure (Baik et al, 2013, 2015; Lerma et al., 2010; Sztwiertnia et al., 2019). The research team in this study have organised the workflow that follows to illustrate and draw the Hazzazi residential building architecturally and to assist them with developing the three-dimensional model. With each of these phases, the researchers encountered a different type of issue related to documentations, illustrations, and techniques being employed. The following figure represents the steps pursued in order to fulfil the modelling stage (see Figs. 6 and 7):

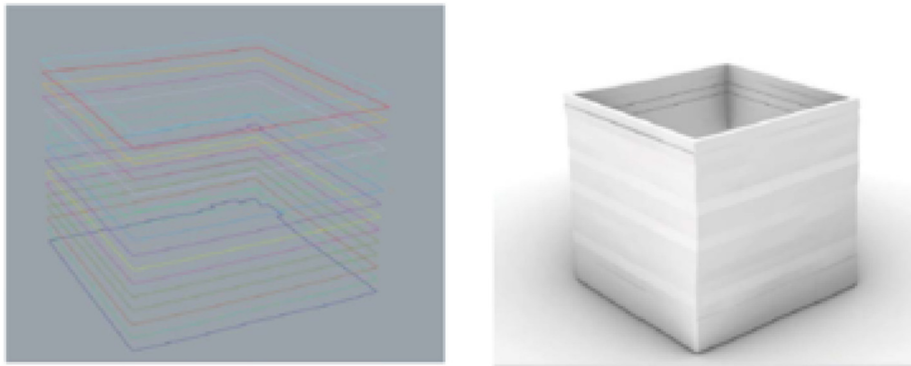

Fig. 19. Stitching step for Hazzazi house.

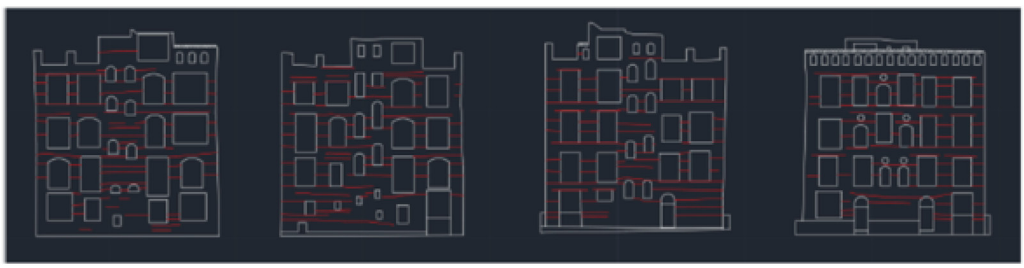

Fig. 20. Openings of the Hazzazi House facade.

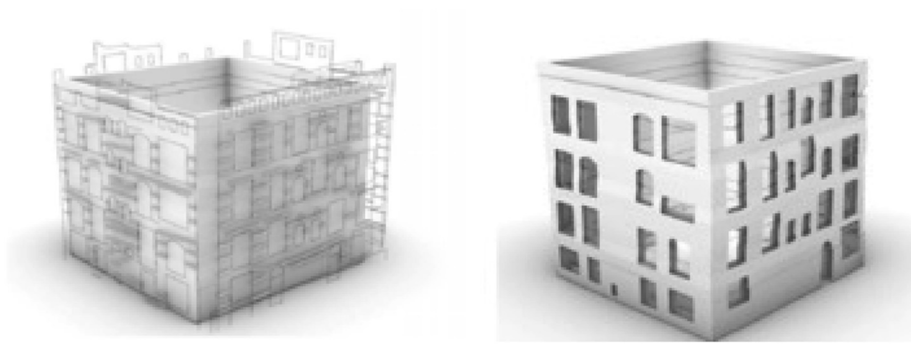

Fig. 21. Placing the openings on the Hazzazi House Facade.

Fig. 22. Architectural components of Hazzazi house.

3.2. Obtained results and discussion

When the technology became more commercialised during the 2000s, terrestrial laser scanning was one of the most popular technologies used to represent the complexity of 3-D structures to be modelled in the 3-D environment (Baik et al., 2013; Lerma et al., 2010). TLS can be used to measure the existing condition of buildings, which is the most important reason to use this technique in Heritage Building Information Modelling. Additionally, terrestrial laser scanning offers a high level of accuracy and it also takes less time to conduct the scans on the cultural sites (Murphy et al., 2011; Murphy et al., 2013). The TLS systems role can be defined as an automatic measurement system, which measures the 3-D coordinates based on the selected objects' facades. After which the produced data is then represented in 3-D point cloud form. According to Murphy et al. (2011), based on the scanned surface, each one of these points has "x, y and z coordinates". Moreover, the angular orientation of an object can be determined for every range measurement via the pointed laser ranger, which includes an encoded reflective surface. Dore and Murphy (2017) described these point clouds as the smallest level of detail abbreviated as LOD-0, representing a higher level of detail from abundant abstract data.

Moreover, within the field of 3-D object scanning, laser scanning includes a combination of laser beams and controlled steering. The shape of

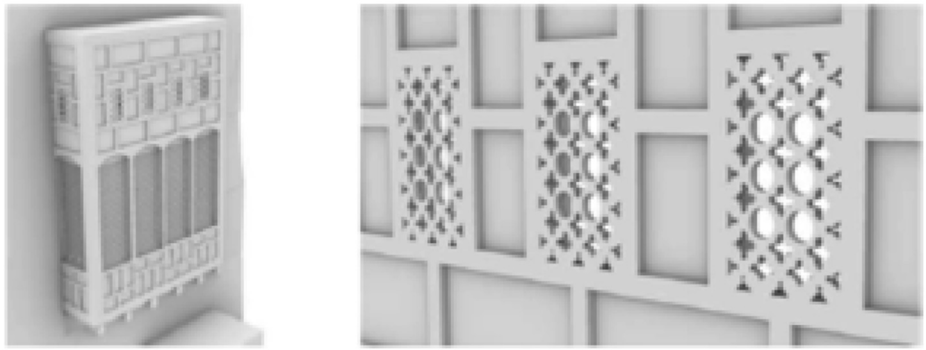

Fig. 23. Three-dimensional model of Hazzazi House.

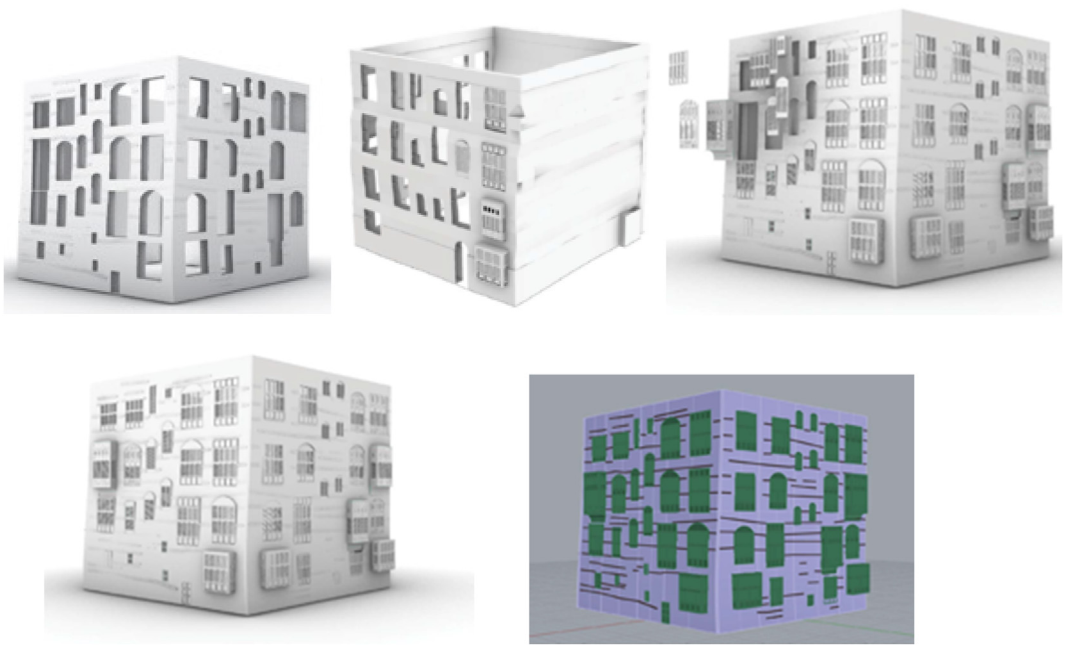

Fig. 24. Placing the architectural elements on the Hazzazi House's facades.

the objects, buildings, and landscape are able to be captured by noting the distance measurement for each direction. As a result, the construction of a full 3-D model rangefinder includes an integration of multiple surface models, produced from a number of angles, or the merging of other known constraints. A rotatable base can be the tool utilised in order to place small objects in a manner that mimics 3-D photogrammetry.

TLS has been introduced as a common technique for the acquisition of data for as-built BIM projects since 2009 (Francois-Heude et al., 2014; Guillen et al., 2016; Marshall-Ponting et al., 2009; Tang et al., 2010). There are two main reasons for this common adoption (Backes et al., 2014). First, through targeting BIM issues, governments such as the UK and the USA have authorised increased use of laser scanning to represent reality (Kelly et al., 2013). Second, support has originated from CAD leaders due to a need for laser scanning after merging the point-cloud handling devices without the use of plugins in their BIM tools (Guillen et al., 2016; Tang et al., 2010).

In Fig. 8, it is seen that the targeted building is ready to scan through the BIM tools and it is evident that the results of the position of these scientific tools are placed at an appropriate location in order to obtain the data with maximum accuracy. For Hazzazi house, the team has printed more than 70 targets to place on the exterior and interior façades. Targets are made in order to allow the device to locate itself in comparison with the previous station, thus they are able to overlap well and make one overall 3-D model. The obstacle, which the researchers may face is that the targets might be removed by other people who might be a visitor to the old city or by one of the organisers. These issues mean that the targets have been needed to be placed again in exactly the same spot; otherwise, the team needs to prepare another scan (see Figs. 9 and 10).

3.3. Registration

The idea of cloud registration is to integrate a range of scanned places with different identity. The integration is taken from a framework that exists in relation to the two Scan-World of constraints that link equal connecting points or intersecting point clouds. This method calculates the total parallel conversions for every aspect of the Scan-World in the system, thus constraints are corresponded as closely as possible, according to Leica Geosystems. Registering these scan stations involve several methods that can be used. This may be accomplished by applying either one of them or in combination, for instance, using target to target based or cloud to cloud based or both at a time (Akash Singh and Lingeshwaran, 2017; Mills and Barber, 2004). Moreover, GPS can be used to determine the laser scanner location and according to Cheok et al. (2017), using the GPS will allow the scans from every position in order to ascertain a common frame of reference in a coordinate project system.

In the Hazzazi House case study, target-to-target registration was used. This encompassed registering multiple point cloud scans into one point-cloud file with control targets relating to the point clouds. Additionally, there were three (HDS black and white “B\W” targets), and a common link among each point cloud registration in between. The result of the registration could be used in line with Murphy's research (2012), thus as a base frame for the geometry of the historic structure, which could then be modelled in different modelling software, such as 3-D MAX, Autodesk Revit, AutoCAD and Sketch Up.

3.4. Point cloud registration

Initially, Leica Cyclone 8.1.1 was used to register the scans for this case study. For registration purposes, many Scan-Worlds corresponding points in overlapping sections were linked. The elevation above sea level and the point sets were registered under the coordination system. Figs. 11–13 display over three Scan-World registrations that have been organized for the Hazzazi Historical House that has taken three days to collect data and generate outcomes(see Figs. 14 and 15).

3.5. Noise trimming

After transferring the scanner's point cloud, several programs can be used in the critical step for filtering and evaluating the point cloud data. The process of placing the overshoot and repeated zone, while scanning and deciding whether to scan over, is called the data evaluation. Furthermore, noise trimming refers to data filtering, reducing, smoothing noise, and resampling the data. In the case of Hazzazi House, the noise was removed from the registered 3-D point cloud by Leica Cyclone, and the data processing stage required ten working days to complete. Figs. 16 and 17 illustrate the results of the 3-D point cloud model scan groups. Moreover, it is demonstrated that the Hazzazi Historical House 3-D point cloud model resolution average was 70 mm on the object surface. The major issue in trimming was to remove the surroundings around the house, such as other houses, trees, humans, and several unnecessary objects. This issue took approximately 10 h to complete.

3.6. Slicing

The point cloud was dissected and sliced into layers; thus, by doing so, the researchers were able to accurately define the thickness of the walls and the indoor spaces. Therefore, the more slices there were, the more accurate the data became for the architectural drawings. After this step, data was exported into one of the three-dimensional modelling programs (see Fig. 18).

3.7. Stitching

The major obstacle faced by the researchers were that none of the free or trial versions of the software were able to provide any aid with transferring the points cloud into a prepared three-dimensional model. Therefore, the researchers resorted to the more traditional method of drawing and illustrating the architectural documentation in order to authenticate the house. Exporting the point clouds however, contributed to the drawing of the plan's layout. Consequently, it helped to build a closer version of the building to the reality. It eventually produced the model analogy of the topography of the walls (see Fig. 19).

Another important issue still remained as the researchers were confronted for illustrating the building facades from the point cloud. Therefore, the team decided to export the elevations from Autodesk Recap to Autodesk AutoCAD in order to draw the facades without any elements. This method helped in studying the openings and their sizes, as shown in Fig. 20. Moreover, the team found a solution by locating the specific place of openings by following a certain procedure, as presented in Fig. 21.

The same issue was faced by the team in regard to drawing the architectural components. The researchers used Autodesk Recap to export every component as a figure to redraw in Autodesk AutoCAD, which was the same procedure applied to all the elements. The researchers illustrated the architectural elements, such as the windows and other elements, separately, then combined, attached, and placed the architectural elements to the facades. Thereafter, the Auto CAD files were imported into Rhino software in order to create the three-dimensional model. Fig. 22 underneath provides a representation of this result(see Figs. 23 and 24).

3.8. Concluding remarks

UNESCO declaration came into effect very recently in the late 2014 for the city of Jeddah to become one of the critical areas both cultural and historical significance in the KSA. However, the importance of conserving historical buildings in the historical regions of Jeddah was not much popular to the local and central government because of the demand of additional resources. In this circumstance, the department of architecture in the King Abdulaziz University perceived the need of preserving historical buildings and started to document them voluntarily without any assistance. Several students, researchers, and voluntary groups were involved in order to carry on this research project so that the documentation processes could convince stakeholders about the importance of these old buildings in the society. This would also generate economic activities once the documentation processes were completed. Consequently, local government organizations would understand the importance of these local heritage buildings in the community and would certainly enhance the national tourism activity to generate revenue.

Multiple factors would alter this research's various equations and might take the documentation in a different direction. For instance, lack of basic setups, and on other occasions, advanced setups, could change the content and outcomes of the research. Furthermore, the absence of information regarding the house, alongside other requirements, such as the need for more than one TLS, appropriate computers (i.e., latest generation processors for faster calculation), financial support, appropriate software to aid the transfer of the points cloud into a three-dimensional model, and other requirements, all added to the complicated issues that delayed the research. If any, or all of these, could be addressed, it would improve the research process significantly. However, heritage buildings, such as Hazzazi House, offered the opportunity to study and preserve these types of buildings using a suitable method through this study in the KSA. Moreover, this research outcome opts to comprehend documenting heritage buildings' considering the complications in terms of design and preservation. Additionally, employing these mentioned methods, historically significant buildings can be demonstrating critical roles for the betterment of the economy and can upheld the history of the country.

Author's statement

Thank you very much for reviewing the article with the comments. We have changed the color into blue that demonstrates changes as recommended by the honorable reviewers and editor.

We are appreciating your feedback in improving our manuscript.

Declaration of competing interest

The authors declared here no conflict of interests in publishing this manuscript.

Acknowledgment

We are acknowledging the supports provided by the Department of Architecture and Geomatics at King Abdulaziz University for data and anonymous volunteers in order to conduct field surveys.

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