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Use of Innovative Tools and Techniques for Heritage Preservation in the Digital Era: Academic Research on Asaf Khan's Tomb in Lahore

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Abstract

In today's digital era, as resources diminish and globalization provokes more regimented situations, innovative technologies such as parametric modeling, Building Information Modelling, 3D printing, and 3D scanners present dynamic answers for conserving and preserving traditional buildings. The main aim of this research is to explore digital technologies and tools to indicate how they can be of assistance in heritage preservation. Moreover, it also aims to identify the techniques that can make this laborious process more efficient and precise. All around the world, heritage sites are brought to life with the help of augmented models. This research highlights the digital methodology, tools, and techniques not fully explored due to limited funding and opportunities but present here as the evolving concept in the field of heritage conservation. It is more about the examination and investigation of the preservation process with the help of digital technology. It also explores the extent of possibilities and opportunities these digital tools can provide. Digital techniques and tools are extensively used within the traditional heritage internationally. However, Pakistan is still lagging behind in this domain. This study reconnoiters the impending uses of digital techniques in preserving architectural heritage and highlights how simple usage of these instruments can make the whole process more efficient and convenient. The outcomes specify that these tools provide many advantages over the traditional methods of conservation and have proved to be more useful and accurate. The application of photogrammetry to create models of old structures is also discussed. Moreover, the creative use of these tools to develop cordiality to original structures without replacing or damaging them is explored. This paper examines the application of these cutting-edge technologies for the preservation of architectural heritage in Pakistan with specific reference to a Mughal era structure in Lahore, that is, Asaf Khan's Tomb. Despite the

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rich architectural heritage of Lahore, there is no proper conservation methodology currently practiced to preserve it. The above mentioned structure was surveyed, documented and the then-current situation was modeled using different softwares including Building Information Modeling in Revit. For the climatic and solar analysis of the structure, Ladybug which is a Rhino plug-in was explored and Microsoft Form it was used for the detailed solar energy analysis.

***Keywords*:** building information modeling, digital tools and technology, heritage conservation, photogrammetry

Introduction

Lahore is a city with a very rich architectural heritage. Its architectural heritage includes many tombs, monuments, mosques, gardens, residences, and offices, whichwere mostly built during the Mughal, British imperial, and postcolonial eras. These buildings are an asset to our country. Due to the rapid urbanization of Lahore city, its cultural heritage has beencompromised due to neglect (Brown, 2009). Heritage data is a collection of a vast and heterogeneous quantity of historical information, which is often dispersed in various archives.It may include drawings, literature, portraits, photos, archival studies, reviews, and other materials related to the structure. Over the courseof years, techniques for surveying, modelling, and depiction have evolved methodologically with the intervention of technology. The invention of laser scanning, photogrammetry, building information modelling, analysis of data techniques, and computer-based visualization have shifted the mode of examining historical and pertinent knowledge from traditional methods towards modern methods of documentation that use 3D models. New techniquessupport the methods of collection, analysis, calculating, and commute of the huge quantity of sources and data. In the current digital era, it is importantto go beyond the theoretical and operative separation between the 3D model and database model towards cohesive models, whichproduce three-dimensional objects and integrated information simultaneously.

In this paper, the author addressed the importance of several digital tools and techniques that can help in the conservation of cultural heritage sites. The authordiscussed those resources and options offered by digital

technologies that can help in the conservation process of historic architecture.It also shows how to designa digital 3D model by the data gathered by both primary and secondary sources. This study presents results from research experimentation performed by 4thyear architecture students in Lahore, Pakistan. The site has been visited and surveyed to develop exact drawings for developingBuilding Information Model (BIM) on Revit. Once the model has been developed on Revit, several analyses wererun on different software.These analyses explored how modern technology and tools can help facilitate the tedious traditional process of conservation.

Asaf Khan's tomb is situated in Shahdara Bagh, Lahore.It is located opposite to Jahangir tomb. These two monuments share a common wall. This mausoleum was constructed in the 17thcentury for a Mughal minister named Mirza Abdul Hassan Jah, who was also titled as Asaf khan. Its architecture is based on the central Asian architectural style. When compared to other tombs of the Mughal era, it can be seen thatthis tomb is unique in design, construction, and finish. Furthermore, at present, the tomb demands immediate architectural conservation due to environmental degradation and neglect (Asher et al., 1992).

Conservationists and researchers are using virtual reality models to accurately analyze old and derelictstructures to understand and record the construction methodology used inthe past. Additionally, Building Information Modelling (BIM) is also being used to develop detailed and intricate digital models to examine the current condition of architectural constructs.It is also being usedto predict future threats tothe constructs,without even being present at the site.It is predicted that very soon, the use of these tools will become necessary.Hence, this study aimed to advisePakistani researchers to shift their focus towards the latest tools and technologies in the field of architecture. Digital tools when used accurately permits easy documentation of prestigious cultural heritages and helps record the current conditions of architectural constructs. This highlights the necessity of conservation of cultural heritage sites.

Literature Review

Conservation of heritage, historic,indigenous, and vernacular architecture is a sustainable concept.Natural disasters such as storms, earthquakes, heavy

rains, and floods can be quite detrimental to the cultural heritage of any region. Traditional means of conservation are not efficient in such a situation since they have many limitations. Usually, they are slow when used and are very time-consuming. On the other hand, digital tools and technologies can aid researchers during the conservation and help gather accuratedatain a much more advanced manner. Furthermore, analysis, surveying and modeling via the latest digital technologies led to various methodological changes in the field of architecture.The use of digital tools, such as laser scanning, and advancedmodelling software transformed the process of gathering and processing historical information. They can be useful since they can help to process a massive amount of data and information in a short duration. “Understanding the physical fabric of a site is an important first step in finding the right conservation strategy, and documentation is the first step in understanding”(Karachaliou et al., 2019). Hassani et al. (2015) claimed that conservation of cultural heritage comprises mainly digitizing, arciving, visualizing and reproducing 3D data. While this codification appears to be satisfactory for collecting data, it neglects to address how outside powersaffect sites of cultural heritage (Almerbati & Headley, 2016).

There are four phases of a documentation process, namely evaluation, diagnosis, intervention, and monitoring. Evaluation involvesa basic examination of existing buildings to understand the preceding activities for thegiven site. The diagnosis phase identifies the cause of damage and decay of abuilding. During the intervention phase, appropriate and proposed measures are selected to renovate and preserve the building. Monitoring is the final phase. It is the process of reviewing the whole procedure to verify the validity and authenticity of the heritage building after conservation. The contribution of geomatics is fundamental in all the four phases described above.

The metric survey is abenchmark for all types of documents and data that is required during analysis, diagnosis, intervention, and monitoring. Later on, during the basic documentation process, a metric survey of the building is done, after which the basic drawings are prepared. Digital tools are employed for more accuracy and efficiency duringthe documentation process. In this way, the data collected using various tools is processed by

BIM to generate the desired product. To put it simply, Building Information Modeling (BIM) is a procedure thatprovides informationabout the entire life pattern of a structure, from project to construction, maintenance, and dismantlement. BIM depends on whether the 3-D model recognizesdigital elements such asconstructive objects (walls, floors, windows, etc.), which are transferred from predefined parameterized libraries (Antonopoulou & Bryan, 2017).

Table 1

Digital Techniques and Methodologies to Preserve Heritage Structures

Metric survey	It involves the basic measurements of the building, to precede with the preparation of existing building drawings.
Laser scanners for Scanning the structure	This is a modern digital technology that is a controlled diversion of laser beams, visible or not visible within the site that has to be scanned, this technology incorporates controlled steering of laser beams with a laser range finder. After taking the measurements of the building, the laser scanner promptly captures its surface shape. It is based on the principle of triangulation to obtain the geometry of the desired building. This method has also some limitations that include the lack of ability to create the textures. Another shortcoming of this method of building scanning is that it is unable to distinguish the material differences.
Photogrammetry	It is the method of recording the structures of the buildings. It can develop good 2D and 3D data sets of the chosen building. It can produce accurate and precise results, also the 2D and basic 3D representations of the buildings.
Structured light beams method	In this digital technology, the use of light projection is utilized in a particular pattern on the object surfaces of the chosen building to get the deformed information from the reflected patterns of light.

3D scanning	3D scanning is also an advance digital technology that utilizes the 3D scanner for the analysis of the building under observation. The 3D scanning employs both the methods of laser scanning, 3D surveying co-ordinate system. The 3D scanner generates very highly accurate 3D models according to the goals of the users. This method is also being used in Pakistan for various conservation projects of heritage buildings
Silhouette formation method	This method can be considered as an application of the structured light beam method. It has lesser accuracy and precision. In this method, a deformation map of the building or any object is generated by the concentration shadow. The deformation map refers to the map of detoriated part of the object or building
Building Information Modeling	This method is called Building Information Modelling. It is used for the 3-D modelling of the heritage building to ensure its conservation, work programming, reconstruction simulation and project management. It employs a digital software to create a fully detailed 3D model of the chosen building. Autodesk Revit is a software of BIM. The 2D layout plan of the building is linked with Revit. Then a complete 3D model is created considering the documentation process and data collection. After the model is being created on Revit, it is analyzed in various ways. As a result of the analysis, accurate drawings can be generated as well as computer simulations of the building that can ensure the validity and authenticity of the conservation process of the heritage building.
Augmented Reality (AR) and Virtual Reality (VR)	Superimposition of digital data on observer's insights of reality. In VR peripheral acuities are limited as much as possible while in Augmented Reality they are essential, because the computer-engendered imageries pedigrees on the vision of the real world.

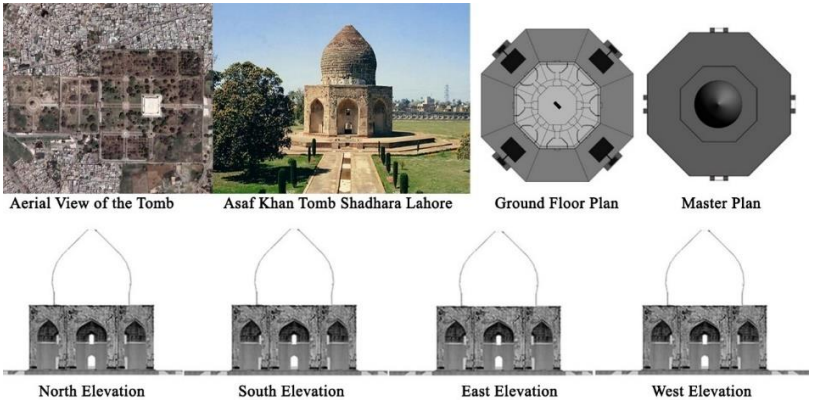
Thus, the digitalization of historic buildings is a process that is composed of various stages. It starts with the documentation process. This process demands the coordination of various professions such asarchaeology, civil engineering, architecture, structural engineering, and information management. This process is very intricate sinceit involvesa large amount of documentation of the desired building. The digitalization process comprises data collection, semantics, and 3D modelling.Modern digital tools that assist the conservation process are

Architectural Documentation of Asaf Khan Tomb Lahore

Asaf Khan's Tomb is located in in the center of the "Chaharbagh", which is a square walled garden. It is very uniquely contructed with walkways and connected water channels.The main feature of the tomb is that it is octagonal in shape. internally and externally. The octagonal chambers are standing on an octagonal platform that has four pools located in the direction of the of the four pathways(Chaudhry, 1998). The main gate is located in the middle of the south wall. Thedouble dome of the chambers is "pear-shaped". The garden is 300 yards square as shown in Figure 1.

Figure 1

Asaf Khan Tomb Architectural Analysis. Source: Author

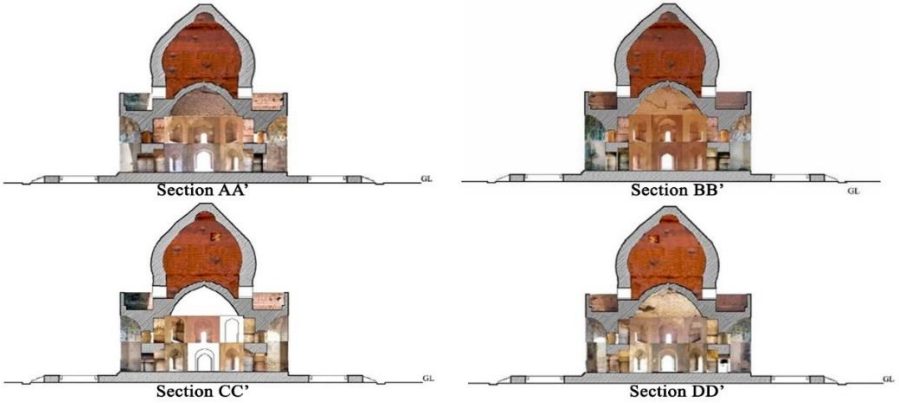


The external dome stands on a high drum. The neck divider is 80" in thickness, it isconstructed with blocks measured 8" by 5½ " by 1". The layer of mortar on the exterior wall is 4" thick. The polygonal segment contains

arched entrances, each 377" in width and 66" in stature, up to the keystones. Here are some sectional details as shown in Figure 2**.**

Figure 2

Section of Asaf Khan Tomb, LahoreSource: ghn.globalheritagefund.com



Proposed Digital Methodologies for the Conservation of the Tomb

Metric Survey

A metric survey of Asif khan's tomb with dimensional details of the building was carried out. Adetailed footprint layout of the building was drawn. It was then created on Autodesk Auto Cad.

Total Station

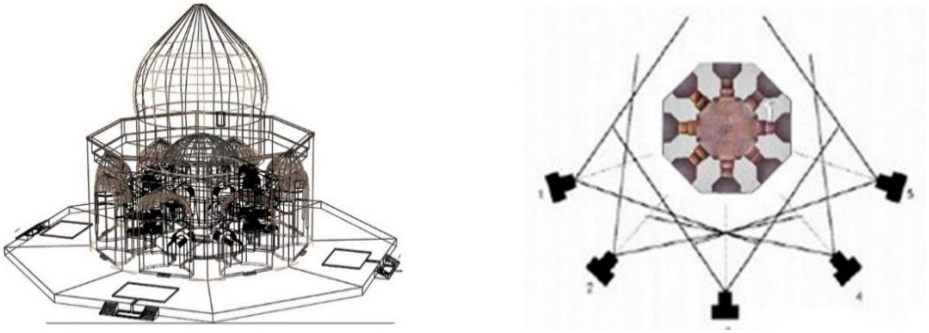
Total station was used to generate and analyze the 3D details of Asaf Khan's tomb. This model would help in the conservation process of the building since it highlights the flaws and damaged parts of the buildingas shown in Figure 3a.

Silhouette Formation Method

The silhouette formationmethod can also be applied to the tomb as shown in the figure below. The laser beams are directed to the tomb at various angles. The tomb would be analyzed via visual mapping. This method would generate multiple high definition photographs of the tomb, which would improve the process of conservation.This can be seen in Figure 3b.

Figure 3

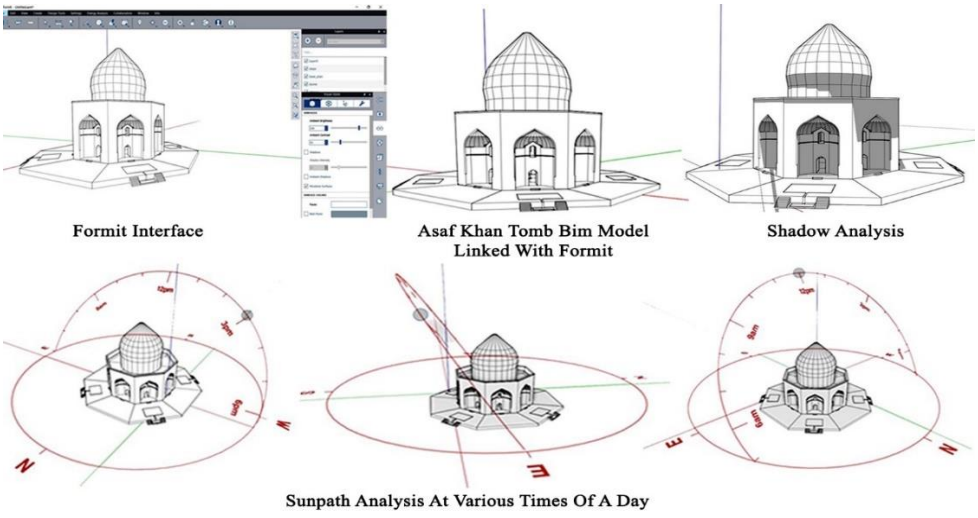
Asaf Khan Tomb Analysis using Total Station and Silhouette Formation Method



BIM (Building Information Modelling)

Figure 4

Sun Path and Shadow Analysis of Asaf Khan Tomb by using BIM Model



The 3D model of the building is prepared on Autodesk Revit (Version 2018) as shown in Figure 4. The 2D plans that were obtained viathe metric survey and documentation process were drawn on the Autodesk AutoCAD. Then it was linked with Revit, whichcreatedthe 3D model by considering

the actual linear and vertical dimensions, heights, and building materials of the site. The proposed model did not have the actual building's flaws or damaged elements. With the help of the 3D Revit model, the tomb can be analyzed from any angle. Furthermore, we can viewsectional details of the building via BIM from any side of the building.

Solar Analysis of The Tomb

Conservation of historic sites depends upon the social, economic, and environmental conditions of a country (Broström & Svanström, 2011). Solar analysis reveals solar pathways with regards to the structure of the site, this analysis fasciliates in the conservation of the building during different solar periods. (Bruke, 2017). Solar analysis, when performed at an early stage, helps the conservatorstake precautions to reduce risk and damageto the structure. Autodesk Formit was used to conduct a solar analysis on the existing structure of Asaf Khan'stomb as shown in Figure 5. The result of the yearly solar analysis of the structure is given in Figure 6.This analysis examined and monitored the effect of sun rays on the structure tocalculate the deterioration time of the surface.

BTU stands for British Thermal Unit. The British Thermal Unit is a unit usedto measure energy. One BTU is the amount of energy taken to raise the temperature of one pound of water by onedegree Fahrenheit at sea level.The analysis generated from the Formit gives us information about the extent of damage by solar radiation ona particular area. The analysis shows BTU per square feet. It also shows that solar radiation mostly affected open areas.

Analysis of the shading factors is conducted viaFormit, which displays the year-round sun trajectories.The results suggest that the sun rays affect the structure throughout the year as there is hardly any shade around it.

Ladybug is a plugin in Rhino thatis used to identify the dry-bulb temperature, wind speed, and relative humidity of the structure as shown below. This analysis is useful for predicting the deterioration risk of the tombas shown in Figure 7. In accordance with the results of the analysis, measures should be takento reduce or prevent further deteriorating of the site(Stanco et al.,2017).

Figure 5

Solar Analysis of Asaf Khan Tomb for Al the Months of the Year 2020

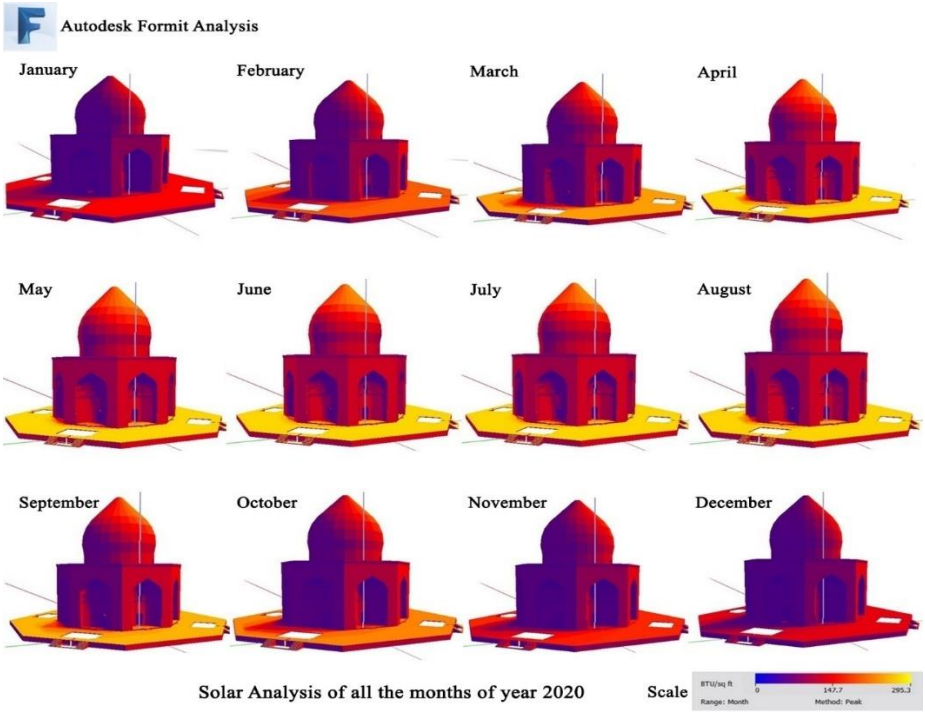


Figure 6

Solar Analysis of Asaf Khan Tomb of the Year(Cumulative) 2020 and by Each Month

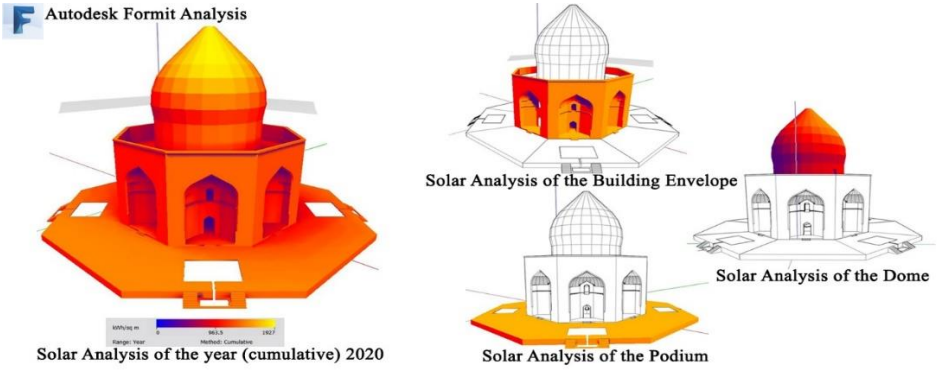
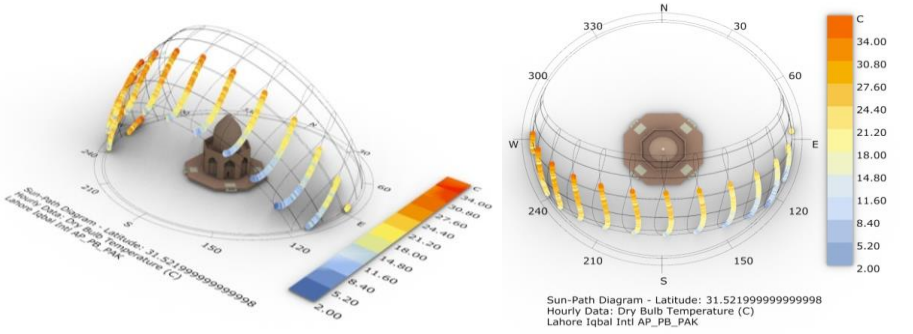
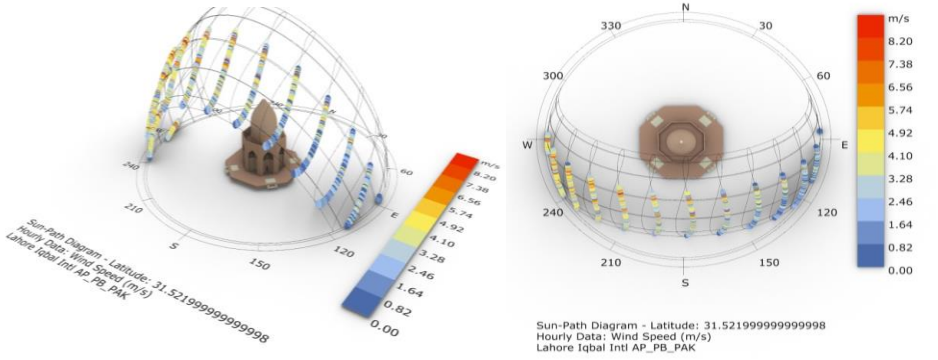


Figure 7

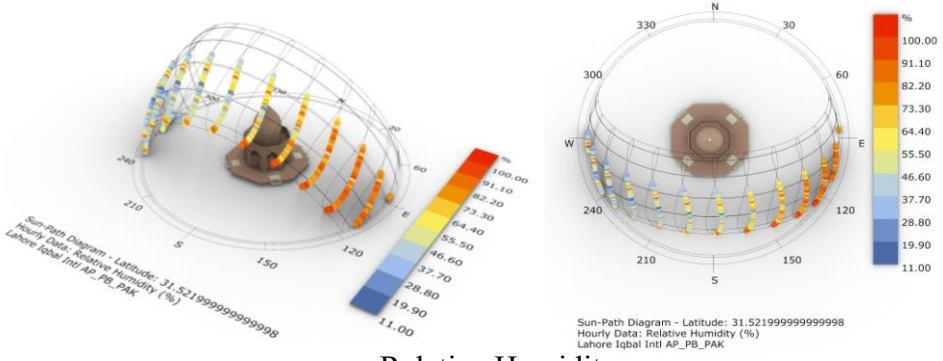
Asaf Khan Tomb Analysis using Ladybug (Rhino Plugin)



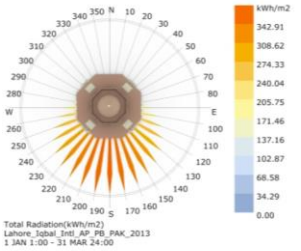
Dry Bulb Temperature



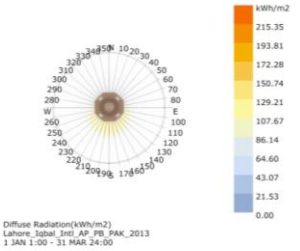
Wind Speed



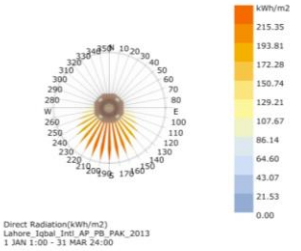
Relative Humidity



Total Radiation



Diffuse Radiation



Direct Radiation

Laser Scanning and Point Cloud Creation

Different scanners offer different scanning radius and speed, accuracy, and portability, however, their basic methodology is the same. A laser scanner emits a quick and constant laser beam towards the zone being examined. The unit of the scanner spreads the laser both vertically and horizontallyto systematically sweep the beam over the chosen area. When the beam hits neighbouring items, some energy bouncesback to the machine, which catches it and uses a timer to estimate the distance from the machine to the object. Sweep results are typically delivered with different textures and colours and for this, built-in or external cameras are utilized. Filtered data is superimposed on the pictures taken by the cameras. The scans are taken from scan targets around the site, which are linked together in the software.The final result is an assembly of specific scans, which are then merged to produce a single presentation called a Point Cloud. In any case, this is just a point by point 'dumb' 3D portrayal, which could betransformed into a shrewd model using data. Before modelling, the Point Cloud information is embedded into Autodesk Recap, where interruptions are manually rejected, leaving just the necessary zone. This model is then embedded into Autodesk Revit, where the geometric model is developed by tracing over the Point Cloud file.

Discussion and Analysis

This BIM Model of Asif Khan'stomb collects and examines accurate data of the existing state and layout of the structure. Thismodelis incredibly handy and a steadfast resource for conservators. It reduces the necessity to pursue expensive, time-taking, and possibly intrusive surveying.It also

reduces the chancesof human error that are naturally linked with such a methodology. Additionally, it provided accurate details of sections, floor plans, and elevations within seconds without using any non-accurate techniques. These records can be utilized to acquire accurate network inventory for the conservation process.

BIM modellingcould be utilized as a planning tool to reclaim stone works.It can also be usedto locate objects as a visual guide device. With the assistance of this model, maintenance schedules and point by point room information sheets with a log of past issues and activities can easily be created with little to no margin for error. High-goals Point Cloud permits overview building sections and their condition,which limits site disturbances and diminishes surveying costs. Furthermore, this model can give a visual stroll through and around the tomb for virtual visits. Scaffolding simulation for renovation planning scenario planning and simulation (e.g. plan an exhibition inside a room) can also be given through this model. This model gives access to remote and accurate data with the help of mobile technology, which, in turn, helps researchers make reviews and reports without much hassle.

Table 2

Comparison between Traditional and Digital Methodology

Traditional Methodology	Digital Methodology
1- The traditional methodology focuses on the project ina in a linear manner and acquires data in separate layers.Its process of collecting data and the actual database are disjointed.With this technique, the 2D model must be drawn plane by plane. For example, if for a building we want three-floor plans, eight sections, and four elevations, we must draw all of them one by one. Any modification in one plan would	1- In the BIM methodology, all production is automated. The 2D planes are directly extracted from the model.Any modification in one plan would automatically be made in the other plans in BIM methodology.To obtain visualizations in 3D, you want to use a model or a virtual model.Although this methodologyallows us to visualize the project

Traditional Methodology	Digital Methodology
need to be manually added to the other plan since these plans are of the same project.	volumetrically andcalculate the needed materials for conservation, this model does not contain any information about the weather.
2- Measurements and budgets are also done by hand.After measurement of all surfaces, unit prices are also manually applied in accordance to the given budget. We are again faced with anidentical problem when using this methodology.Any modification has to be manually updated within the budget. If, for instance, two windows are deleted, then we must modify the budget and delete the previous data of thetwo windows manually.	2- This methodlogy saves cost and time in production.The most important advantage of this methodology is that all aspects of the project can be found in a single database. This database is the BIM model. Unlike the traditional method,the BIM system relies on the creation of a central model, which createsa precise and virtual recreation of the building under scrutiny.All data necessary for the project stems from this model.
3- The traditional ways of building in historic environments, includingthe useof local building materials, building techniques, and local traditional building forms of skilled masons, constitute a significantaspect of the authenticity of building culture.	3- Another significant advantage of this methodology is the3D visualization technology, which is indirectly related to the central model. The BIM model contains information about every element usedin the project.It also contains data about the materials with which the elements are built as well.. Thus, even if the materials are modified, the 3D visualizations would still be automated. Furthermore, the 3D visualization would be closer to reality since this methodology incorporates physical information

Traditional Methodology	Digital Methodology
	about the materials. BIM software are usingincreasingly better visualization methods, evolving from traditional static rendering to virtual tours and 360 degree visualizations.
4- It was observed that the traditional methods do not provide accurate information in terms of documentation of elements.	4- 3D scanning/3D digitizing uses metrological methods to establish the scale and shape of the scanned objects.This is done via an optical device that rotates around the desired scanned model/ the structure under scrutiny. These devices use laser technology and sensors to calculate a model's xyz coordinates employing a technique called triangulation. Boehler and Marbs (2002) explain that the data obtained from triangulation isusedtocreate line drawings, CAD models, visual animations, and 3D surface models. In their study, Boehler and Marbs (2002), compared the new 3D scanning and traditional photogrammetry techniques in heritage recording.

Conclusion

Considering the present condition of the historic buildings in Lahore, Pakistan, the conservation of heritage buildingsneeds to be given precedence. The findings of the research reveal that the use of digital tools and technologies can make the conservation process more efficient and authentic. With the help of this BIM model, every minor detail of the

building can be analyzed and studied. In comparison, the traditional methods of conservation are time-consuming, tedious, and difficult to use. Following the discovery of modern digital technologies and innovations in the field of architecture,Pakistani conservatorsshould shift their focus from traditional methods to digital tools and technologies for conservation. This research advises researchers to employ latest methods of examining and analyzing site data for a conservation.

Thus, the 3D virtual restoration method and contemporary tools can be used to examine the entire monumentand its different states.Furthermore, all intrusions of the monument can be illustrated in drawings and 3D representations via the BIM method. Solar geometrical analysis can aidconservators in the decision-making process for the conservation of any historical building. It can also help finalize the selection of material and techniques based on the orientation of the buildings.

The laser scanning and photogrammetry data can be used as a baseline data sets for the evaluation of the actual state and the effect of the intrusion by the use of 3D geometry in virtual space. BIM can be utilized for structural or energy related future conservation and rehabilitation processes.Furthermore, converting multitude of traditional archives into a single and coherent unified model can essentially improve the whole process of conservation. It also considerably speeds up the process of documentation as compared to the traditional method of documentation.This method of documentation archives structural history, architectural arrangement, and the reasond behind the deterioration of the cultural heritage sites. Most importantly, this software helps in the curation and examinationof a large amount ofvisual data, which is neccesarry in the restoration processThis research, as mentioned in the title, is academic. It overviews the latest digital methodologies used in the process of conservation.

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