ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume X-M-1-2023
29th CIPA Symposium "Documenting, Understanding, Preserving Cultural Heritage:
Humanities and Digital Technologies for Shaping the Future", 25–30 June 2023, Florence, Italy

A STRATEGY USING HERITAGE DOCUMENTATION FOR MANAGING CHANGE OF THE HISTORIC CENTRE OF BUKHARA

O. Vileikis
Institute of Archaeology University College London (UCL), 31-34 Gordon Sq, London WC1H 0PY, United Kingdom – o.vileikis@ulc.ac.uk

KEY WORDS: mapping, survey, heritage documentation, conservation guidelines, heritage changes, Silk Roads, Bukhara

ABSTRACT:
Bukhara, historic city of the Silk Roads, has been going through changes for more than 2000 years. The historic centre is UNESCO World Heritage since 1993 including hundreds of monuments such as madrassas, mosques and caravanserais, and an urban fabric containing the traditional Bukharian houses. As a dynamic city in Uzbekistan, its transformation is ongoing. A number of previous studies, including a large scale UNESCO field campaign, have been carried out to identify the overall condition of this historic city. Being most of the traditional houses privately owned and built of earthen materials, these studies have highlighted that this type of heritage is under threat of high impact of changes. Therefore, there has been a need of guidelines to protect and manage change of this outstanding heritage. Appropriate decisions in heritage conservation are based on timely, relevant and accurate information about the conditions, materials and evolution of heritage buildings and landscapes. To support these tasks, two main international projects, the University College London (UCL) Central Asian Archaeological Landscapes (CAAL) funded by Arcadia Fund, and the Traditional Bukharian Houses Documentation and Conservation approaches funded by the World Monuments Fund (WMF) are supporting the heritage management of city of Bukhara in partnership with the International Institute of Central Asian Studies (IICAS), the local administration, universities and the Bukharian community. This paper presents the current two large projects to create a digital database of the mahallas -*neighbourhoods* and its traditional houses by documenting heritage attributes, and ultimately produce the Guidelines on Conservation, Maintenance and Adaptive Reuse recognising heritage regeneration, as a core principle, and the contribution of heritage towards the achievement of the UN 2030 Agenda and its Sustainable Development Goals (SDGs).

1. INTRODUCTION

1.1 Digital Bukhara Past, Present and Future

Bukhara situated on the Silk Roads in current Uzbekistan is over 2000 years old (see Figure 1). Over centuries, caravans transported silk, spices and other precious goods from the Far East to Europe along the Silk Roads. Bukhara was an important stop-over for caravans, it was a place where not only goods, but also culture and ideas were exchanged. Bukhara developed into an important city for Islamic culture.

Figure 1. Location of Bukhara in current Uzbekistan. Background layers: Esri Terrain, USGS, The State Committee of Republic Uzbekistan on Statistics.

Today, Bukhara is still a unique example of medieval city along the Central Asian Silk Roads. As such, the Historic Centre of Bukhara became a UNESCO World Heritage property in 1993 as this heritage area meets three criteria of Outstanding Universal Value (OUV) (Republic of Uzbekistan, 2012). The criteria not only recognise monumental building such as mausoleums, caravanserais and madrassahs, but also the urban fabric with its traditional water system, mahallas -*neighbourhoods* and vernacular architecture as illustrated in Figure 2.

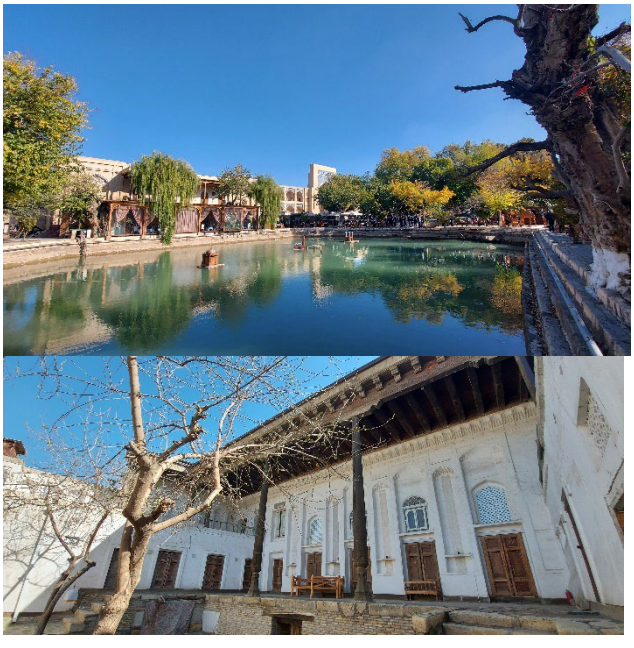

Figure 2. Lyabi Hauz -*pool* (upper) and interior of courtyard in traditional Bukharian house (bottom).

After the designation of Bukhara as World Heritage, its protection became a commitment of the Republic of Uzbekistan and Bukharians. These obligations are fixed legally at three levels: international, national and local (see Table 1) (UNESCO, 1972a; Republic of Uzbekistan, 2001).

This contribution has been peer-reviewed. The double-blind peer-review was conducted on the basis of the full paper.
https://doi.org/10.5194/isprs-annals-X-M-1-2023-269-2023 | © Author(s) 2023. CC BY 4.0 License.

LEVEL	LEGAL DOCUMENT
International	Convention concerning the Protection of the World Cultural and Natural Heritage (1972)
National	Law of the Republic of Uzbekistan on Protection and Use of Cultural Heritage Properties No.269-II of 30.08.2001
Local	Various legal acts of obligatory and recommendation character, including these Guidelines.

Table 1. Legal framework of Bukhara as World Heritage.

Extensive work has been carried out in the historic centre of Bukhara towards its protection as an outstanding cultural heritage, while managing change. From 2008 to 2013 the UNESCO Office in Tashkent in collaboration with international and national universities carried out a survey of the Historic Centre of Bukhara World Heritage property. It was a rapid survey to identify the state of conservation of the dwellings, social factors and needs of the people living within the listed property (Vileikis and Allayarov, 2014, 2015; Vileikis et al., 2017). As a result, the survey 216 hectares of World Heritage area and more than 4000 dwellings. In addition, other inventories have been taking place with specific focus as the studies of the Center for Jewish Art (CJA).

Both, the comprehensive survey of UNESCO and the 1990s CJA database were a good initial baseline information as a record of the historic city. However, to manage the living historic centre of Bukhara and propose guidelines for conservation, maintenance and adaptive reuse that will answer to the current needs, more detailed and updated survey was needed.

In 2019, the Central Asian Archaeological Landscapes (CAAL) a University College London (UCL) and Arcadia Fund funded project was launched with the aim to map and create a database of the Central Asian cultural heritage, including the Historic Centre of Bukhara. One year after, the World Monuments Fund in partnership with the International Institute of Central Asian Studies (IICAS) initiated the project for the documentation and development of conservation guidelines for the city. The earlier has been building a Geospatial Information System (GIS) database of the historic urban landscape e.g. monuments, sites and dwellings. The latter aimed to record in detail the traditional Bukharian houses and mahallas.

This paper will present the two current large heritage documentation studies towards the development of the conservation guidelines and supporting decision making of the cultural tangible and intangible heritage in the dynamic city of Bukhara. The results presented are part of the research of the author, in collaboration with the local team in Bukhara.

1.2 Documentation for Cultural Heritage

The United Nations (2015) recognizes with its Sustainable Development Goals (SDG) that the world should "Strengthen efforts to protect and safeguard the world's cultural and natural heritage" (Goal 11.4) to "make cities and human settlements inclusive, safe, resilient and sustainable" (Goal 11). For this reason, identification and documentation of cultural heritage is a key component in the development of mankind. As stated by Clark (2010), understanding a heritage site is the first step to selecting any conservation strategy, and documentation is the first step in understanding. Documentation and well-established baseline information can serve in the study and protection of a heritage site by recording its values and monitoring its integrity over time. Thus, appropriate decisions in heritage conservation are based on timely, relevant and accurate information about the conditions, materials and evolution of heritage buildings and landscapes.

Aside from the Convention concerning the Protection of World Cultural and Natural Heritage (UNESCO, 1972a), there are other conventions and internationally recognized charters for cultural heritage and documentation standards (UNESCO, 1972b; ICOMOS, 1996; Historic England, 2016). They aim to guide stakeholders and site managers to improve its documentation and interpretation of the sites. These documents provide guidance of the use of digital tools, workflows and platforms for a wide range of levels of documentation detail and scales of the sites.

Digital tools are used in the heritage recording process to acquire, process, and produce digital media, including all digital data capture forms, ranging from photographs to rectified images, CAD to photogrammetry, use of drones, total station to 3D scanning, as well as others such as lidar sensors and emerging devices. They can be divided into metric surveying and recording, and other non-destructive diagnostic techniques. Digital workflows are the methods or approaches utilized by heritage recording specialists to carry out a cultural heritage digital recording. A summary list of workflows and tools for heritage recording is shown in Table 2.

WORKFLOW TOOL	PURPOSE IN CULTURAL HERITAGE	FURTHER LITERATURE
Remote Sensing: Satellite Imagery, Digital Aerial Photography (aircraft - UAV), Aerial Laser Scanning (LiDAR: Light Detection and Ranging	3D models and maps of objects and environments Map and monitor cultural landscape, cultural routes and complex archaeological excavations; Digital Terrain and Surface Models; Topographic and landscape mapping; Verify boundaries and buffer zones; model impact of site management decisions and policy options; multi-temporal data; Understand a historic landscape; monitor and mitigate environmental changes, vegetation type; map and detailed survey of urban areas and archaeological sites; disaster monitoring; monitoring system for planning and archaeological excavation; create orthophotos and thermal-orthophotos Fluorescence-based maps (raster data)	Hernandez, 2002; Remondino, 2011; Colomina and Molina, 2014; Rinaudo et al., 2012; Williams, 2012; English Heritage, 2011; Raimondi et al., 2009
Photogrammetry - Terrestrial: Digital cameras (DSLR, Mirrorless, 360 cameras) Photogrammetric software Total Station or GNSS for absolute orientation of photogrammetric models Photogrammetry - Aerial: UAV	Record flat facades and large amount of detail; use of control points; draw architectural façade; create a drawing for a large area containing great detail; Digital Surface Model; identify damage e.g. determine location and quantity of erosion of building materials and surface change; ante-disaster record; monitor direction and magnitude of crack propagation. Outcome: 3D Dense Point Clouds, 3D	English Heritage, 2009; Remondino, 2011; Feilden, 1987; ICOMOS International Committee on Heritage Documentation (CIPA) 3x3 Rules Waldhäusl et al., 2013; English

WORKFLOW TOOL	PURPOSE IN CULTURAL HERITAGE	FURTHER LITERATURE
equipped with cameras Photogrammetric software Total Station	Textured meshes, Ortho-corrected images Digital Surface Model, Drawing for a large area containing great detail Field survey measures; topographic mapping, building plans and sections; precise control network measurement; monitor structural movement e.g. 3D distortion	Heritage, 2009
3D Scanning: 3D Scanning (Mobile Laser Scanners and Terrestrial Laser Scanning) 3D scanning processing software Total Station or GNSS for absolute orientation of photogrammetric models	Mid-range: Build models and drawings of complex objects; survey building façades and interiors; surface models; produce detailed maps. Close range: sculpture relief carving; 3D printing; virtual reconstruction; interactive virtual museums; scientific archives. Outcome: 3D Dense Point Clouds, 3D Textured meshes, Ortho-corrected images	Barber et al., 2006; English Heritage, 2011; Remondino, 2011; Tucci et al., 2011
Geoferencing: Global Navigation Satellite System (GNSS), Global Positioning System (GPS); Differential Global Positioning System (DGPS), Total Station (EDM)	Topographic mapping, (archaeological) landscape surveys, inventory mapping linked to cartographic coordinate systems; create a 3D model to do metric and topological analysis on an archaeological excavation unit; establish permanent survey control to aid excavation; monitor sites for conservation purposes, e.g. key elements to ensure that the same photo will be taken with the same view and position	English Heritage, 2005; Losier et al., 2007
Panoramic Photography and High Resolution Panoramic Photos (Gigapan)	Large and 360° outdoor and indoor panoramas; document architectural buildings; create virtual museums; 3D reconstruction Identify disturbances; select tests and test areas to determine causes of discoloration; determine cause and cleaning methods e.g. for stone staining; in monitoring to take controlled photopoints	Luhmann, 2004; Remondino, 2011; Shum and Szeliski, 2000; Walton, 2003; Fangi, 2010
Geophysical survey: geophysical prospection e.g. with Ground Penetrating Radar (GPR), Electromagnetics, electrical conductivity	Archaeological imaging or mapping; landscape analysis; create maps of subsurface archaeological features; detect subsurface objects, changes in material properties, structural modifications, voids and cracks	Kvamme, 2003; Kvamme, 2013

Table 2. List of tools for recording and monitoring the condition of cultural heritage.

Lastly, digital platforms are an electronic stage used to visualize, manage and communicate digital media, often publicly. Nowadays, platforms for heritage inventories are popular, together with Geographic Information System (GIS) platforms. One example is the Getty/World Monuments Fund Arches Heritage Inventory and Management System, a generic open-source platform launched in 2013. A great advantage of this system is its functionality as open source, and no license fee is required. It follows open data standards published by the Open Geospatial Consortium (OGC) making it compatible with desktop GIS applications (Carlisle et al., 2014). Current examples of the implementation of Arches as a platform to inventory and map its historic resources are the HistoricPlacesLA of the City of Los Angeles, the Philippine Heritage Map, and the National Heritage Inventory of the Kingdom of Bhutan (Myers, 2016; Williams, 2016). Recently, Historic England developed Arches for the heritage inventory of Greater London and the City of Lincoln. In addition, the Global Digital Heritage project has an implementation of Arches including 3D data.

2. METHODS

The heritage documentation methods below were used to map and survey tangible and intangible cultural heritage of the selected areas of the Historic Centre of Bukhara, serving as a pilot project for further detail survey. The assessment was conducted at two levels of scale: mahalla (urban scale) and traditional houses (architectural scale).

- Literature review and data of previous studies and field surveys (UNESCO 2008-2013, list of historic buildings, monument passports and monitoring records of the Bukhara Heritage Agency)
- Focal meetings with stakeholders in Bukhara;
- Identification of attributes that convey the OUV and criteria;
- Mapping of the urban areas using aerial photogrammetry (DJI Mavic 2 Pro) (see Figure 3); and orthophoto superimposed on the map of Bukhara of 1910 by Parpheov and Fenin; 360 degrees videos and photos using Insta360;
- Development of a database in QGIS with a public face using Arches;
- Survey of the traditional houses: door-to-door forms (using the same format of the UNESCO survey 2008-2013);
- 3D scanning of selected houses using FARO CAM2 Focus (see Figure 4);
- Cultural Mapping: Semi-structured interviews to a selection of homeowners using video recorder to produce a short documentary.

Figure 3. Site recording using DJI Mavic 2 Pro drone with children of Bukhara and the IICAS team.

Figure 4. Site recording and processing 3D scanned data with students of the Tashkent Turin Polytechnic University (TTPU) and the IICAS team.

3. RESULT AND DISCUSSION

3.1 Values Assessment – definition of attributes

Identification of attributes was carried out for the two levels of scale, and based on the OUV and criteria of the World Heritage property -the ***why***. The definition of these attributes is relevant to the documentation strategy as they reveal -the ***what*** is documented. Large literature review, archival research and focal meetings with the local teams supported this task.

Mahalla: The Mahalla is a unique phenomenon of Central Asia. The Mahallas were originally founded by a family, ethnic or professional community. Each mahalla had its own boundaries where families had their own lands with courtyard houses. In the 20th century, the mahallas also gained an administrative function as the smallest units of local authorities. The following are the attributes of a mahalla:

- Narrow streets
- Labyrinth Street layout (Urban Pattern)
- Two High and Proportion
- Water System
- Exterior Materials: timber, frame and brick for the houses (earth) and no payment for the streets

Figure 5. Traditional house illustrating the attributes that convey the OUV from the exterior façades.

Figure 6. Traditional house illustrating the attributes that convey the OUV in the interior courtyard.

Traditional Houses: The vernacular architecture of Bukhara is highly unique for Central Asia. The following were the attributes identified characteristic of this typology. They present a high contrast between the exterior and the interior:

- Delicate traditional materials and techniques: timber frame and brick (clay, row or burnt) infillings finished by clay plaster
- Modest facades and flat roofs
- Modest entrance and doors
- Sophisticated form and functional structure with restricted height
- Lively courtyards
- Summer aivan or nim-aivan - including windows and timber columns
- Decorated mekhmonkhona -*guestroom*.

3.2 Mahalla Mapping

A QGIS database was developed based on the UNESCO database survey (2008-2013). It contains the records and state of conservation of 4417 dwellings. The database was adapted to the standards of the CAAL project for a consistent integration (see figure 7). QGIS was selected as a tool as it is Free and Open Source Software (FOSS). As the UNESCO database was already built using international standards for cultural heritage, no major changes were implemented, for example, additional values were created related specifically to the traditional houses such as materials and courtyard typologies. A public platform using Arches Data Management System is under development.

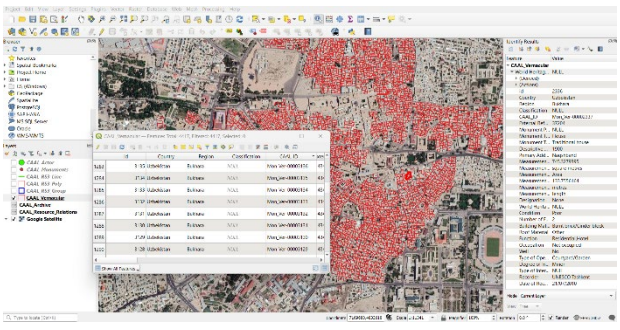

Figure 7. GIS database of the Historic Centre of Bukhara in QGIS using CAAL standards. Source; CAAL project.

As shown in Figure 8, a smaller area of study within the historic centre was selected for detail survey. The area of study was surveyed based on the map of Bukhara of 1910 by Parpheov and Fenin (Gangler et al, 2004), superimposed on the orthophoto

taken in 2021 by the International Institute of Central Asian Studies (IICAS). The orthophoto was produced from aerial photogrammetry taken by DJI Mavi 2 Pro with a height of 80 meters.

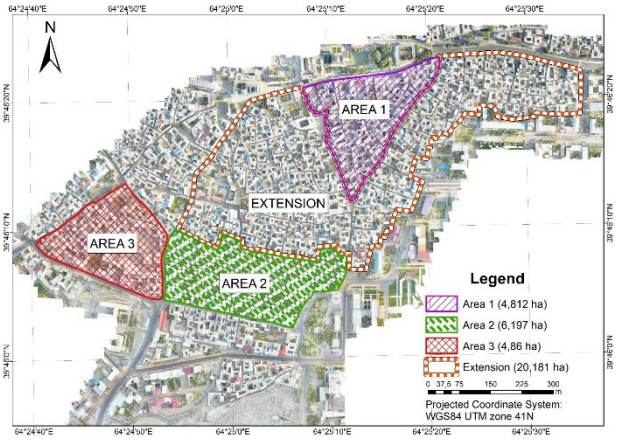

Figure 8. Map of the area of detail research. Baseline data: georeferenced orthophoto from aerial photogrammetry.

The orthophoto supported the analysis of the mahallas urban fabric and structure. A high percentage of the houses have changed their flat roofs for inclined roofs. The earlier are easier to maintain as the original ones made of earth require high maintenance and special traditional techniques (see Figure 9).

Figure 9. Orthophoto in area 1 (see Figure 6).

All streets were systematically recorded using the Insta360. As shown in figure 5, the use of the 360 photos and videos of the urban fabric were a rapid ground recording technique that allowed after the field survey a detail assessment such as type of pavement, electricity poles or urban furniture. It also recorded the intangible heritage of Bukhara and the daily lives of Bukharians, such as the markets and children going to school in the mornings serving as a snapshot in time of the city. 137 360 degrees videos were produced. New studies by Barazzetti et al. (2020) for condition mapping using 360 degrees images are under development. Thus, this data collected could have a further in the future.

Figure 10. Example of photos extratected from 360 videos using Insta360.

3.3 Survey of Traditional Houses

A detailed survey was conducted to a selected number of houses. The prioritized houses were on the national heritage list or identified by the previous surveys as having high heritage values.

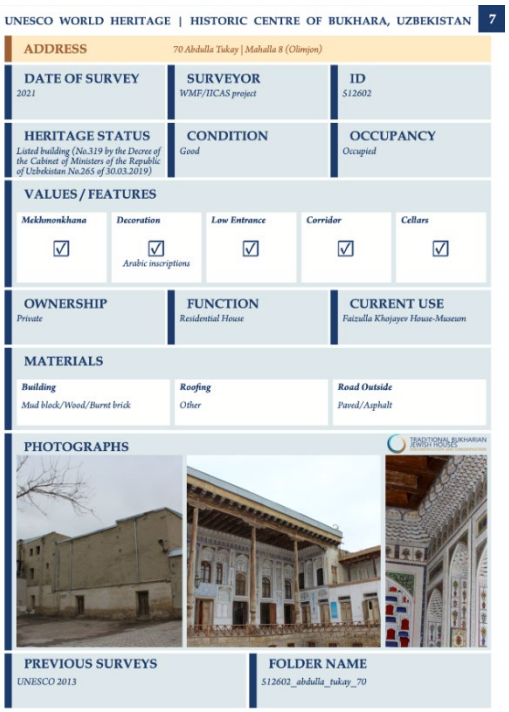

Figure 11. Filled out example of survey form for values and condition assessments.

A fiche was created for each one of these houses after carrying out door-to-door interviews and documentation (see Figure 11). The fiche follows the same international recognised standards of the UNESCO survey (2008-2013) (for further details see Vileikis et al (2017).

A comparison between this updated survey and the previous allowed to understand the changes of the houses and the needs of the homeowners. The traditional houses are changing as they need to be adapted to the current needs of the owners. These changes were always part of the living heritage where families were growing or getting smaller, the houses were single-family homes or community shared houses, or the owners changed with different religions. Despite this changes, a number of attributes remained, the most prominent the courtyard and the ayvans. The mekhmonkhona keeps of being the main room, but it is sometimes used also as a bedroom, or has adopted other uses based on the needs of the homeowner.

Three houses were surveyed with the CAM 2 Focus FARO 3D scanner and photogrammetry to capture high quality of details (see Figure 12). From them, architectural drawings were drawn using AutoCAD. These records are example of best-preserved traditional houses of Bukhara.

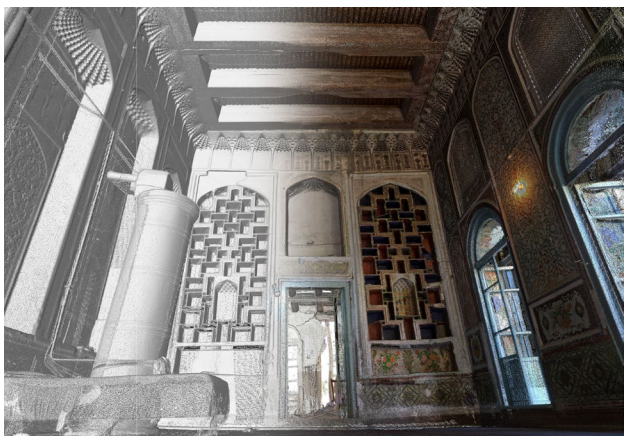

Figure 12. Example of survey results 3D scanner point clouds without textures (left) and with textures (right).

3.4 Cultural Mapping

Beyond the global significance, the Historic Centre of Bukhara provides its residents with a range of economic, social and recreational values – it is a living heritage reflecting the outstanding traditional Bukharian lifestyle. The Historic Centre of Bukhara also contributes to sustainable development, the UN Agenda 2030 and its 17 Sustainable Development Goals (SDG). The traditional houses contain intangible histories that has passed through generations and were linked to the houses.

To record these histories, interviews to three homeowners were carried out. These were recorded to make a short documentary film: *Three Houses, Three Stories, One Bukhara*. The homeowners highlighted the importance of Bukhara as a multicultural city, and they hope this will remain in the coming generations (see Figure 13).

Figure 13. Cultural Mapping: the semi-structured interviews to owners of traditional Bukharian houses during the recording.

3.5 Guidelines for Conservation, Maintenance and Adaptive Reuse

The Historic Centre of Bukhara has adopted a Conservation Approach for any interventions within the historic centre. They have been drafted to align them with international standards, but adapted under a values-based approach for the wider local context taking the UNESCO (2011) Recommendation on Historic Urban Landscape (HUL) into account. The main conservation activity is to safeguard all the attributes identified, taking as a priority the ones directly expressing or contributing to the OUV. This will mean to continuously maintain these attributes and take actions to reduce the risks that might have a negative impact on them.

The publication *Traditional Bukharian Houses and Mahallas. Guidelines for Conservation, Maintenance and Adaptive Reuse for residents and house owners of the Historic Centre of Bukhara*, with illustrated examples, gives practical guidelines to the homeowners to not only conserve, but maintain & repair, and to the professionals such as architects to propose changes for rehabilitation by highlighting and preserving the heritage values (Vileikis, 2023) (see figures 12 and 13). It was launched in May 2023 in Bukhara with the participation of the WMF, IICAs team members, regional authorities, stakeholders and mahalla leaders representing the community. The publication is available in Uzbek, Russian and English.

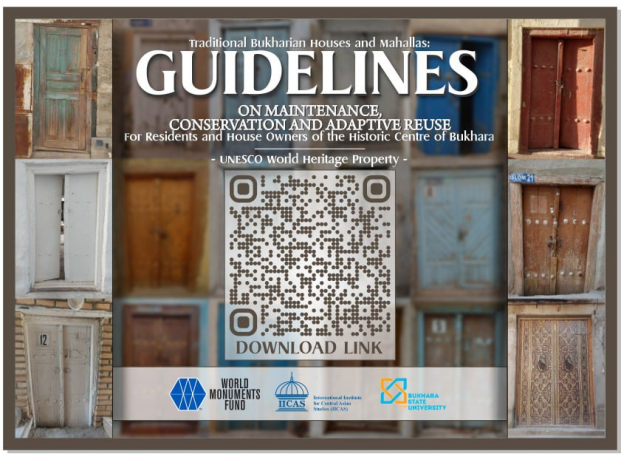

Figure 12. Poscard with QRCode of Guidelines illustrating doors of traditional houses documented. Distributed to stakeholders, owners and residents in Bukhara.

Figure 13. Guidelines showing illustrated glossary and features of the houses such as the traditional materials.

4. CONCLUSION

The Historic Centre of Bukhara, World Heritage property since 1993, is an outstanding example of heritage and wider values of a living central Asian city. As all cities, changes are a major threat to the heritage values, however with systematic and high standards documentation and information, the city responsible authorities could better make decisions and manage change.

With the support of two international projects and a large database of previous studies two international projects were launch to support two levels of recording: mahalla and traditional houses. The results successfully used a combination of digital heritage recording techniques, including aerial and terrestrial photogrammetry, 3D scanning, 360 degrees videos and photos, context and detail photos, and video recording to capture the current state of the historic city.

Based on the updated information and previous studies, Guidelines for Conservation, Maintenance and Adaptive Reuse were produced. This documennt will serve as a guide for residents and owners of the traditional houses. In addition, the GIS database of the city was updated. Further dissemination and workshops on the implementation of the guidelines, as well as training on the use of GIS for the relevant authorities, is foreseen.

Changes in historic cities are foreseeable. Homeowners are looking towards good quality of life, and commodities of the 21st century, and this requires a different approach in conservation of traditional houses. The heritage documentation of the historic city of Bukhara has been an ongoing systematic process that the city should embedded as part of their regular policies and workflows, a challenge still open to surpass.

ACKNOWLEDGEMENTS

The author would like to thank the IICAS, WMF, and the Bukhara State University team for their support in the field, research and dedication to produce the outcomes presented in this paper. Deepest appreciation to the key national and international institutions that were part of the process: National Commission of the Republic of Uzbekistan for UNESCO, UNESCO Tashkent Office, Khokimiyat of the City of Bukhara who hosted this work, and the Authority of Bukhara Region for Cultural Heritage. Also, thanks to the local support of the Center for Applied Arts "Ustoz Shogird", the Secondary School No.36 of Bukhara, the Regional Center for Restoration (ustos association), the Bukhara Engineering Technological Institute, and the Turin Polytechnic University in Tashkent (TTPU). Special thanks to the generous support provided by Arcadia Fund - a charitable fund of Lisbet Rausing & Peter Baldwin., the David Berg Foundation and Tianaderrah Foundation / Nellie and Robert Gipson, and the WMF. Katta rahmat city of Bukhara, its people, stakeholders and the Republic of Uzbekistan!

REFERENCES

Barazzetti, L., Previtali, M., Scaioni, M., 2020. Procedures for Condition Mapping Using 360° Images. *ISPRS International Journal of Geo-Information*, 9(1). doi.org/10.3390/ijgi9010034.

Barber, D.M., Dallas, R.W.A., Mills, J.P., 2006. Laser Scanning for Architectural Conservation. *Journal of Architectural Conservation*, 12(1), pp. 35–52. doi.org/10.1080/13556207.2006.10784959.

Carlisle, P.K., Avramides, I., Dalgity, A., Myers, D., 2014. The Arches Heritage Inventory and Management System: a standards-based approach to the management of cultural heritage information, *Access and Understanding – Networking in the Digital Era*, Dresden, Germany.

Clark, K., 2010. Informed Conservation: The Place of Research and Documentation in Preservation. *APT Bulletin*, 41(4), pp. 5–10.

Colomina, I., Molina, P., 2014. Unmanned aerial systems for photogrammetry and remote sensing: A review. *ISPRS Journal of Photogrammetry and Remote Sensing*, 92, pp. 79–97. doi.org/10.1016/j.isprsjprs.2014.02.013.

Fangi, G., 2010. La Fotogrammetria sferica. Una nuova tecnica per il rilievo dei vicini, *Archeomatica*, 1(2), pp. 6–10.

Feilden, B., 1987. *Between Two Earthquakes. Cultural Property in Seismic Zones*. Rome: ICCROM and the Getty Conservation Institute.

Gangler, A., Gaube, H., Petruccioli, A., 2004. *Bukhara, the eastern dome of Islam: urban development, urban space, architecture and population*. Stuttgart: Edition Axel Menges.

Goodman, D., Piro, S., 2013. *GPR Remote Sensing in Archaeology*. Springer Geotechnologies and the Environment.

Hernandez, M., 2002. Use of satellite imagery and geographical information systems to monitor world heritage. *Monitoring World Heritage*, 10, pp. 98–109.

Historic England, 2005. *Where in Earth are We? The Global Positioning (GPS) in archaeological field survey*. Swindon: Historic England. https://www.historicengland.org.uk/images-books/publications/where-on-earth-gnss-archaeological-field-survey/ (19 May 2023).

Historic England, 2009. *Measured and Drawn. Techniques and practice for the metric survey of historic buildings*. Swindon: Historic England. https://historicengland.org.uk/images-books/publications/measured-and-drawn/ (19 May 2023).

Historic England, 2011. *3D Laser Scanning for Heritage. Advice and guidance to users on laser scanning in archaeology and architecture*. Swindon: English Heritage Publishing. https://historicengland.org.uk/images-books/publications/3d-laser-scanning-heritage2/ (19 May 2023).

Historic England, 2016. *Drawing for Understanding Creating Interpretive Drawings of Historic Buildings*. Historic England. https://historicengland.org.uk/images-books/publications/drawing-for-understanding/ (19 May 2023).

ICOMOS, 1996. Principles for the recording of monuments, groups of buildings and sites. http://www.icomos.org/charters/archives-e.pdf (4 April 2023).

Kvamme, K.L., 2003. Geophysical Surveys as Landscape Archaeology. *American Antiquity*, 68(3), pp. 435–457. doi.org/10.2307/3557103.

Losier, L.-M., Pouliot, J., Fortin, M., 2007. 3D geometrical modeling of excavation units at the archaeological site of Tell 'Acharneh (Syria). *Journal of Archaeological Science*, 34(2), pp. 272–288. doi.org/10.1016/j.jas.2006.05.008.

Luhmann, T., 2004. A Historical Review on Panorama Imagery. *ISPRS Archives*. *Panoramic Photogrammetry Workshop*, Dresden: ISPRS. www.isprs.org/proceedings/XXXIV/5-W16/ (18 April 2023).

Myers, D., 2016. Finding efficiencies and pooling resources to improve federal, state, tribal, and local heritage inventory systems. *With a World of Heritage So Rich: Lessons from Across the Globe for U.S. Historic Preservation in its Second 50 years*. Washington, DC: US/ICOMOS; U.S. Advisory Council on Historic Preservation.

Raimondi, V. et al., 2009. The fluorescence lidar technique for the remote sensing of photoautotrophic biodeteriogens in the outdoor cultural heritage: A decade of in situ experiments. *14th International Biodeterioration and BiodegradationSymposium*, 63(7), pp. 823–835. doi.org/10.1016/j.ibiod.2009.03.006.

Remondino, F., 2011. Heritage Recording and 3D Modeling with Photogrammetry and 3D Scanning. *Remote Sensing*, 3(6), p. 1104.

Republic of Uzbekistan, 2001. *Law No. 269-II On the preservation and Utilization of Cultural Heritage Properties (30.04.2001)*. www.lex.uz/index.aspx (20 August 2022).

Republic of Uzbekistan, 2012. *Retrospective Statement of OutstandingUniversal Value Historic Centre of Bukhara*.

Rinaudo, F., Chiabrando, F., Lingua, A., Spanò, A., 2012. Archaeological Site Monitoring: UAV Photogrammetry Can Be an Answer, *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XXXIX-B5, pp. 583–588. doi.org/10.5194/isprsarchives-XXXIX-B5-583-2012.

Shum, H.-Y., Szeliski, R., 2000. Systems and Experiment Paper: Construction of Panoramic Image Mosaics with Global and Local Alignment. *International Journal of Computer Vision*, 36(2), pp. 101–130. doi.org/10.1023/A:1008195814169.

Tucci, G., Cini, D., Nobile, A., 2011. Effective 3d Digitization of Archaeological Artifacts for Interactive Virtual Museum. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. *ISPRS Trento 2011 Workshop*, Trento: ISPRS. http://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XXXVIII-5-W16/413/2011/isprsarchives-XXXVIII-5-W16-413-2011.pdf.

UNESCO, 1972a. *Convention Concerning the Protection of the World Cultural and Natural Heritage*. Paris: UNESCO.

UNESCO, 1972b. Recommendation Concerning the Protection, at National Level, of the Cultural and Natural Heritage. *Adopted by the General Conference of UNESCO at its seventeenth session*, Paris: UNESCO. http://portal.unesco.org/en/ev.php-URL_ID=13087&URL_DO=DO_TOPIC&URL_SECTION=201.html (2 September 2022).

UNESCO, 2011. *Recommendation on the Historic Urban Landscape*. UNESCO. http://whc.unesco.org/en/activities/638 (16 April 2023).

United Nations, 2015. Transforming our world: the 2030 Agenda for Sustainable Development - A/RES/70/1.

Vileikis, O., Escalante Carrillo, E., Allayarov, S., Feyzulayev A. 2017. Documentation for Preservation: Methodology and a GIS Database of Three World Heritage Cities in Uzbekistan', *ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci.*, IV-2/W2, pp. 311–318. doi.org/10.5194/isprs-annals-IV-2-W2-311-2017.

Vileikis, O., 2023. *Traditional Bukharian Houses and Mahallas. Guidelines for Conservation, Maintenance and Adaptive Reuse for residents and house owners of the Historic Centre of Bukhara*. Almaty: IICAS. https://drive.google.com/drive/folders/1YerRuA-zolrH0TFqJhuDxwAe6fqY1SEG?usp=share_link (19 May 2023).

Vileikis, O., Allayarov, S., 2014. Strengthening the role of community in the protection and management of the Historic Centre of Bukhara. *The Right to [World] Heritage. Conference Proceedings*. *The Right to [World] Heritage*, Cottbus-Senftenberg: IAWHP, pp. 207–218.

Vileikis, O., Allayarov, S., 2015. Enhancement of the implementation of the World Heritage convention through strengthening the protection and management mechanism in the historic centre of Bukhara. *Revisiting Kathmandu, Safeguarding Living Urban Heritage*. *Revisiting Kathmandu, Safeguarding Living Urban Heritage*, Kathmandu: UNESCO Office in Kathmandu, pp. 133–140.

Waldhäusl, P., Ogleby. C., Lerma, J. L., Georgopoulos, A., 2013. 3 x 3 rules for simple photogrammetric documentation of architecture CIPA. http://cipa.icomos.org/wp-content/uploads/2017/02/CIPA__3x3_rules__20131018.pdf (22 January 2023).

Walton, T., 2003. *Methods for monitoring the condition of historic places*. Wellington, N.Z. : Dept. of Conservation (Department of Conservation technical series ; 27.). http://www.doc.govt.nz/Publications/004~Science-and-Research/DOC-Technical-Series/PDF/docts27.pdf.

Williams, T., 2012. Unmanned Aerial Vehicle Photography: Exploring the Medieval City of Merv, on the Silk Roads of Central Asia. (15), pp. 74–88. doi.org/10.5334/ai.1522.

Williams, T., 2016. Silk Roads in the Kingdom of Bhutan and the Development of a National Heritage Inventory. Archaeology International, (19), p. 122=133. doi.org/10.5334/ai.1918.