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Virtual Reality-based Digitisation for Endangered Heritage Sites: Theoretical Framework and Application

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Abstract.
The longevity and survival of the ancient heritage sites, especially those in isolated locations, have been gradually threatened over the past decades, due to the globalisation and subsequent socio-cultural changes. As a result (of these changes), the future of these ancient sites remains uncertain. Therefore, this study aims to develop a digitally integrated framework using Virtual Reality, VR, technology to digitally document and create a simulated environment of the endangered heritage sites and present how new urban and construction developments may impact their presence. Hence, this study applied a qualitative longitudinal method to present the steps required to collect the data, develop a narrative-based framework and interactively present it via the VR project. The developed framework was, then, validated through the field data collection, across five years, from a very unique case study; Kandan, Iran as the last cone-shaped community settlement in the world, and its result was effectively displayed and exhibited at QUT IMPACT exhibition in Australia over a one-week period. The outcomes of this research could successfully raise awareness, encourage engagement and action and question the status quo of this heritage settlement through an interactive and engaging exhibition with the public.

Keywords. Digital heritage, digital technology, emerging technology, virtual reality, endangered heritage sites, endangered community, Kandovan

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1. Introduction & Background

According to UNESDOC (2003), digital heritage can be defined as one of the unique resources of human knowledge which contains cultural, scientific, technical and other types of information created using digital means. The term digital heritage can be also assigned to existing analogue resources which later on were converted into the digital form. Over the past few decades, an increasing danger has been threatening the cultural heritage around the world, in the form of natural disasters, war and armed conflicts, uncontrolled tourism and unrestrained urbanisation (UNESCO, 2020). Considering this trend, the improvement of documentation methods, mainly by combined effects gained by the synergy of methods of valuable architectural and cultural monuments, objects or sites, have become increasingly important (ICOMOS, 2020). These documentations can then become invaluable sources of information and contribution for recording and perceptual monitoring of these significant sites as a mean of support to archaeological, architectural, and other art-historical research (ICOMOS, 2020).

Concerning the digital methods of documentation and recent developments in the field of Virtual Reality (VR) technologies, various digital and virtual systems have been designed to document cultural heritage contents in the practice (Caggianese et al., 2018; Carrozzino & Bergamasco, 2010; Styliani et al., 2009). “Undoubtedly today, 3D technology (either virtual reality, augmented reality or mixed reality) helps us in the representation and interpretation of reality, present and past, so it has become a powerful ally of the social sciences and humanities, especially cultural heritage and archaeology” (Ioannides et al., 2017, p. 3). A significant amount of cultural digital heritage content has been developed and become accessible online on various websites and platforms. These digital contents allow interested visitors to visit the desired cultural and heritage sites without the risk of destructing and damaging them (Caggianese et al., 2018; Pletinckx et al., 2000; Wojciechowski et al., 2004).

Academically, there have been various methods developed for creating interacting and engaging heritage documentation frameworks and methods. One framework developed by Wang (2018) was the virtual exhibition of the museum and exhibition hall of Kangmeiyuanchao Zhanzheng (KMYC).

In this work, Wang (2018) provided verbal instructions for object orientation, including battle tours, gallery space, in addition to a three-dimensional interface. The technological framework of this virtual exhibition utilised photogrammetric techniques with Autodesk Maya and Unity game engine to create an interactive and stimulating visual environment, where viewers could walk through the spaces. Spatial modelling, animating and rendering were completed using Maya and Unity was then utilised to implement effects, scripts and shades. Wang (2018) also created narratives to ensure the content understanding by the users and assist further by navigating them through the virtual environment. JanusVR browser was used in the final stage as a three-dimensional interface, to engage users, particularly younger generations, with FireBoxRoom.

Another framework was developed by Güleç Özer et al. (2016) to represent Parion theatre, a significant ancient city situated in Biga, Turkey and dating back to 600 BC, using Augmented Reality (AR). In this work, Güleç Özer et al. (2016) utilised Multirama method in order to represent and document this important historical site digitally. This method "combines photogrammetric digital model and the solid modelling geometry either in the form of simply digital models or the co-existent of digital and 3D-printed models" (Güleç Özer et al., 2016, p. 188). The outcome of the photogrammetry model is 3D printed, in this method, and is synthesised through AR with the broader context of the site. The users can look at the scale model using the camera of a tablet computer, and are able to switch on and off various representations overlaid on the live video feed of the model (Güleç Özer et al., 2016; Nagakura & Sung, 2014; Nagakura et al., 2015). The method mainly consists of three stages, starting with documentation which is done using the photogrammetric method. The second stage includes data processing and modelling, focusing on revamping the 3D photogrammetric images. The final stage presents the 3D reconstruction of the cultural heritage via an AR application.

Miyamae (2016) developed a different method of digitising cultural heritage and artefact in particular. She focused on the problem of the digital archive data not being used enough for creating digital contents in the current format. Miyamae (2016), therefore, suggested the multi-class production framework "which uses digitised object data based on 3D scanning techniques, where reliable data from 3D measurement can be used more easily than before" (p.663). In this framework, the data are separated into three classes, based on the ways that the data will be utilised, to "high class," "middle class," and "low class". The high-class models are used for research purposes and as research resources. Middle-class models are majorly used in digital media, and it is being used by designers for creating digital media contents. Low-class data are more appropriate for general resources and are being used broadly for general purposes and freely available. Regarding the advantage of this method, Miyamae (2016, p. 666) argues that in this model "the reliable acquired data can control the quality of the end products because the data has an objective aspect and it is embedded on process according to this framework. Access privileges and copyright would be controlled if intermediate products were created clear in each section. This virtue would be of help to solve the problems of digital data protection and copyright issues.

Another popular methodology which has been applied frequently for digitising the richness of cultural heritage, in recent years, is Building Information Modelling for historic buildings (HBIM). In this method, a wide range of BIM software is utilised integrally in order to capture the existing building and transform it into the digital formatted contents. However, Banfi et al. (2019) argued that this framework is not suitable for the use of non-expert users, as it does not allow a simple reading of different types of information for them. Therefore, Banfi et al. (2019) suggested an innovative SCAN-to-BIM process based on novel Grades of Generation (GOG 9 and 10) to digitally document and represent complex cultural heritage. They have chosen the structure of the Basilica of Sant'Ambrogio in Milan as their case study. This framework consists of four steps, including data collection and 3D survey, model generation: from geometric primitives to complex HBIM, HBIM mapping: the proper connection of different information and data to the historical model and the development of layered web-interface based on 360° panoramas for historical, material and geometric analyses. This virtual tour, in the end, illustrated

different stages of the basilica's construction, using different panoramas for a simple reading by non-expert users.

However, in a different study, See et al. (2018) used a storytelling approach to create a room-scale VR cultural heritage product of the tomb of Sultan Hussein Shah, Malacca, Malaysia, in a public setting. In this method, the photogrammetry was used for data collection from the actual heritage site. Sensor-based head mount displays and workstation with high calibre graphic processing unit were further utilised to create the room-scale and realistic VR project.

The selected case study for this project is Kandovan village, situated in the central district of Osku County, in the East Azerbaijan Province of Iran. Kandovan covers an area of approximately 81,400 m2 or 8.14ha. This village is particularly unique due to its rare cone-shaped rock architecture (Figures 1 & 2). More importantly, Kandovan is the last surviving cone-shaped settlement in the world which has maintained its social life to date. The uniqueness of Kandovan was recognised by being registered on Iran's national heritage list. Its distinctiveness is likewise suggested by the United Nations Educational, Scientific, and Cultural Organisation (UNESCO) which reasoned that this type of architecture "… is one of the most original and powerful expressions of our ability to create a built environment with readily available resource" (Frank & Moukala, 2017, p. 1), the only other similar example of this rare type of architecture is found in the Goreme Valley, Cappadocia, Turkey (Hajirasouli & Banihashemi, 2020). "Despite their unique architectural similarities, these settlements offer a stark contrast; while the Kandovan settlement has sustained its social vitality for nearly 900 years, Goreme has ceased being a community and now functions mainly as a tourist attraction" (Hajirasouli & Banihashemi, 2020, p. 3). This signifies Kandovan as the last inhabited rock cone-shaped settlement in the world (Hajirasouli & Banihashemi, 2020; Hajirasouli et al., 2018; Hajirasouli et al., 2019). Despite its uniqueness, this settlement is relatively unknown to the western literature.

Kandovan was relatively untacked by the outside world until 2007, and the inhabitants enjoyed a mostly harmonious coexistence with nature. Hence, Kandovan was able to maintain its traditional architectural practices, culture and society for nearly nine centuries. However, Post 2007 and with the opening of a 5-star hotel, profound changes to the context of Kandovan have become evident. "Similar to the fate that has befallen numerous other heritage societies and architectures", Kandovan village is now being endangered and threatened by the advent of globalisation, in the form of tourism. This has resulted in dramatic changes to the traditional lifestyle of its locals and unique architectural fabric, changes that have become marked in the past two decades (Hajirasouli & Banihashemi, 2020; Hajirasouli et al., 2018; Hajirasouli et al., 2019).

2. Research aim

Given that the architectural context of Kandovan had experienced profound changes over the past decades and the gap in the literature regarding the documentation of this unique settlement (Ching, 2017; Hajirasouli & Banihashemi, 2020; Kempe, 1988; Oliver, 1987, 1997, 2007), one of the primary goals of this study is to introduce Kandovan as the last cone-shaped settlement in the world which has maintained its social life today, yet increasingly endangered by modern human activities. Using emerging technologies, this study also aims to improve recognition, enrich appreciation and raise awareness for Kandovan and propose the solution for the other threatened and endangered cultural heritages and sites around the globe.

Besides, the holistic analysis of the literature indicates that there is still limited research on the digitalised methods in collecting and recording visualised contents from cultural heritage sites and developing meaningful patterns of changes and transformations over time. This research, therefore, aimed to fill this gap and develop a digitally integrated framework of the longitudinal observations of the cultural and historic sites and present it via the interactive platform of VR technology. The results of this framework were further validated through the data collection and analysis from Kandovan. The VR-integrated platform prototype was developed through the longitudinal data collected from the site

and exhibited as a tour exhibition to the public in order to illustrate how this historical site has been transformed during the time, and new construction developments and urbanisations have endangered its historic presence.

3. Material and methods

3.1. Theoretical Framework Development

Architectural heritage and historical settlements are more difficult to exhibit in museums or exhibitions compared to other heritage artefacts, due to their size and complexity. However, according to Güleç Özer et al. (2016), even if it is possible to fit a building piece within an exhibition room or space, the presentation would not be comprehensive and entirely meaningful enough, due to the lack of the context. By separating a building from its surrounding natural and built environment, that piece loses its connections and ties to its context, and therefore, misses a lot of meaningful data and visual appearance. Thus, public cannot perceive the architecture comprehensively and experience it entirely if the context is not presented and included in the exhibition. Another significant factor which must be carefully considered while exhibiting a historical piece of architecture is the notion of time, and the changes that an architectural entity has gone through over time. Therefore, in presenting heritage architecture and sites, particularly those that have been damaged, it is essential to document and present the original form of the architecture as well as the altered one. “In a historic site, usually, it is meaningless to look at the ruins without knowing how the ruins previously looked” (Güleç Özer et al., 2016). This study focuses on developing a framework which puts users in a real-world experience of visiting heritage settlements while observing the changes that have happened over the time to these cultural heritages.

Hence, this section presents the steps to the development of this framework of exhibiting heritage settlements and longitudinal data-driven model using VR technology. The objective of this framework is to investigate the practicality of integrating qualitative longitudinal data to Rhinoceros 3D as a computer-aided design (CAD), and the architectural visualization software; Twinmotion, in the form of a workable and presentable procedure for creation of a VR-integrated digital heritage project. This framework focuses on observing endangered and threatened cultural heritages and communities over a period of time, to document and investigate the depth and pace of changes and alterations happening within such communities. Güleç Özer et al. (2016) classify the studies about the application of VR and heritage architecture into three main groups including the works running on tablets, which make it easy to perceive the models; works creating different perceptions using a VR interface in the physical environment, and works presenting an interactive information representation. The framework discussed in this research is classified in the third group.

The work here is carried out in three stages of documentation, data processing and modelling, implementation and content presentation. During the documentation stage, longitudinal data are collected using the case study method. In the second step, processing and modelling stage, tools are suggested for correcting the collected data including maps, images and photographs and creating a longitudinal data-driven model using Rhino and adding effects by Twinmotion for a realistic perception and sense of place. The simulated environment is then exhibited through VR technology using Oculus headset and Alien computer. The step-by-step development of this proposed framework is outlined in Figure 3.

The first step consists of data collection. Since this framework is focused on observing, documenting and describing the changes in a longer time span (Saldaña, 2003), the longitudinal qualitative approach is suggested to be an appropriate methodology. According to Corden and Millar (2007), although the meaning and definition of ‘long’ are not clear in this approach, and there are no set rules about the frequency of collecting the information, the minimum of two or more rounds of data collection are

required for a period of one year or longer. In addition, it is not necessary for the collected data to be identical, but it should be comparable (Corden & Millar, 2007; Derrington, 2019). A longitudinal qualitative study includes making research decisions that are concerned about the length of time, the reasoning for the specific methodology, as well as participants, and data gathering measures (Derrington, 2019). Similar to other qualitative studies, developing a longitudinal research protocol starts with the selection of data collection methods, such as interviews, observation, survey and instruments such as photography and document reviews. However, unlike other qualitative methods, longitudinal studies are built upon the frequency and the length of the data collection period, which is determined by the researcher. According to Saldaña (2003), the frequency of data collection can be defined as the waves of data collection, demonstrating the regularity in the data collection process.

In step 2, a longitudinal data-driven model is created by processing the collected qualitative data and preparing it for the final stage of implementation and exhibition. Data can be acquired using 3D scanning techniques or 2D scanning, surveying and measurement techniques. This choice depends on the nature of the study, available resources and context of the study, and it should be decided on a case-by-case basis (Miyamae, 2016). The required level of accuracy in the collected data is also dependent on the purpose of the project. In this regard, English Heritage (2007) notes that the level of required accuracy is typically related to object, its size and the purpose of the survey (Miyamae, 2016). Since this framework is designed for, and targeted at heritage settlements in larger scales, compared to one building or an artifact, 2D laser scanning, maps and orthogonal drawings appear to provide sufficient and convincing resolution. A longitudinal data-driven model is created using Rhino. In this method, all the acquired information is transferred into accurate 2D drawings using a compatible 2D software such as AutoCAD or Revit. The results of this process are then transferred to the Rhino for 3D modelling. Making 3D from 2D drawings can assist with making discoveries as one can better perceive the complex structure compared to the 2D information (Miyamae, 2016). The 3D Rhino model, then, can be transferred to Twinmotion for a realistic and high-quality simulation of the entire heritage settlement and its surrounding built and natural environment. During this process, various contextual factors such as texture, material, colour and the climatic condition can be added and modified to produce a desirable and realistic final product. The utilisation of the different tools is in light of the availability and ease of the applications for different parts of this research.

Step 3 consists of implementation and content presentation. According to Rahaman (2018) and Moscardo (1999), to increase the visitors' 'attracting power' and 'holding time', an exhibition should be novel and exciting. They believe that engaging and attractive exhibitions are more likely to result in user's mindfulness and consequently interpretation of the project. "An effective interpretation process can help to mediate the present experience of end-users with a new complex historic environment by involving them in the engendering of cognitive conflicts and challenging them to explore the environment; while allowing them to collaborate and share knowledge" (Rahaman, 2018, p. 216). Using mixed reality technologies (MR) such as AR and VR media through handheld devices can offer such an interaction and experience. This framework uses Oculus Rift S to situate the users in a real-world simulated environment to enhance the experiential qualities of the exhibition.

In addition to the attractiveness of the content presented, easy orientation and freedom of visit, further, affect the overall perception and experience of the exhibition (Copeland, 2006; Rahaman, 2018). To address this aspect, and since this proposed framework is based on the narratives which are constructed over a period of time to tell stories about changes in the heritage, ancient and historic communities and settlements, narratives and storytelling strategies are used. Posters, labels, panels and other means of visual narratives and presentations can be used to provide background information to the users prior to their virtual tour. A guide and storyteller can also guide users during their virtual tours. To facilitate the easy orientation for users while experiencing their tour in this simulated environment, Oculus Rift S touch controllers are used by the visitors to navigate and walk through the settlement freely.

3.2. Validation of the theoretical framework

To test this framework and explore the current conceptualisation of challenges and opportunities in employing extended reality tools for cultural preservation, this study adopts and employs this method in a real-world experiment. As mentioned by Zellmer-Bruhn et al. (2016, p. 400), "experiments isolate causal variables and enable a strong test of the robustness of theory: they provide convincing evidence for theories." Therefore, a digital heritage project named as "Bridging between the past and future using emerging technologies" was designed and implemented for this purpose. This project was exhibited at Queensland University of Technology's (QUT) Design Week IMPACT Exhibition in late 2019 in Queensland/ Australia. By implementing the framework through this exhibition, the validity, reliability, strength, weaknesses and gaps of this method can be identified, and further suggestions can be made. This research covers state of the art in extended reality tools that could be employed for the accessibility and analysis of cultural heritage. Hence, it emphasizes how extended reality tools can contribute to the preservation and conservation of cultural heritage. The entire process for designing this digital heritage project can be seen in Figure 4.

3.3. Research design implementation

To undertake this research, multiple qualitative data rounds were collected within the data interval of one round every two years and across five years, in total. Therefore, the frequency of this study is two years, and its time span is five years (Derrington, 2019; Yin, 2003). According to the framework suggested by Derrington (2019) and Yin (2003) and the nature of the study, this frequency and time span were considered to be sufficient to provide a clear understanding of the nature, depth and pace of the changes taking place in the architecture and community of Kandovan. The reliability of this method has been acknowledged and endorsed by various researchers (Corden & Millar, 2007; Derrington, 2019; Saldaña, 2003).

3.3.1. Step 1: Data collection and analysis

During the documentation stage, step 1, a longitudinal case study was selected as the method of data collection to gain meaningful insight and examine the nature and extent of changes in the architectural fabric of Kandovan (Creswell, 2013; Rallis & Rossman, 2012). Adding longitudinally in a five-year case study, three field trips were undertaken, to collect data including interview from the locals, documents, archival records and direct observations (Glesne, 2016; Yin, 2014). This data was collected over ten weeks during three field trips and during both summer and winter, so as to fully understand the social and cultural dynamics of this community and its built form. Undertaking case study research, in general, requires the utilisation of multiple sources of evidence (Stake, 1995; Yin, 2014) including direct observations, interviews, documents, archival records, participant observations, and physical artefacts (Yin, 1994). To generate the narrative for this study, apart from participant's observations, all of these sources of evidence were used to collect and analyse data. Prior to data collection and conducting field work, a research protocol was established to increase the reliability and accuracy of this study (see Table 1).

Direct observation was used to observe and record the day-to-day life and social structure of the inhabitants of Kandovan. During this process, the built environment and architecture of Kandovan were also surveyed using 2D laser scanner. Audio and video recording, survey drawings, sketches, notes and memos were used to document these aspects. The collected data were then coded and analysed so as to discover the emergent narrative. Semi-structured interview was additionally applied, using general questions on the specific topic regarding the changes in the built environment that this heritage village has gone through. In-depth interviews were undertaken from 14 participants out of 62 households, amounting to 22.5% of the households living in Kandovan at the time of the study. The interviews were selected using a theoretical or purposive strategy based on their aims, objectives as well as their relevance to the research question (T. Schwandt, 2007; T. A. Schwandt, 2007). Saturation occurred after

the fifth in-depth interview, as the interviewees were providing "no additional information about the attributes of any category" (Fellows, 2015, p. 100). Nevertheless, to ensure the reliability and accuracy of the collected data, interview samples were increased to 14. The interviewees were selected from both genders, 43% females and 57% males, and from various age groups ranging from young adults (18 years) to the elderly (70 years) inhabitants (Table 2).

Furthermore, travel brochures and four academic studies were collected as the documents for this study. These documents were only accessible through the National Library of Iran. Descriptive architectural information on Kandovan was also collected from government organisations and local entities. The archival records obtained for this study included materials collected from news organisations, public and governmental websites. Other files that were accessible by the public, including maps, Iranian census records, harts of the geography of Kandovan, and survey data from the University of Tabriz, Tabriz Islamic Art University, and Tabriz Municipality Research Centre were also collected. These collected documents were then translated, back translated to address the reliability and accuracy of the translation, transcribed, and analysed to draw the narrative for this study.

The unique cone-shaped architecture of Kandovan was the primary physical artefact studied and recorded for this study. Oliver (1997) believed that studying historical settlements are crucial since they can be a rich source of primary information about a given community's social, traditional, cultural and economic context. It should be considered that almost all surviving heritage and historical settlements which are still habitable have been altered over the years to continually respond to their residents' changing requirements. This has also been the case for Kandovan community and its cone-shaped and rock dwellings; although it has been continually habitable for 850 years, the architecture of this community has radically changed to respond to the residents' changing needs and requirements. Therefore, the cone-shaped rock settlement of Kandovan was documented using architectural drawings, surveys, sketches, and photographs.

The validity and reliability of the collected data was ensured by using various sources of evidence. As suggested by Yin (2009, p. 115), this method is one of the most significant strengths of case-study data collection, which allows the researcher "… to address a broader range of historical and behavioural issues …". Furthermore, and once all the required data was collected, factual consistency and robustness were established using evidence convergence from all five sources (Figure 5).

Once the collected data, including interview transcripts, documents, archival records, and field notes were transcribed, they were then thematically analysed. The method of data analysis is recognised as one of the most accepted data analysis techniques which improves the rigour of qualitative studies (Boyatzis, 1998; Braun & Clarke, 2006; Fereday & Muir-Cochrane, 2006; Miles & Huberman, 1994; Miles et al., 2013). The first step to be taken in this method was coding and categorising the collected data using Nvivo software and three coding methods of grammatical, elemental, and exploratory (Saldana, ~ 2015). The emerged codes were then regrouped to generate categories based on the similarity of their meanings and concepts in order to generate a comprehensive synthesis of the data (See Appendix A) (Allen, 2017; Given, 2008). These categories were then summarised and recategorized in order to identify prevailing themes. Two general themes of changing socio-cultural factors and changing architectural fabric were identified as the relevant objects of this thematic analysis, each theme was then sorted into further subcategories. Figure 4 visualises this data analysis process.

The findings have suggested that the architectural fabric of this heritage community has dramatically changed over the years and centuries. These alterations, however, have had a dramatic increase over the past two decades. The main reason identified for these changes, according to the result of data analysis, was the changes in the socio-cultural aspects of the residents. The results also indicated that architectural alterations to the context of Kandovan are manifested in two main areas. First, the spatial, formal, and functional characteristics of the traditional cone-shaped architecture have been greatly

altered. Second, a continuously growing wave of modern structures, development, and extensions to the cone-shaped buildings is evident. Figure 6 illustrates the narrative generation as the result of the data analysis process. Based on this result, the longitudinal storyline for the VR project was created. This VR storyline first illustrated the village in its intact condition when there was no man-made structure in the context of the community, using the fixed pre-design frames. Once the users experienced this community in its natural form, they were then guided into the next frames, where they could experience the extent and nature of changes happening to the village, in different stages, utilising the results of the data analysis. The last frame showed the village in its most recent condition, where the rapidly growing number of the contemporary and inharmonious constructions created a 'wall' which hid the ancient and unique fabric of this settlement behind it. This growing wave of new constructions in the village can be considered as the most significant danger and hazard that threatens the natural and ancient architectural fabric of Kandovan. Therefore, this study focuses on this area of change. However, focusing only on the exterior aspects of architecture is resulted in a creation of a medium resolution product. Further studies are required to focus on both internal and external qualities in order to create a more realistic experience for the users.

3.3.2. Step 2: Data Processing-longitudinal data-driven modelling

During the second step, the collected longitudinal data including maps, survey drawings, survey measurements and photographs which were collected using three sources of data, namely, documents, archival records, and direct observation were transformed into a digital 3D model and prepared for the virtual exhibition. Accurate 2D drawings were generated by Revit using the result of the 2D laser scanner, surveys, maps and orthogonal drawings. The outcome was then imported into Rhino for 3D modelling, as this software allowed the creation of the complex forms of cone-shaped dwellings and topography of Kandovan using polygon meshes, surfaces, and NURBS curves. The first step in modelling of Kandovan was to create the natural and original state of the settlement, before recent constructions and modifications. To do so, 'patch' command was used to create and develop the topography of the site, and 'loft' was used to recreate the cone-shaped structures and architecture of the settlement. River and the paths were modelled using 'project' command and then were split from the rest of the site. Once this stage was completed, the recent construction in the context of Kandovan was added in a different layer, using simple cubes to represent the architectural form and volume of these structures (Figure 7).

Twinmotion was considered to be appropriate to use for further curation of this project. This software allows a comparably speedy way to prototype in VR, review the project, and create an immersive experience. To be able to import this 3D model from Rhino into Twinmotion for further curation, the model was needed to be exported into a compatible file format to Twinmotion first. At the time of the study, importing a 3D model directly from Rhino to Twinmotion was not possible without losing any important 3D information. After several attempts with different file formats (STL, OBJ, FBX, COLLADA, 3DS), SketchUp file (SKP, Trimble Navigation) was selected as the format to export and import files between Rhino and Twinmotion. Once the 3D model was imported to Twinmotion, the result of data collection over the five years of the field study was used to add texture, colour, environmental and contextual features to the 3D model. Different seasons and the day-to-day life within those seasons were also simulated to generate a realistic perception and experience for the users (Figure 8). The outcome of this stage was rendered as pictures, videos, QR Code, and a 360 Degree video.

3.3.3. Step 3: Implementation and content presentation

The outcomes of the step 2 were presented and exhibited in QUT's IMPACT exhibition during late 2019, in the Step 3. Narrative strategies were used to create better content understanding and navigating through the simulated environment. A narrative in the form of a poster provided background information to the users, prior to their VR tour. A 360 degrees video was repeatedly playing on a

separate screen in the exhibition space. A QR code was also provided and exhibited within the space, to give a free access to this 360-experience to the visitors. Oculus Rift S headset, touch controllers and Alienware Laptop were used to present this VR to the visitors. Four fixed frames and sceneries were designed in Twinmotion, in the form of a narrative to walk the users through Kandovan and tell the story of changes that happened in this settlement, starting from the original state and ending with the current status quo of this settlement (Figure 9). Each of these captured frames allowed users to move and experience the settlement, freely, as long as they desired. The visitors were instructed about the project and how to use the controllers before their VR tour. A designer was always present in the scene to guide the visitors and provide comments and narrative as requested by the users. As an immersive VR experience and 360 degrees, YouTube video[1] was designed and based on the employed framework, the outcome of this exhibition can be considered as both low- and middle-class digital 3D models.

4. Results and discussion

Over the last few decades, cultural heritage, landscapes and communities have been increasingly endangered by a wide variety of factors, including unrestrained tourist development, depopulation, uncontrolled urbanisation, intensifying disaster risks and climate change (UNESCO, 2019, 2020). In many cases, these invaluable cultural sites have become degraded before their documentation and recognition can be recorded. In the last decade's several digital innovations, VR technologies, have been designed to digitally document and present cultural contents to remote visitors in an attractive manner. This study, however, introduced a new holistic method using VR technologies to digitally represent the longitudinal alterations in a heritage site. The aims and contribution of this VR project are outlined below.

This project was aimed to simulate a real-world and realistic experience and perception for the users by representing the contextual factors and conditions of Kandovan. Some of the simulated contextual factors in this experiment include various climatic conditions in different seasons, curating the materiality of different types of architecture within the context of the study and representing the animal species existing in that region. This VR project was also applied to inform and educate the users about the level and nature of alterations and changes which have been taken place in the architectural fabric of Kandovan. This aim was achieved by placing the users in the simulated environment of original and modified Kandovan. Original Kandovan refers back to the village in its original and natural status. In this interface, users experienced the very early stages of settlement in the village, where the local residents were only using the cone-shaped rock as their dwellings. Modified Kandovan, however, refers to the village in its current situation and with the recent unauthorised constructions. Hence, this process was resulted in a better and deeper perception and understanding of the reality of the changes, experienced by the architectural context of the settlement. Since the natural, historical and heritage characteristics of Kandovan's vernacular architecture had been marginalised, those structures that remained had likewise deteriorated. Such a simulation will raise awareness, provoke users and governments ultimately to challenge and question the status quo of such communities. This will further call for actions to provide a resilient and sustainable future for the case and other endangered cultural heritage and communities around the globe.

The contribution of this research can be expanded on three main criteria:

1. A contribution to the body of knowledge by introducing Kandovan as the last cone-shaped settlement in the world using emerging technologies, VR in particular.

[1] https://www.youtube.com/watch?v=e3mojPo0cLY

2. A contribution to the field of endangered heritage sites and built environment by improving the recognition and raising awareness for Kandovan and other endangered communities and cultural sites Introducing
3. A new holistic method and theoretical framework, using VR technologies to digitally represent the longitudinal alterations in a heritage site and examining the validity and reliability of this framework by testing it.

This VR project also enables the interested visitors and users to experience and enjoy this rare and unique community without causing further degradation of the socio-cultural and architectural fabric, caused by uncontrolled mass-tourism. It also contributes to the presentation and promotion of Iran's cultural heritage and conservation of its ancient architecture in light of the implementation of this framework.

In the exhibition of this digital heritage, the notion of virtuality was related to observing conditions in tangible and physical spaces and defined the character of the user's aesthetic experience presented through technological conditions (Dziekan, 2011). The concept of virtuality also functions, as claimed by Thwaites et al. (2019), on a subconscious and intuitive level of audience's engagement utilising various methods that showcased the interdependence among the space, objects and perceptual process of interceded digital heritage contents.

Some of the primary key learning of this exhibition was gathered from post-presentation discussions with the audiences and visitors. These post-presentation discussions happened in a face-to-face and open-ended discussion manner. As this project was exhibited in QUT IMPACT exhibition, focusing on the topic of 'change by design', the main audience cohort of this project were about 250 academics, researchers, scholars, PhD students, industry partners, governmental authorities as well as general public. The overall result of this exhibition confirmed that this digital heritage was well-received by the visitors since a comparably large number of people was eager to experience and interact with this VR project. The questions asked by the visitors during this post-presentation stage indicated their curiosity and concern about the survival of Kandovan and other endangered ancient and heritage communities. This can be considered as a proof of the concept discussed by Thwaites et al. (2019) that virtuality operates on an intuitive level. Most of the visitors argued that the contextual aspects and special effects added to this VR enhanced the sense of place and resulted in an increased level of sympathy and empathy towards this community.

It was argued that the unfolding narrative of this project which was happening prior to the exhibition and during it, increased the engagement of the visitors within the project (See Appendix A). Another significant point discussed by the users, which was found effective in their overall experience, was the freedom of movement through the project in physical, conceptual and time dimensions. Users could freely explore or even construct their own narratives by moving through each of the five designed frames. This project was also reshared and retweeted on social media, such as Twitter, encouraging the debate and discussion amongst researchers and scholars as well as the public awareness about the sustainability of Kandovan and other endangered communities.

In the end, it can be argued that the aim of this VR project was achieved, since it introduced a rare and unique settlement to the visitors, unknown to the western literature up until that point. It also provided them with an understanding of the consequences of the fast-approaching globalisation to Kandovan and other invaluable communities and settlements in various parts of the world, by endangering their longevity. It raised awareness and provoked action to be taken for the preservation of cultural heritage.

5. Conclusion

This project applied VR technology to create a simulated environment of the last cone-shaped community in the world, Kandovan settlement. It places the users inside the real-world context and environment of this settlement, to experience the level of changes that this community has gone through, over the last two decades. This project aimed to raise awareness about the heritage communities which their longevity and resilience are endangered by human activities such as war, local conflicts, and tourism with the approach of globalisation. Therefore, it aims to inspire a future sustainable environment for this community, including their social, economic, and environmental aspects, through promoting sustainable development, using emerging technologies.

Nevertheless, the study findings should be considered with caution due to a number of limitations. That is, only architectural fabrics of the heritage site were applied in the digital heritage transformation framework and VR processes. While other aspects of the heritage site such as urban forms and civil structures can be included in the data collection and development as well. Furthermore, the project was exhibited among in one academic exhibition however, it can be exhibited towards larger audience groups including various roles and entities and higher publicity in order to deliver broad-based outcomes.

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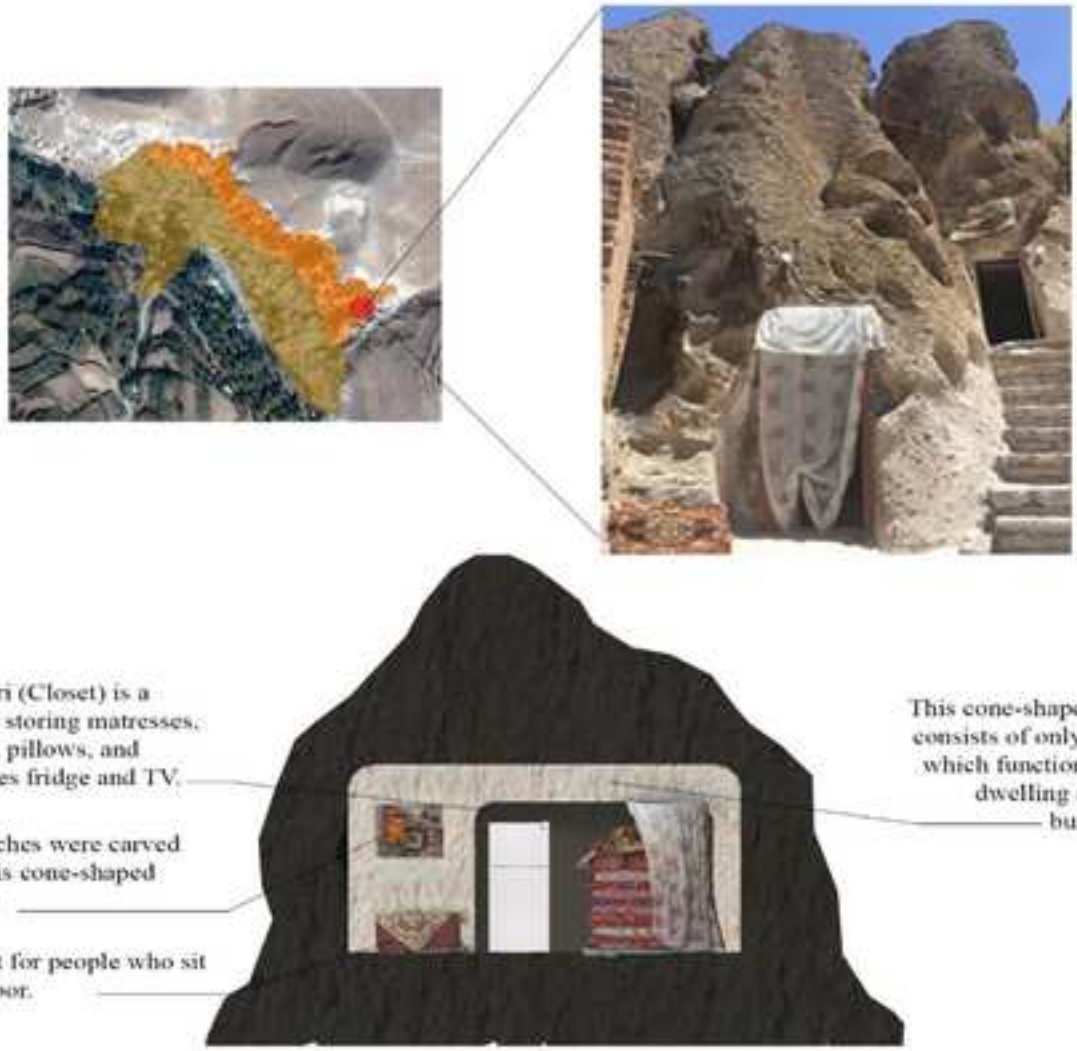

Figure 3. The step-by-step development of the proposed framework for digitizing cultural heritage.

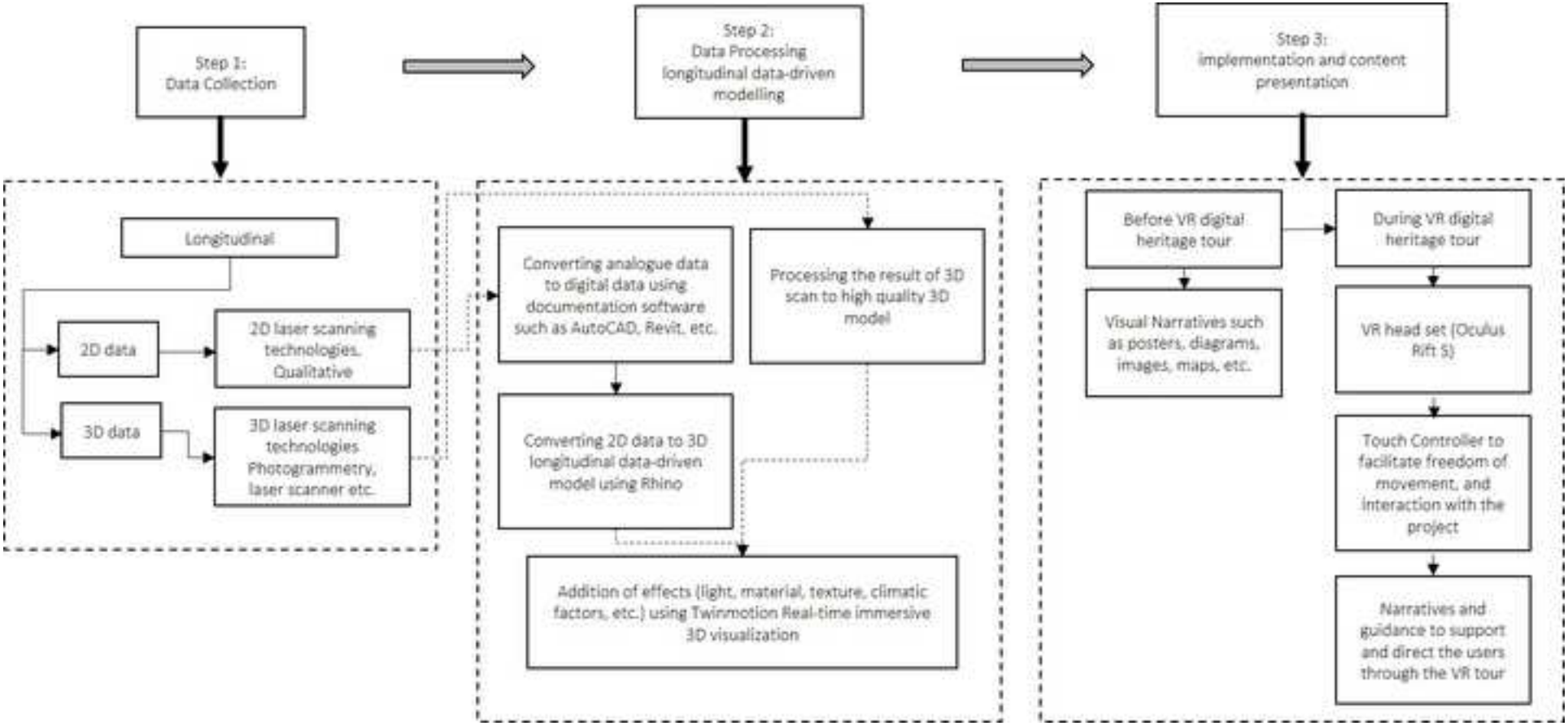

Figure 4. The step-by-step process of designing and exhibiting Kandovan's digital heritage project.

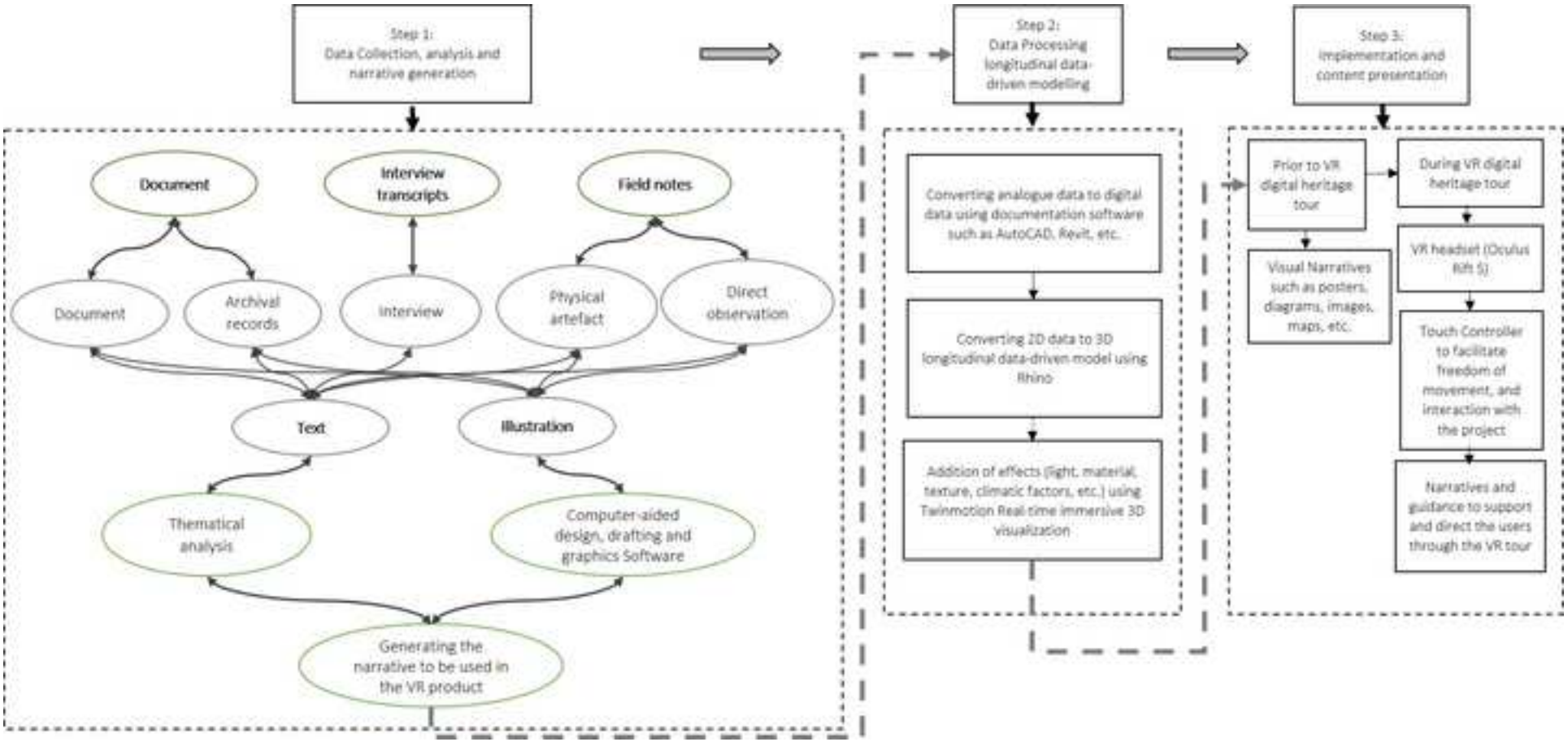

Figure 5. Convergence of evidence. Adapted from “Case study research: design and methods (Vol. 5.),” by R. K. Yin, 2003, Thousand Oaks, Calif: Sage, p. 100.

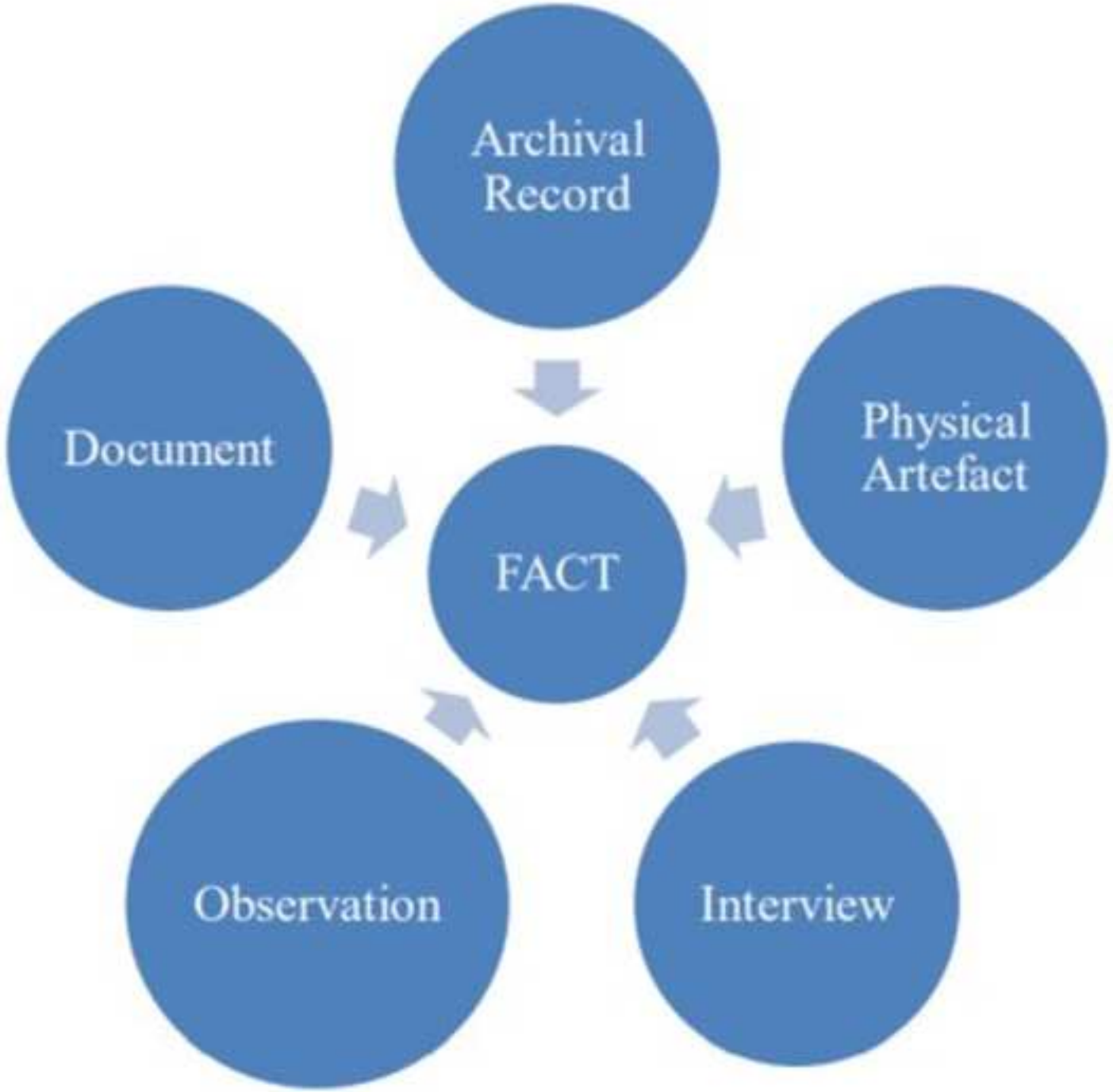

Figure 6.The generated narrative from the result of data analysis. Click here to access/download;Figure;Figure 6.jpg

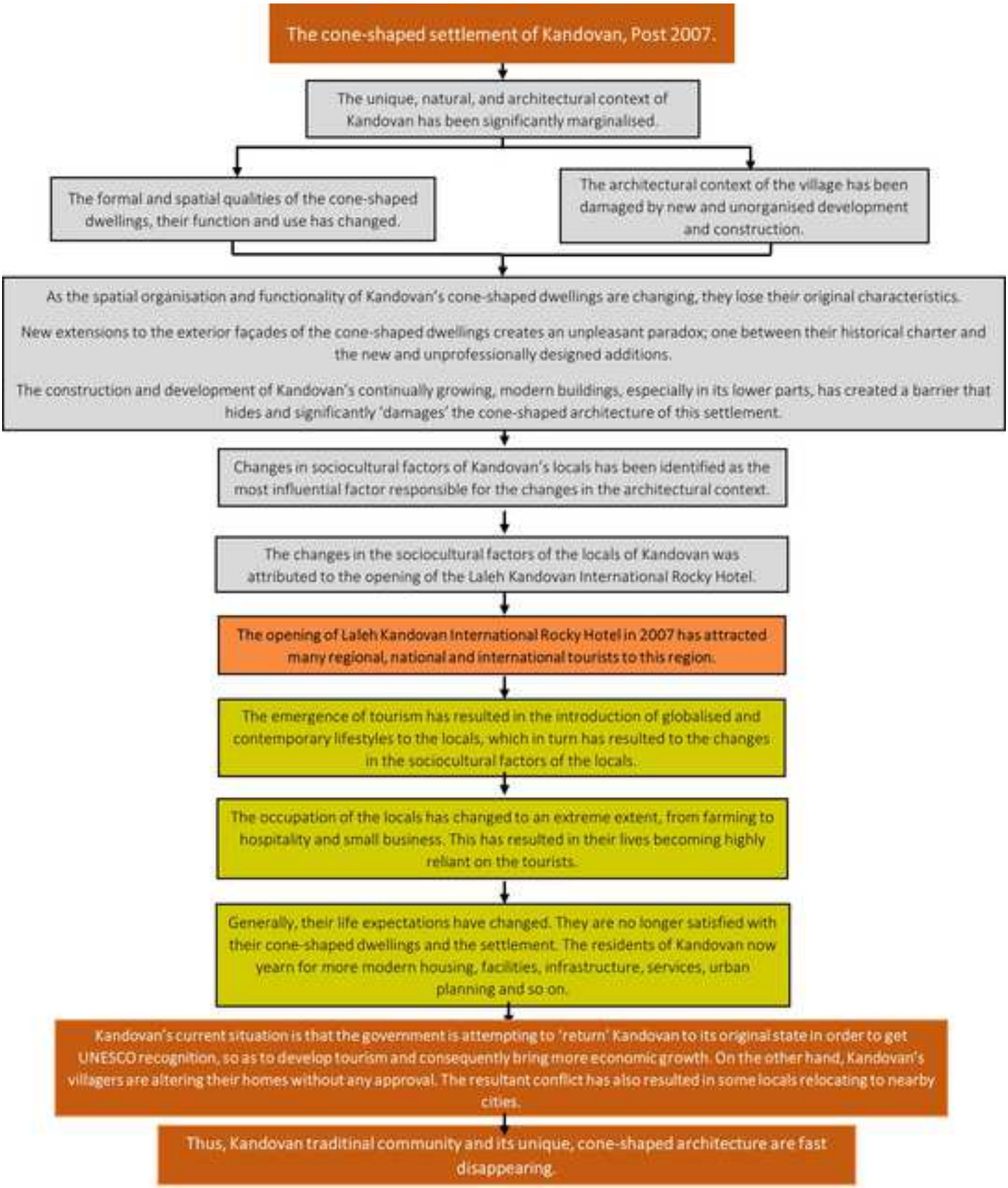

Figure 7. 3D modelling process in Rhino.

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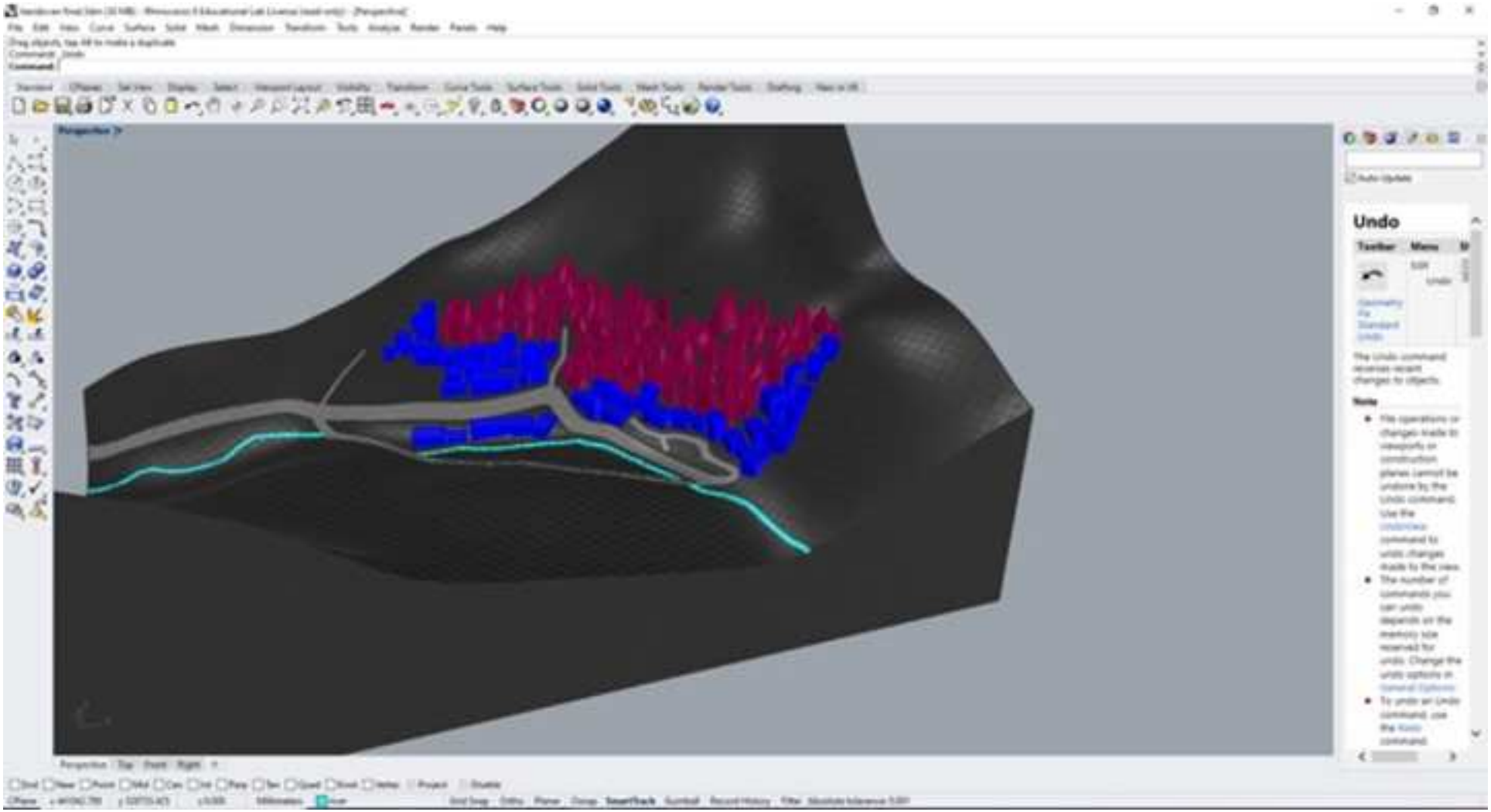

Figure 8.The outcome depicted in Twinmotion environment and the 3D video of Kandovan.

Click here to access/download;Figure;Figure 8.jpg

Figure 9. Four designed frames of narrative in Twinmotion.

Click here to access/download;Figure;Figure 9.jpg

Table 1. The research protocols.

Field procedure

Sources of data to be collected, the places to visit, the people to be contacted, and the events and phenomena to be observed:

- The sources of data to be collected: direct observations, interviews, documents, archival records and physical artefacts.
- Fieldwork will be conducted in the general vicinity of Kandovan and at the National Library of Iran, University of Tabriz, Tabriz Islamic Art University, Tabriz Municipality Research Centre, Cultural Heritage, Handicraft and Tourism Organisation of East Azerbaijan, and the Cultural Heritage, Handicraft and Tourism Organisation of East Azerbaijan.
- In Kandovan, people to be contacted and interviewed are primarily long-term residents and the management of Laleh Kandovan International Hotel. Likewise local, regional and national Public servants might also be interviewed but this is dependent on their consent.
- The events to be observed in Kandovan are the day-to-day activities of locals.

Expected preparation prior to the fieldwork

- Obtaining ethical clearance for the fieldwork
- Preparing a list of semi-structured questions
- Preparing audio and video recording tool/s, personal computer, etc.
- Preparing measurement and drawing tools
- Contacting potential interviewees
- Planning travel and accommodation in Iran, Tehran, Tabriz, Oskou and Kandovan.

Table 2. Demographic details of the participants. Adapted from (Hajirasouli & Banihashemi, 2020).

Participants	Age	Gender	Locality	Occupation
No.1	43	Male	Local	Former Farmer - Small Business Owner at the Time of Study
No.2	44	Male	Non-local	Hotel Manager
No.3	35	Male	Non-local	Hotel Manager
No.4	24	Female	Local	Small Business Owner
No.5	29	Female	Local	Small Business Owner
No.6	28	Female	Local	Small Business Owner
No.7	18	Female	Local	Small Business Owner
No.8	60	Male	Local	Former Farmer - Small Business Owner
No.9	45	Male	Non-local	Hotel Manager
No.10	30	Female	Local	Small Business Owner
No.11	70	Female	Local	Former Farmer - Small Business Owner at the Time of Study
No.12	31	Male	Local	Former Farmer - Hotel Staff at Time of Study
No.13	32	Male	Local	Former Farmer - Small Business Owner at the Time of Study
No.14	23	Male	Local	Small Business Owner