Original Research Article

Documentation of the Changes of Shahrestan, the Oldest Bridge in Isfahan, Based on Descriptive and Visual Documents, Using Augmented Reality Technology

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Abstract

Augmented reality technology (AR) has provided many opportunities for researchers. AR has been used to reconstruct historical buildings that have been destroyed or have lost their original forms. Shahrestan Bridge, the oldest bridge in Isfahan, Iran, has had substantial changes in its form and function over the years. AR can reveal the original form of this building to visitors. This method can also acquaint visitors with the changes in the bridge over time. Purpose of the study: This study reveals the original form and function of this bridge by analyzing the available descriptive and visual historical documents for the first time. Also, identifying the locations of the main buildings around the bridge have been considered in this study. This article is based on library research and field study. First, descriptive documents were studied and visual documents were scrutinized, and then the 3D model was recreated based on the documents. We have represented the original form of the bridge and designed an AR apparatus for displaying it to the general public on site. We have also identified the location of the architecture surrounding the bridge. Our study revealed that the arched spans of the bridge have gone through very few changes while the customs house and buildings near it have gone through major changes.

Keywords: *Augmented Reality, Representation, Documentation, Shahrestan Bridge, Descriptive and Visual Documents.*

Introduction and Problem statement

Shahrestan bridge is the oldest bridge on the river of Zayandeh-rood. This bridge is located in Jey County, the first county that was developed in Isfahan. The form and function of most of the bridges in Isfahan have changed over time. Descriptive and visual historical documents are excellent tools for characterizing such changes. Without understanding the changes in the form of the historical buildings, the restoration projects may result in different forms and functions from the original building. Unfortunately, the Shahrestan bridge has been incorrectly restored in certain parts over the last century and, consequently, has lost its original form.

In this study, we have taken advantage of descriptive and visual documents to characterize the changes in the form of the Shahrestan bridge over time. Then,

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using AR technology, we have represented the original appearance of the bridge to be displayed to visitors on site. This AR display creates a better representation of different facets of the bridge and helps the visitors to visualize its original form. The findings of this study can be used as a guide to the proper restoration of the Shahrestan bridge in the future.

In addition, understanding the original form of this bridge can help to determine the changes that the bridge went through the time.

This article seeks to answer the following questions: How do descriptive and visual documents represent the changes in the Sharestan Bridge?

How does augmented reality help the representation and better understanding of the original form of the bridge for visitors?

Theoretical foundation and literature review

Analysis of related documents revealed that researchers have studied the Shahretan Bridge and its surroundings in several specific areas. Shahrestan Bridge and its surrounding area have not been extensively studied in the past. Some historians who have studied historical events in Jay County have also mentioned the Shahrestan Bridge (Gilanentz, 1959; Lockhart, 2009). Early historical geography books have provided an overall description of Jay County and its buildings in addition to detailed historical events (Hoeltzer, 1975; Curzon, 2016; Flandin & Coste, 1854). However, the focus of these books has mainly been on the important events and figures in Jay County rather than the forms and spaces of the buildings in it. In some studies, descriptive documents that demonstrate the original form of a building are represented visually and compared with other documents (Homayooni & Valibeig, 2021). Other descriptive documents have only mentioned the name of the Shahrestan Bridge or described its functions (Tavernier, 1678). For the first time in our study, we are going to

describe the original form of the Shahrestan Bridge and the changes it has gone through. Furthermore, in previous studies, researchers represented the original form of other historical buildings based on descriptive and visual documents. In these studies, destroyed parts of the buildings were modeled based on old documents, which paved the way for this research (Valibeig & Soleimani Moghaddam, 2018; Valibeig & Kourangi, 2019). Accordingly, in this research, comparative studies between different documents have revealed the original form of buildings over time.

The original idea for AR was developed by Thomas Cadell in 1990 (Corps, 2017). AR adds virtual images to the real world around the user. This image interacts directly or indirectly with the user, which is a remarkable feature of this technology. The main difference between AR and virtual reality (VR) is that in AR some of the information that the user receives exists in the physical world. This virtual information is provided to complement or enhance the real world (Flavián, Ibáñez-Sánchez, & Orús, 2019). This makes it possible to compare the virtual image with the surrounding reality at the same time. In recent years, many researchers have applied AR in their studies that involve representing tangible heritage. Research in this field shows the significant impact of this technology on attracting tourists to sites and monuments (Merchán, Merchán & Pérez, 2021; Cranmer et al., 2020; Graziano & Privitera, 2020). The unique potential of this technology has also attracted tourists to historic sites that have been less visited in the past (Merchán et al., 2021). Also, some researchers have used AR to represent the original form of a building that has been destroyed or changed (Liestøl & Hadjidaki, 2020). This method acquaints the visitor with the history of cultural heritage (Jung et al. 2020). Education is another application of this technology. Research has shown that AR has a significant impact on students' perceptions of cultural heritage

(Redweik et al., 2017; Petrucco & Agostini, 2016). A variety of methods and devices can be used in AR technology. However, the use of smartphone systems has been more welcomed due to better accessibility (Wang, Xiang & Fesenmaier, 2016). Thus, the success of AR in recent years is directly related to the expansion of smartphone use (Han, Tom Dieck & Jung, 2019).

Methodology

Most of this research is based on historical research and analysis of historical sources. This research is qualitative and the method is descriptive-analytical. Analysis of historical documents including descriptive and visual documents and field studies and also, comparative studies of documents with each other and with the current situation were done.

Visual documents used in this paper include history books and narratives, travelogues, historical geography books, and other documents providing descriptions of the Shahrestan Bridge and its surrounding environment. We also studied visual documents, such as pictures, sketches, aerial photos, and maps. We determined changes in the form of the Shahrestan Bridge over time by analyzing these documents and documented those changes using AutoCAD software. Finally, using AR technology, we represented the original form of the Shahrestan Bridge for displaying on the site.

Discussion

The process of physical changes in the Shahrestan Bridge is discussed and analyzed separately under two general headlines: descriptive documents and visual documents. The process of changing the main buildings around the bridge is also discussed in this section.

• Descriptive documents

We have divided the findings of this project into two general categories of descriptive and visual documents. We sorted the descriptive documents chronologically by the historians or the authors of travelogues. These documents are from the period between the 11th and the 21st century (Table 1). Most descriptive documents have briefly described the form of the bridge (Gres, 1973; Chardin, 1927; Ouseley, 2004; Dieulafoy, 1887) or its location in the city (Tavernier, 1678; Mostofi, 1996). There is a very limited number of documents that have described the changes in the form of the bridge over time (Honarfar, 1956; Javaher Kalam, 1969; Richards, 1931; Blunt, 1966). Some documents have mentioned historical events that took place in the area where the bridge is located. One of the most important events in which the name of the Shahrestan Bridge is seen and it is linked with the killing of the Arab khalifa of Isfahan, Al-Rashid, who is buried near the Shahrestan Bridge (Emad al-Din Katib, 2004; Kashani, 1977). Another event is the Afghans' attack on Isfahan, which overthrew the Safavid Empire. The war between Safavid and Afghans took place close to the Shahrestan Bridge (Gilanentz, 1959; Lockhart, 2009; Mostofi, 1996). Other documents have also discussed buildings that were once located near the Shahrestan bridge (Mafarrukhi, 2006; Asef, 1969) (Table 1).

Studying these documents revealed that this bridge was established during the Sasanian Empire (Dieulafoy, 1887; Blunt, 1966). The bridge was then completed and restored during the Saljuqi Empire (Jafari Zand, 2002). In the Safavi period, the Shahrestan Bridge was abandoned and its structure was damaged considerably (Chardin, 1927; Tavernier, 1678). Later, at the end of the Safavi period, the attack of Afghans on Jey County led to even more damage to the bridge (Gilanentz, 1959; Lockhart, 2009). These damages continued during the Qajar Empire due to the neglect and incompetence of local governors. Major restoration of the Shahrestan bridge started in the Pahlavi period. According to the descriptive documents,

Table 1. Analysis of the available descriptive documents mentioning the Shahrestan Bridge. Source: Authors.

Name	Date	Important point
Mafarrukhi	1087	Next to the Shahrestan Bridge is a palace called Green Palace (Mafrukhi, 2006).
John Chardin	1673-1677	Shahrestan village was located near the Zayanderood river, which had a long and narrow bridge over it. Shahrestan Bridge is a route to the south (Chardin, 1927).
Yvonne Gres	1708	The top of the Shahrestan Bridge looks like the back of a fish (Gres, 1973).
Petros di Sarkis Gilanentz	1722	Mahmoud Afghan fought for eight days near the Shahrestan Village, north of a bridge with the same name, but made no progress (Gilanentz, 1959).
Jean-Baptiste Tavernier	1724	Shahrestan Bridge is a route for those who go from Isfahan to Shiraz (Tavernier, 1678).
Mohammad Mohsen Mostofi	1738	Shahrestan was a village in the east of Isfahan, and there was a bridge with the same name near this village on the Zayandehrood River (Mostofi, 1996).
Mohammad Hashem Asef	1787	On one side of the Shahrestan Bridge, they built the forty-column palace (Asef, 1969).
William Ouseley	1811-1825	The Shahrestan bridge is not very long and has only ten or twelve openings (Ouseley, 2004).
Eugene Flandin	1840	Shahrestan bridge connects the northern and southern parts of the city (Flandin, 1854).
Ernst Holtzer	1870	The Sharestan Bridge is about half a mile from the other three bridges. It was built in a very suitable location, although it was not well maintained (Hoeltzer, 1975).
Wilfrid Blunt	1974	The stone foundations of the Shahrestan Bridge are probably Sassanid. In the upper parts of the bridge, bricks blogged in the Seljuk period. The design of the bridge is not quite neat and is now about to ruins. Customs house still stands in the northern part of the bridge (Blunt, 1966).
Jane Dieulafoy	1881	Shahrestan bridge has stone columns and the upper part and its vault have been made of bricks someday after the initial foundation (Dieulafoy, 1887).
Lawrence Lockhart	1890	Mahmoud Afghan sent a number of his men on 23 March 1724 to attack the Shahrestan Bridge (Lockhart, 2009).
Arbab Isfahani	1891	The Shahrestan is the ninth bridge of Isfahan, which is on the eastern side of the city. The bridge was named after a village near the city. The builder is unknown (Isfahani, 1989).
George Nathaniel Curzon	1892	The Shahrestan Bridge has a short distance from the new city, which leads to a village with the same name (Curzon, 2016).
Guy Le Strange	1905	Shahrestan Bridge has built near the old castle of the city (Guy, 2011).
Mass'oud Mirza Zell-e Soltan	1910	Al-Rashed was killed in the north of the bridge, and a tomb was built for him next to the bridge (Zell Al-Soltan, 1983).
Frederick Charles Richards	1930	Shahrestan Bridge is badly damaged and it is dangerous to cross at night (Richards, 1931).
Ali Javaher Kalam	1951	The Shahrestan Bridge has eleven vaults made of stone, plaster, and brick. The vaults of the bridge will soon be collapsed. It is not possible to cross the bridge because there are large and small holes in the middle of it (Javaher Kalam, 1969).
Lotfollah Honarfar	1951	The Shahrestan Bridge has made of stone and brick. In the past, it was called Jey Bridge or Saruye Bridge. During the Diliman and Seljuk periods, the Shahrestan Bridge was the only significant bridge in Isfahan. Over time, the Shahrestan Bridge was restored and changed (Honarfar, 1956).
Abbas Beheshtian	1961	Shahrestan Bridge is now collapsing due to a lack of maintenance and restoration (Beheshtian, 1964).
Abolghasem Rafei Mehrabadi	1971	Shahrestan is one of the ancient bridges located four kilometers east of Isfahan (Rafei Mehrabadi, 1973).
Ali Asghar Mirfatah	1976	The customs house in the northern part of the Shahrestan Bridge seems to be less old than the bridge (Mirfatah, 2016).

due to the flooding, the arched span at the south end of the bridge was destroyed during the Pahlavi period. At around the same time, the destructive parts of the bridge were restored by Mohammad Kazerooni1 (Rajae, 2014). Isfahan was expanded and developed along the north-south line during the first Pahlavi king, Reza Shah. Therefore, the Shahrestan Bridge, which was located on the east side of Isfahan, lost its function as a central location in the city. At that time, heavy vehicles were not allowed to pass through the other newer bridges in Isfahan; therefore, they used the Shahrestan Bridge to cross the Zayandehrood river. After Reza Shah, during the second part of the Pahlavi period (1978 A.D) all vehicles were banned from crossing the Shahrestan Bridge (Mirfatah, 2016) (Table 2).

• **Visual documents**
Visual documents can be divided into two general categories. The first category includes 2D images of the bridge and its surroundings, such as architectural blueprints and aerial photos, and maps (Table 4). The second category includes photos taken at the ground level and sketches drawn of the bridge (Table 5).

• **Aerial photos and maps**
Isfahan was once called Jay, which later changed to Shahrestan (Yaqut al-Hamawi, 1983; Abu al-Fida 1978). Jay became a popular place to live during the Islamic period (Abu Nu'aim, 1990). Aerial photos and sketched maps show five significant historical buildings in Jay County. These buildings include the Shahrestan Bridge, the Shahrestan mosque and minaret, the tomb of Al-Rashed, and the town's wall. The Sharestan mosque and minaret and the town's wall are now completely demolished (Table 2). Previous studies that have attempted to locate the mentioned buildings or draw their maps have had some flaws due to incomplete descriptive and visual documents (Mirfatah, 2016). In this project, we studied and analyzed all available descriptive and visual documents and represented the location plan of Jay's five historical buildings with more accuracy (Fig. 1).

To determine the location of the Sharestan mosque and minaret and the town's rampart, we first collected all photos and aerial maps of Jay. Since the Shahrestan Bridge and the tomb of Al-Rashed remain, they were used to locate the other lost

Table 2. Review of the descriptive documents mentioning buildings in Jay. Source: Authors.

|	Shahrestan Bridge	Jey County	Jey Mosque	Al-Rashed Mausoleum	Jey Minaret
Sasanian Empire	The foundation of the bridge was built	The first house was built in Jay	-	-	-
Arab Invasion	The bridge was completed	Development of Jay county	The mosque was built (in 864 A.D.)	-	-
Seljuk Empire	Some parts of the bridge were restored	-	-	The tomb was built (1137 A.D.)	The minaret was built
Safavid Empire	Damage was caused to the upper parts of the bridge	The city was abandoned	The mosque was destroyed and turned into a cemetery	-	-
Qajar Empire	The bridge was badly maintained	The city was destroyed	-	The tomb was restored (1898 A.D.)	The minaret was ruined (1915 A.D.)
Pahlavi Empire	The bridge collapsed in some parts	-	-	The tomb was repaired by an archaeologist (1952 A.D.)	-
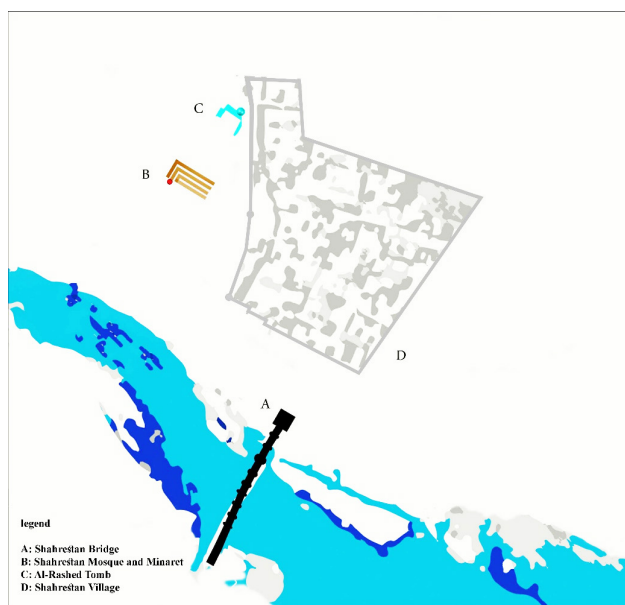
Fig. 1. Final location of the five main buildings in Shahrestan based on our analysis of all of the above documents. Source: Authors.

buildings. We used AutoCAD to model the exact location of these two buildings as references in a 3D setting. Then, we modeled the other three buildings in their location. By repeating this process in every photo and aerial map, we determined the site plan in a more accurate manner (Table 3).

Analyzing these documents also revealed that some of the old sketched maps and documents are inaccurate (Table 4). The location of the Shahrestan minaret in Chiricov's map is incorrect although this minaret was not yet demolished during the sketching of this map (Table 4 Cell 1).

• Pictures and Sketches

The Shahrestan Bridge has had many structural changes since it was first built mainly due to improper uses and being desolate during certain periods.

The oldest visual document remaining from the Shahrestan Bridge is a sketch from 1720 A.D. which shows the east side of the bridge (Table 5, A). In this sketch, the customs house is shown to have two floors. Along the customs house, other buildings are also sketched. There are 10 arched spans in this sketch instead of 11 which has two possible explanations. The first explanation is an error in drawing the correct
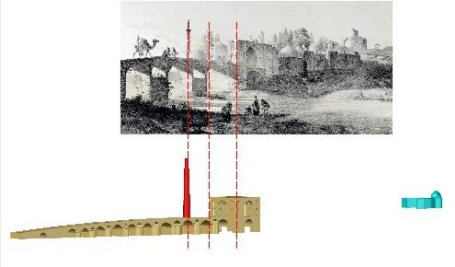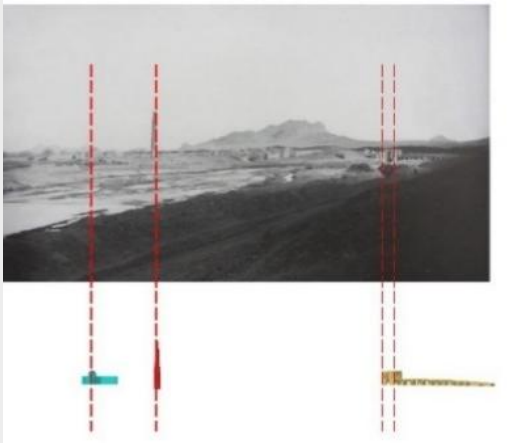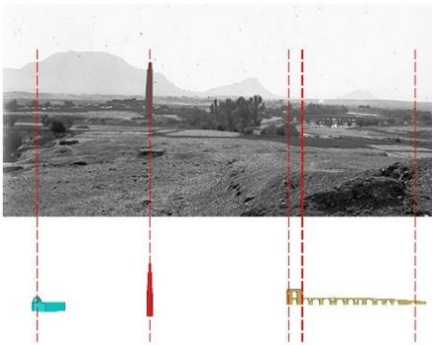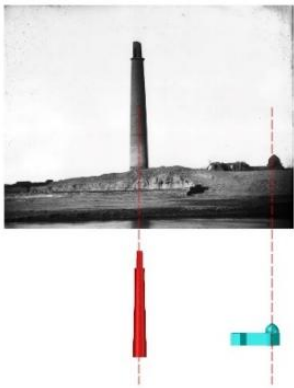
number of spans and the second explanation is the addition of the 11th span in later years. In other visual documents, the 11th span is clearly shown. This span is at a greater distance compared to the other spans. It is because there is a canal for the passage of water close to the main river current.

The second remaining visual document was drawn about 125 years after the first sketch (Table 5, B). This sketch also shows the east side of the bridge. In this sketch, the buildings along the customs house are drawn in detail. In addition, the customs house is shown to have one floor due to the destruction of the second floor. There are some people drawn on the roof of the customs house, which tells us that there used to be a pathway for accessing the second floor of the customs house. In this sketch, the arcades of the bridge are filled with brick lattice walls.

The third visual document remaining from the Shahrestan Bridge is a photo from 1870 A.D. (Table 5, C). This document, for the first time, shows the west side of the bridge. Only one of the buildings that were along the customs house in previous documents remains in this photo. Therefore, the rest of the buildings must have been destroyed sometime between 1845 and 1870. This building was also destroyed later due to neglect. In later photos, the process of how this building was destroyed over time is documented.

Visual documents and the current form of the bridge indicate that the customs house has always had somewhat different facades on its west and east sides. The main entrance of the bridge, which is through the customs house, can be seen in some visual documents. This entrance is shown to have had a pointed arch ceiling (Table 5, G). Other documents show the later collapse of this ceiling. Located west of the customs house, there used to be a building with two entrances, one leading into the customs house and one leading outside (Table 5, J). More recent documents show two buildings located south of the bridge (Table 5, L). The presence of these two buildings in newer
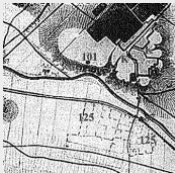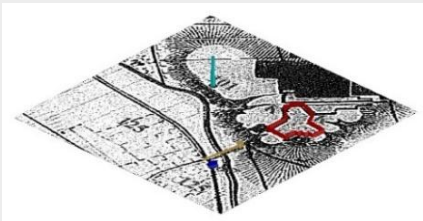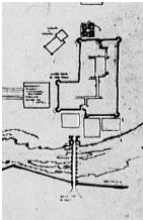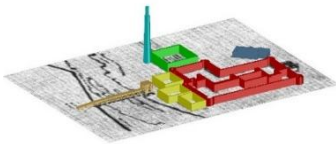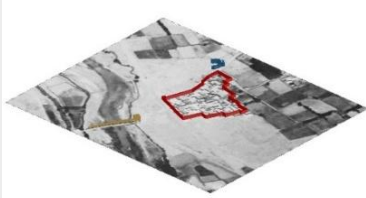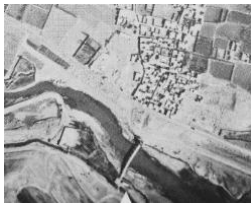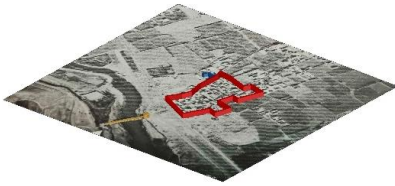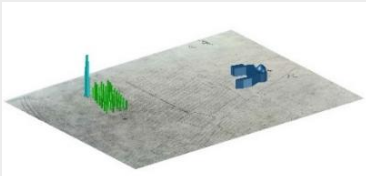
Table 3. Locating the Shahrestan Minaret based on visual documents. Source: Authors.

Date	Picture	Date	Picture
1845		1871	
~1872		~1872	

Legend

🟨 Shahrestan Bridge

🟦 Al-Rashed Tomb

🟥 Shahrestan Minaret

documents indicates that this part is new compared to the other part of the bridge.

The parapet has gone through many changes since the bridge was built. Visual documents show the destruction and reconstruction of different parts of the parapet in different years (Table 5, E & K).

Table 4. Locating the five main buildings in Shahrestan based on aerial photos and maps. Source: Authors.

	Source	Year	Maps	Representation
1	Chiricov	1857		
2	Baudouin	1928		
3	Cultural Heritage Documentation Center	1957		
4	Cultural Heritage Documentation Center	1976		
5	Mirfatah	1976		

Legend

■ Shahrestan Bridge   ■ Shahrestan Wall

■ Shahrestan Mosque   ■ Shahrestan Minaret

■ Al-Rashed Tomb

At some point, due to major damage, the original parapet was destroyed (Table 5, L). Therefore, the Shahrestan Bridge did not have a parapet for a while until the parapet was reconstructed again. Another major change in the structure of the Shahrestan Bridge is the destruction of the customs house ceiling around 1950 (Table 5, H). Reconstruction and restoration of the Shahrestan Bridge officially began around 1970 by the Cultural Heritage Center. During the initial restoration, metal rods were used to stabilize the customs house. This restoration was done without careful study of descriptive and visual documents. Therefore, improper changes to the structure of the Shahrestan Bridge made it different from its original form.

Analyzing all visual documents reveals two major changes to the number of the arched spans, which were originally 10. The first change is the addition of the 11th span. This span was located further away from the other 10 spans on a water canal, which was close and parallel to the river (Table 5, L). The second change, which led to what the bridge looks like today, is the addition of another span between the 10th and 11th spans. This change resulted in 13 spans of equal size (Table 5, N).

There have also been minor changes in the fences and entrances of the bridge which were restored to their original condition later. Since these changes do not affect the overall form of the bridge, we do not discuss them here in detail.

We have simulated the original form of the Shahrestan Bridge according to our findings from historical documents. We used a low-tech form of AR technology to demonstrate this original form to the public. There are a variety of AR methods that have been used to simulate buildings in previous studies. The majority of these studies require visitors to have smartphones to utilize their tools (Boboc, et al. 2019; Panou, Lemon,
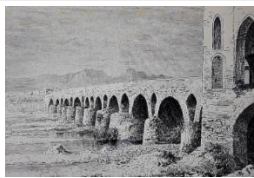
Despoina & Katerina, 2018). Our project has implemented a simple AR tool to demonstrate a 3D wireframe of the original form based on the two oldest documents of the Shahrestan Bridge to all public visitors on site. This tool includes a vertical glass screen mounted on the ground, which creates an overlay of the original form of the bridge on top of its current form, which is visible on the other side of the glass screen (Fig. 2). Visitors can move slightly to change their points of view and compare the original and current forms of the bridge. This on-site tool enables visitors to see any additions to the bridge clearly and get a better understanding of the changes it has gone through. In addition, the low-tech AR technology enables access to all visitors since it does not require a smartphone. More importantly, our representation of the original form of the bridge can serve as a document that can be referred to in future restorations of the Shahrestan Bridge. Another feature of this, in addition to completing the current form of the bridge, is to show the experience of the presence of past designers in the place and their specific perspective for today's visitors.

Conclusion

Analyzing descriptive documents revealed the different functions of the Shahrestan Bridge over time. However, these documents provided little information regarding the form of the bridge. Visual documents demonstrated the structural changes the Shahrestan Bridge has gone through. Visual documents also revealed changes in the original number of arched spans and the form of the customs house.

Different methods of AR technology have been used to document and represent historical buildings. In this paper, we have used the simplest form of AR technology to simulate the original form of the Shahrestan bridge on-site
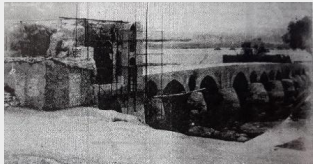
Table 5. The remaining visual documents of the Shahrestan Bridge. Source: Authors

Year	ID	Picture	ID	Year	Picture
1720	A	Cornelius de Bruyn. Source: Bruyn, 1737.	B	1845	Pascal Coste. Source: Flandin & Coste, 1854
1871	C	Ernst Hoeltzer. Source: Hoeltzer, 1975.	D	1881	Jane Dieulafoy. Source: Dieulafoy, 1887.
1928	E	Eric Schmidt. Source: Cultural Heritage Documantation Center.	F	1930	Robert Byron. Source: Cultural Heritage Documantation Center.
1940	G	Unknown. Source: Cultural Heritage Documantation Center	H	1950~	Unknown. Source: Cultural Heritage Documantation Ceneter
1955~	I	Unknown. Source: www.pinterest.com	J	1960~	Unknown. Source: Cultural Heritage Documantation Center.

using all historical documents available. This on-site tool enables visitors to visualize the original form of the bridge compared to its current form and get a better understanding of the changes

Rest of Table 5.

Year	ID	Picture	ID	Year	Picture
1965~	K	Unknown. Source: Cultural Heritage Documantation Center.	L	1967	Marie-thérèse ullens de schooten. Source: www.archnet.org.
1971	M	Unknown. Source: Ettelaat Newspaper.	N	2020	Source: Authors.

it has gone through. All visitors, regardless of access to smartphones, can use this tool to view any additions to the original form of the bridge. In addition, the destroyed parts of the original form of the bridge can be seen simultaneously with the current form of the building. In addition, this representation recreates an experience of the intangible heritage, which is the experience and perspective of the past designer of the building for the visitors.

Overall, our findings include important documents and data for future studies and restorations of the Shahrestan Bridge.

Endnote

1. Mohammad Kazerooni was a philanthropist during the Safavi period.

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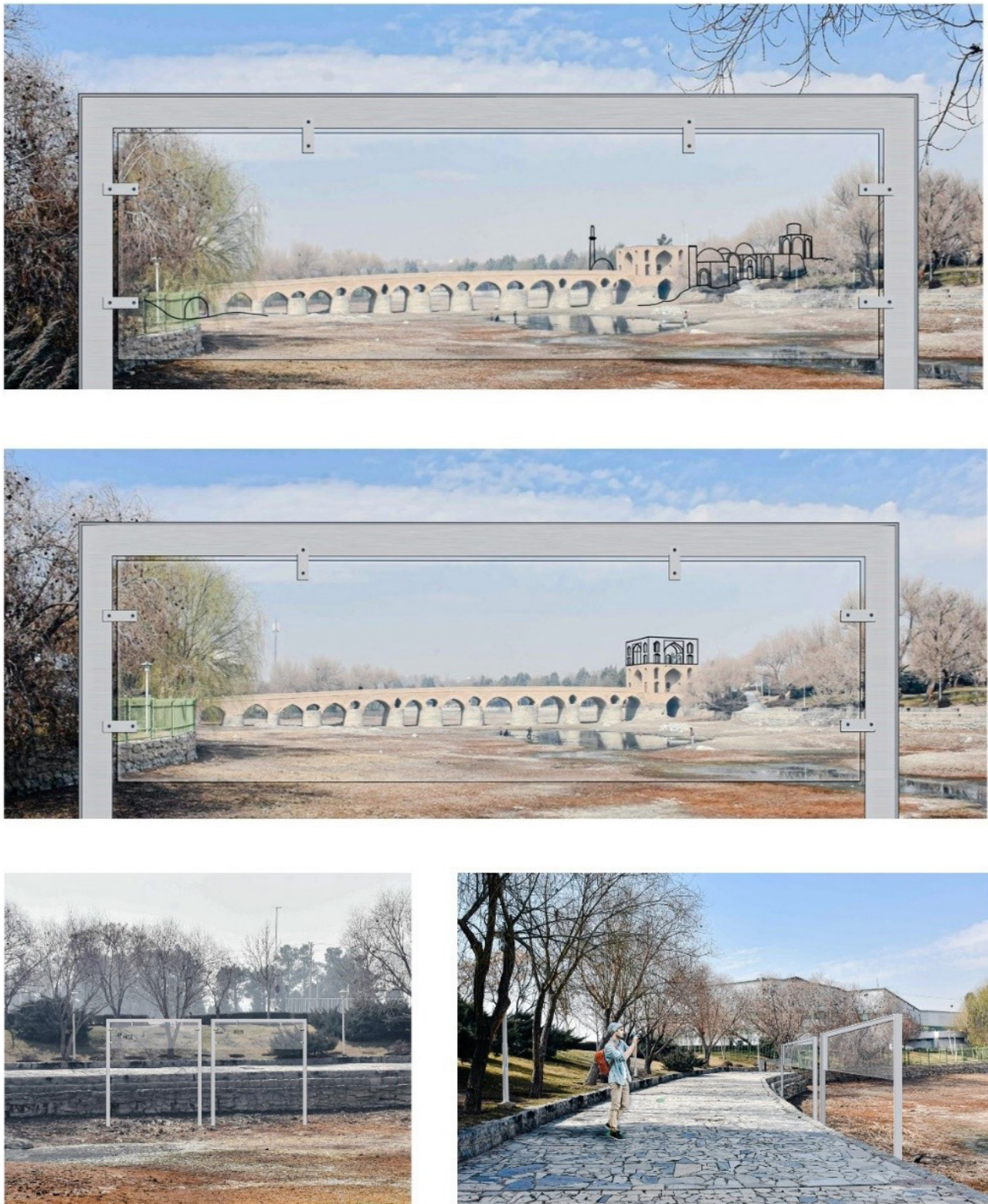• Mafarrukhi. M. S. (2006). *Tarjome-y Mahasen*

Fig. 2. The final wireframe simulation of the original structure of the Shahrestan Bridge. This figure demonstrates how the wireframe will be displayed on-site to all public visitors using a low-tech form of augmented reality technology. Source: Authors archive.

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