

Original Research Article

A Visual Representation of the Physical Changes of the Si-o-Se-Pol Bridge Based on Historical and Visual Document Analysis, with a Focus on Toll Gate Modeling*

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Abstract | The historical bridges of Isfahan are among the most valuable historical monuments of Iran, which have been preserved throughout the ages. The unknown original form and future building changes have made it challenging to conserve this valuable heritage. Si-o-Se-pol bridge, which is part of the tangible cultural heritage of the Safavid era, has historical and architectural values. Despite its great popularity, more research needs to be done on it. Few scientific studies have been done on this bridge. Therefore, more research on this building is necessary. Thus, this research deals with the historical and visual documents left by the building and the changes in appearance and landscape of thirty-three bridges over time. This study aims to document the physical changes in the Si-o-Se-pol bridge and its landscape based on available historical and visual documents and the entrance landscape, especially after the construction of the tollgate. This research used a field and archival study. The reading of ancient documents was done along with comparative analyses. A comparison was based on various visual and historical documents, and buildings of similar forms; it led to the presentation of three 3D models. Physical changes in the entrance's landscape and the form of the bridge were exactly modeled. Documenting and modeling the bridge over the ages shows that many changes have been made in the form and landscape of the bridge. The crown on the eastern facade and the toll gate in the northern landscape of the bridge were added to the building in the Qajar period and destroyed in the Pahlavi era. The construction of the toll gate at the northern entrance of the bridge has changed the threshold landscape in this part of the city. Comparative studies and three-dimensional modeling of the bridge in each period proposed three alternatives for the physical form of the toll gate. Archaeological excavations and the possibility of finding other old documents on this bridge can reveal the final alternative in more detail.

Keywords | *Visual and Historical Documents, Documenting the Landscape Changes of Si-o-Se-Pol Bridges, Modeling Tangible Cultural Heritage, Old Image Processing, Threshold Landscape.*

Introduction | Bridges have played a vital role in expanding communication and traffic on rivers. During the Safavid era, the era of the prosperity of trade and commerce in Isfahan, many bridges were built to connect the two sides of the Zayanderud river (Ehteshami & Bastani Rad, 2007, 43). Some of these bridges were built during this period, and

others were previously-built bridges that were reconstructed or restored during this period. The Shahrstan bridge was built during the Sassanid period on a foundation of natural stones and restored during the Safavid period (Rodger, 1983, 279). The Si-o-Se-Pol bridge, the Khaju bridge, and the Jouie bridge, which were built in this period, aside from providing passage, were places to entertain kings,

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courtiers, and foreign ambassadors. Golrizan and Abrizan festivals were held at the Si-o-Se-Pol and Khaju bridges in July (Mokhlesi, 2015, 69). The Marnan Bridge was also built during the Safavid period, during the reign of Shah Suleiman, which mainly played a communication role. The Jouie bridge, which was made of stones and bricks and had 21 spans, was named as such because of the water canal (Joy) that passed over it (Bahari, 1974, 6). The Khaju bridge was used as a dam, and the ground level below the bridge was higher than the riverbed to store some water (Soltanzadeh, 2015, 193). The Khan bridge was built in the early 11th century on the road from Isfahan to Shiraz, but there are no traces left of it today. However, the longest bridge of this era can be considered the Si-o-Se-Pol bridge, which still has unknown aspects, and the present study will address some of them. The Si-o-Se-Pol bridge, or the Charbagh bridge, was built during the reign of Shah Abbas I. This bridge was established to connect the developed parts of the city, such as Jolfa, Charbagh-e Bala Street, Bagh-e Hazar Jarib, and the Zoroastrian parts, which are located on the south side of the river, with the main part of the city, which is located on the north side of the river. This bridge has changed over time, including adding parts to it and reducing other parts (Tables 1 & 2). Historical and visual documents together can reveal the process of construction and completion of the Si-o-Se-Pol bridge over time. On the other hand, they can determine the course of physical changes in the building, which is a criterion for distinguishing the original parts from the added parts of the building. This study aims to discuss the bridge's physical changes. In this regard, the added parts, how they were added, and how parts of the bridge were destroyed are among the discussions that this study deals with. Also, the toll gate section of the bridge will be specifically analyzed. As a result, a combination of landscape changes has been documented to analyze the physical changes of the bridge over time and to determine the main developed parts of this historical monument.

In this article, the procedures used to conduct the research are first analyzed by analyzing the historical and visual documents from the Safavid period to the present day. To identify significant changes in the bridge, they were modeled according to various documents: the construction and destruction of the bridge's toll gate. This part was specially modeled based on various documents. This research is based on library, analytical, and field studies. First, the original form of the bridge has been analyzed from the Safavid period to the present day. Then the toll gate's development and its headstone were determined based on historical and visual documents. The authors prepared a photograph of the same historical facade to determine the condition of the toll gate and headstone. (Table 3). In addition to this, the architectural features of the toll gate and the headstone were also documented.

Research Questions

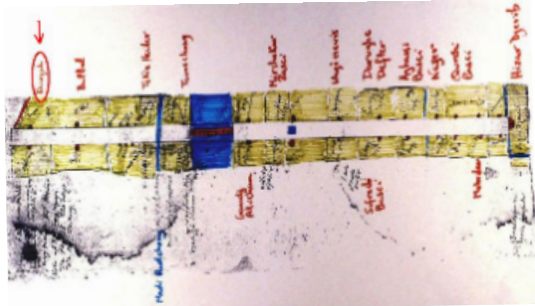
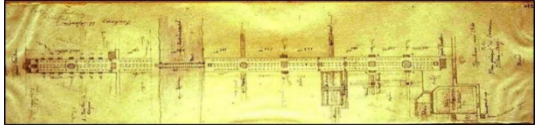
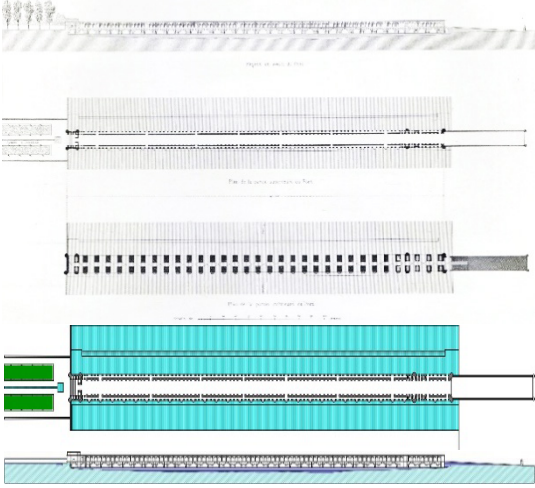

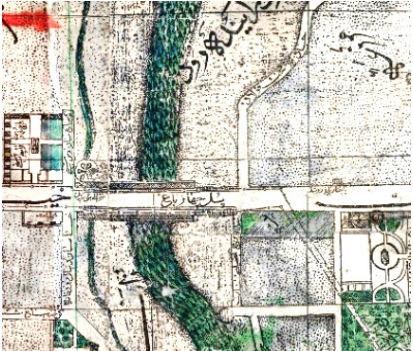
- What physical changes have the Si-o-Se-Pol bridge gone through over time?
- Which parts have been added or removed from the bridge's original structure?
- What physical characteristics did the toll gate part have?

Research Background

Many famous tourists have visited Isfahan and described the bridges of this city in their memories. Della Valle was the first to describe this bridge as an all-brick bridge connecting the Jolfa neighborhood to the old city of Isfahan. This tourist mentioned the bridge's architecture so that people could pass above and below it. The Ab-Pashan ceremony is also performed on this bridge (Della Valle, 2018). In the early 17th century, Tavernier, a French traveler, visited Isfahan. Tavernier believes that four bridges have been built on the Zayanderud river. The one located precisely on the middle axis of the city is known as the Allah Verdi Khan or Jolfa bridge (Tavernier, 2006). Also, Chardin, another famous French traveler, described this building as a beautiful bridge leading to Chaharbagh Bala and Chaharbagh Abbasi streets through two ramps on its sides (Table 3, No. 2-3) (Chardin, 1988). In another source, it is stated that this bridge has railings that are covered parapets. The bridge has various commuting routes, so that in hot summers, people go down the stairs and pass under it, which has pleasant air (Table 3, No. 5) (Sanson, 2018). In the middle of the 19th century, Hoeltzer quoted Chardin's explanation of this bridge in his book (Hoeltzer, 2017). Another tourist who has examined this building attributes one of the commanders of the Great Shah Abbas to the Allah Verdi Khan bridge (Wills, 2011). Some visitors have even considered this building the most magnificent bridge in the world. The bridge was located at the city's entrance in the Qajar era. Therefore, passengers used to pay tolls for passing the bridge. Therefore, tourists knew they were entering a big city (Richards, 1948).

Regarding the studies related to descriptive and visual documents, research has discussed modeling the change process of the headstone of Isfahan's Toopkhaneh square over time (Valibeig & Kourangi, 2019). Another study deals with the narration of maps of Chaharbagh street in Isfahan (Mahdinejad & Qolipour, 2017). Also, another research has reinterpreted the body of the Hezarjarib garden of Isfahan based on comparative studies of descriptive-visual and field studies (Homayouni & Valibeig, 2021). The recreation of Chaharbagh Abbasi street in Isfahan in the Safavid and Qajar periods, with an emphasis on the depiction of travelogues, is another research that has analyzed this topic (Qolipour, 2014). One research related to descriptive and visual documents stated that it is possible to reconstruct historical periods to obtain three-dimensional models virtually. This method protects cultural heritage (García-

Table 1. Visual documentation of Si-o-Se-Pol bridges, historical maps, historical aerial photos, and Contemporary aerial photos (from the end of the 16th century until now). Source: Authors.

NO	Author/Artist	Year	Historic maps/ Aerial photos
1	Engelbert Kaempfer	1684	
2	Pascal Coste	1840	
3	Pascal Coste	1840	
4	Andre Chirikova	1840	
5	Seyed Reza Khan	1851	

Rest of Table 1.

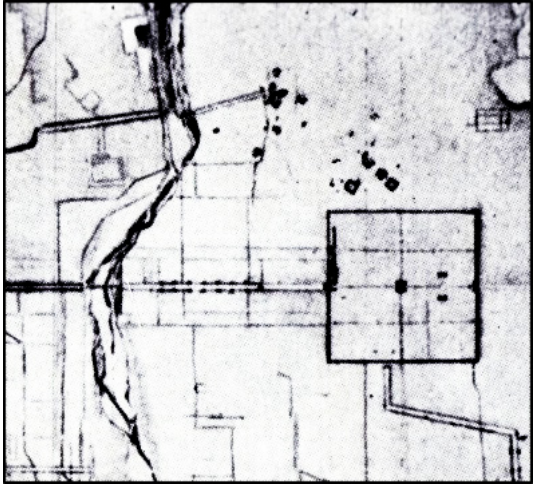


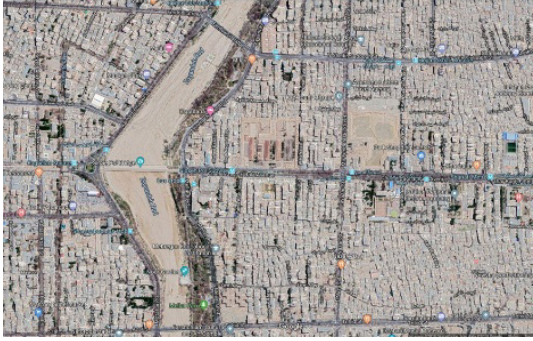
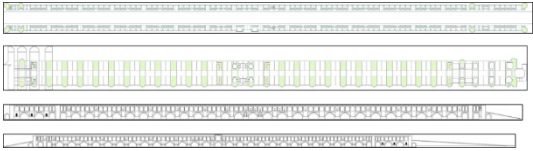
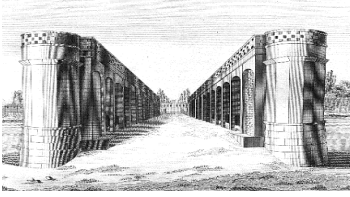

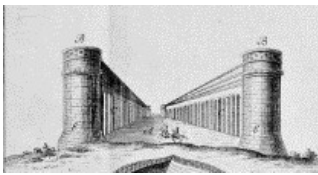

NO	Author/Artist	Year	Historic maps/ Aerial photos
6	Eugène Bedouin	1925	
7	(Aerial Photo) Iran National Cartographic Center	1944	
8	(Aerial Photo) Iran National Cartographic Center	1956	
9	(Satellite Images) Google Maps	2021	
10	Authors	2021	

Table 2. Comparison of four different visual documents of Si-o-Se-Pol bridges. Source: Authors.

NO	Source	Year	Image	Description
1	John Chardin	1673		These four visual documents, recorded at different times, show a belt of brickwork above the entire bridge, which looks like a parapet.
2	Nicolas Sanson	1683		
3	Stör, Johann Wilhelm	1735		
4	louis dubeux	1841		

Molina, López-Lago & Hidalgo-Fernandez, 2021). Another research has discussed the importance of documentation to identify historical monuments as a tool to transfer information to future generations. This documentation can be done in 3D modeling (Erdal & Makineci, 2021). Also, another research deals with the endangerment of many buildings and places that are being done at high speed and states that documenting this evidence makes it possible to prevent their destruction and pass them along to the next generations. This documentation plays a significant role in understanding the cultural importance of societies (Haddad, Fakhoury & Sakr, 2021). One of the methods of preservation can be the use of video games. An article discusses simulating cultural heritage using these games. This causes the transfer of cultural heritage values, and it is a valuable tool for more engagement with cultural heritage (Garcia-Fernandez & Medeiros, 2019). Other documentation methods include 3D scanning technology, which is used in documenting tangible cultural heritage. This is possible even with smartphones (Murtiyoso & Grussenmeyer, 2021). Augmented reality technology has also been discussed in the research. This technology has been used to represent and document the bodies of destroyed historical buildings. With this technology, this research has located and modeled the Shahrastan bridge of Isfahan (Abdellahi & Valibeig, 2022). Using digital technology to document cultural heritage is a global trend in the 21st century. One of the recent research projects that deal with the use of technology in the

preservation of cultural heritage is that the use of satellites or remote techniques helps greatly in this matter (Karagianni, 2021).

Theoretical Foundations

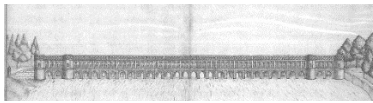
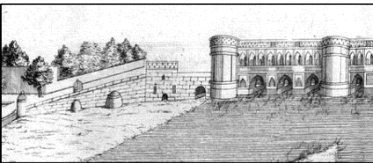

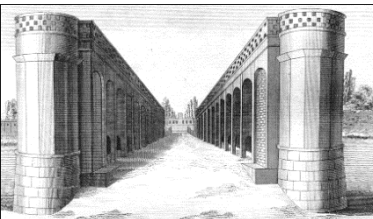

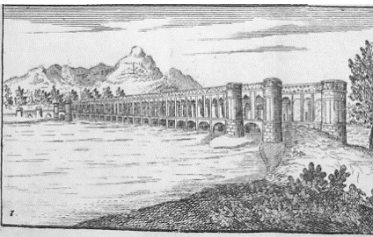
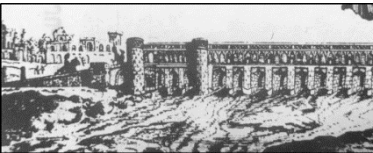

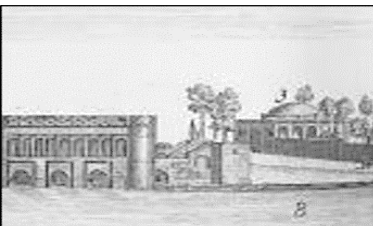

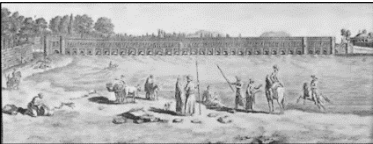



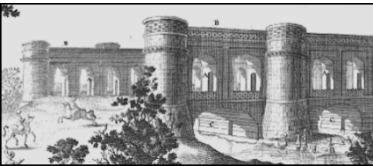

Due to the importance of the Si-o-Se-Pol bridge as a communication route, many researchers have tried to study and introduce it from its construction until now. Most of these studies are travelogues that, along with the introduction of the city of Isfahan, describe the Si-o-Se-Pol bridge. In addition to travelogues, many historical documents have introduced the Si-o-Se-Pol bridge. None of the research carried out so far has mentioned the existence of the toll gate and the headstone, and they have yet to mention its function. Only in Fred Richard's travelogue is a brief mention of the toll gate. In this source, it is stated that travelers have entered a big city after paying tolls (Richards, 1948, 86) (Table 4 & 5).

Research Methods



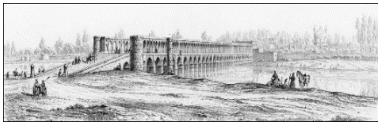





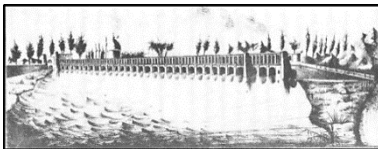



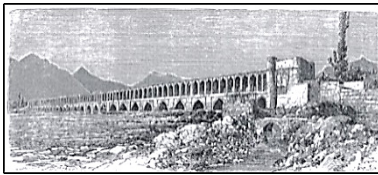

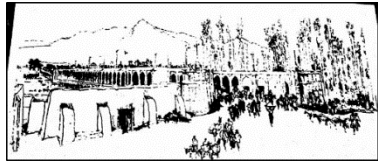

The data of this research is a combination of field and library data. By reading old documents from different periods of the bridge construction and field study of its present situation, the changes in the bridge from the time of its formation to today have been revealed. In this research, all historical documents, including travelogues and existing articles about the Si-o-Se-Pol bridge, were studied and documented. Their points were noted down by the authors.

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Table 3. Visual documentation of Si-o-Se-Pol bridges, historical photos, and their 3D modeling (by the authors). Source: Authors.

NO	Author/Artist	Year	Drawing/Image	Representation
1	Ambrosio Bembo	1671		N.A.
2	John Chardin	1673		
3	John Chardin	1673		
4	Nicolas Sanson	1683		N.A.
5	Engelbert Kaempfer	1684		
6	Cornelis de Bruijn	1703		
7	Cornelis de Bruijn	1703		
8	Cornelis de Bruijn	1703		
9	Stör, Johann Wilhelm	1735		

Rest of Table 3.

NO	Author/Artist	Year	Drawing/Image	Representation
10	Christoph Bernhard	1840		
11	Pascal Coste	1840		
12	Pascal Coste	1840		
13	Jules Laurens	1845		
14	Vertans Yuzukchian	1850		
15	Schroeder	1858		
16	Jane Dieulafoy	1881		
17	Fred Richards	1931		

Then, the visual documents were studied, compared, and analyzed, and consequently, the obtained results were drawn in three-dimensional form with AutoCAD and presented in different alternatives.








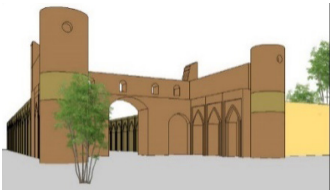

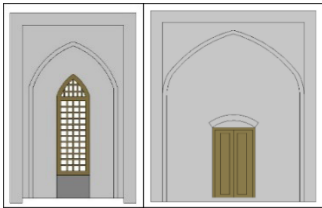

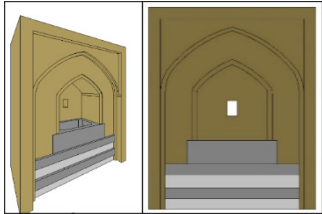
Discussion

The Si-o-Se-Pol was the busiest bridge in Isfahan during the Safavid period. This bridge has connected various

functions in its north and south. According to the findings in the historical documents, the toll gate was located in the northern part of the bridge. Also, a crown has been implemented in the eastern part of the bridge on one of the spans. The use of the toll gate was determined based on descriptive documents and comparative studies. The descriptive documents indicated that the toll gate was used to enter the gardens south of the bridge and considering

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Table 4. Visual documentation of Si-o-Se-Pol bridges, historical photos, and their 3D modeling. Source: Authors.

NO	Author/Artist	Year	Drawing/Image	Representation
1	The Golestan Palace, (The royal houses album)	1890		
2	Khanzad Khan Baba Hoseini	1890		
3	Philip Johnson	1906		
4	Johance Baptist Apkar	1923		
5	Authors	2020		
6	Authors	2020		

that the toll gate does not exist today, analyzing its changes can help to represent changes in the form and function of the Si-o-Se-Pol bridge from the Safavid to the Qajar era (Table 4). According to these sources, there is a stone plinth under the brick belt at the top of the tower. The lower part of the tower is like an incomplete cone covered with stone (Table 6). One of the visual documents clearly shows both towers of the toll gate's entrance from the front view (Table 7). As seen in (Table 7, No. 2 & 3), Hoeltzer seems to be standing on the northern walls of the bridge,

which can be seen on the left side of the photo, and there is a tower on the other side of the photo. A comparative study of these three photos shows the openings on the wall and the brickwork on the top of this tower, and the side towers. Therefore, it can be concluded that the towers in Holtzer's photos were similar to the towers on the bridge. Thus, these documents show precious information for a more accurate representation of the toll gate tower. Due to the visibility of the brick belt and other elements, such as the light pole, the shape and size of the upper part of

Table 5. Visual comparison of old and new photos for the analysis of the bridge's Crown. Source: Authors.





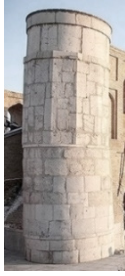


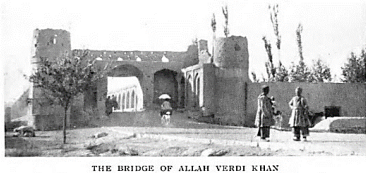


NO	Source	Year	Image	Description
1	Khanzad Khan Baba Hoseini	1890		
2	Philip Johnson	1906		In these pictures, the crown of the bridge can be seen on the eastern side. By comparing it with other Qajar buildings, it seems that it was built in the Qajar period. This part was later destroyed during the Pahlavi period.
3	Authors	2020		

Table 6. Comparison of towers of the Si-o-se-pol bridge. Source: Authors.

NO	Source	Year	Image	Description
1	Authors	2020		left tower, north side of the bridge, (Near Enghelab Square)
2	Authors	2020		Right tower, north side of the bridge, (Near Enghelab Square)
3	Ernst Hoeltzer	1862		left tower, south side of the bridge, (Near Chaharbagh Bala street)
4	Authors	2020		Right tower, south side of the bridge, (Near Chaharbagh Bala street)

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Table 7. Visual documents showing the historical towers of the toll gate, comparative studies. Source: Authors.

NO	Source	Year	Image	Description
1	Johance Baptist Apkar	1923		The toll gate towers in the northern part of the bridge- Currently does not exist
2	Ernst Hoeltzer	1880		Western view: one of the towers of the toll gate
3	Ernst Hoeltzer	1880		The photographer's view is slight to the northwest. Therefore, the toll gate tower can be seen here (similar to photo #2).

the toll gate tower were modeled more accurately. Current calculations show an approximated height of one hundred and eighty centimeters. The openings on the wall were also to control traffic and collect tolls from passengers (Table 7). According to the analysis of the historical and visual documents, two chambers were built on both sides of the toll gate. One of these chambers was for receiving tolls, and the other was for entering and exiting the city. Based on visual documents, the toll gate and the existing spaces probably indicate a door in the entrance part of the bridge, which was used to control the entry and exit. Unfortunately, there is no specific visual document related to this door. Also, the structure of the toll gate is depicted in Flandin's historical maps (1840) and Seyyed Reza Khan's map (1925). Therefore, it can be concluded that the toll gate must have been built before 1840 and was destroyed almost after 1925 (Tables 7-9). In addition, these details are drawn in the Yuzuk Chian Sketches (Table 10). Consequently, it was found that there were five arcades on the upper wall of the toll gate. However, we can see these openings also in the later photos. Based on these findings, three alternatives have been modeled for the entrance of the toll gate:

Alternative 1: The toll gate, which was located north of the bridge, could have four walls, two of which were facing the bridge and were connected by arcades. Furthermore, the parts marked in green could have been traffic control routes (Table 11, No. 1).

Alternative 2: Same as the previous alternative, but with a wall where the main entrance was located and connected the two sides of the bridge (Table 11, No. 2).

Alternative 3: Almost similar to the previous two alternatives, this building can have four walls and a gate with more details on the northern side (Table 11, No. 3).

Conclusion

The Si-o-Se-Pol bridge connects the north of Isfahan city to its south and is also located along the Charbagh axis, which divides the city into eastern and western parts. This bridge has played a significant role in the landscape of the entrance to the city. The changes in the northern entrance of this bridge have caused changes in the landscape of the historical entrance of the city. This study has creatively modeled the form of the building, its entrance landscape, and the changes that have taken place, according to the visual documentation and the time attributed to it for the first time. Analyzing the historical and visual documents of the Si-o-Se-Pol bridge provided a better understanding of the physical changes of the bridge by specifying, identifying, analyzing, and modeling the crown of the bridge and the toll gate, which have not been noticed until now. In this respect, the first step was to analyze the historical photos and images of the Si-o-Se-Pol bridge (especially the documents that have been rarely seen and analyzed so far). By carefully analyzing these photos and pictures and comparing them with the current state of the bridge, the physical differences between them and the current form of the bridge were found. Documenting the remaining visual documents, along with studying ancient documents, provided the basis for investigating the changes in the building. Since other researchers have yet to mention or investigate the toll gate or the crown, there is no proper information about

Table 8. Visual documentation of the toll gate on the Si-o-Se-Pol bridge. Source: Authors.

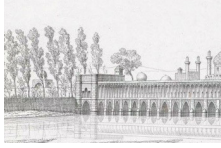
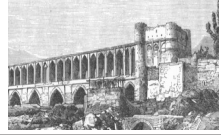





NO	Source	Year	Image	Description
1	Pascal Coste	1840		Visual documentation of Si-o-Se-Pol bridges (northern side), The damages of the later periods, and unprincipled conservation, without returning to the original form of the monument.
2	Jane Dieulafoy	1881		
3	Ernst Hoeltzer	1880		
4	Johance Baptist Apkar	1923		

Table 9. Visual documentation of the south side of the Si-o-Se-Pol bridge, Comparative study. Source: Authors.

NO	Source	Year	Sketch/ Image	Description
1	John Chardin	1673		Visual analysis of Safavid and Qajar documents and comparative studies with similar buildings, certainly the construction of toll gate in the Qajar period has been done. There is no such part in the visual documents of the Safavid period (for instance, the Chardon documents).
2	Authors. 2020 (Representation of Chardin's image, 1673)	1673		The building shown in Chardin's sketch is on the south side of the bridge. Therefore, this building is not a toll gate for the bridge.
3	Authors	2020		




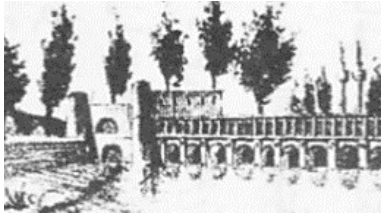
them. Therefore, for the first time, this study revealed their existence through the comparative analysis of images. Therefore, it was found that during the Qajar period, a structure was added to the north of the bridge, which is known as the toll gate, and was used as a gate to collect tolls and control traffic. Considering the lack of evidence to represent the architectural features of the toll gate, visual

documents were used to decipher this structure's overall spatial arrangement and function. Based on the conducted comparative analysis between historical documents, three alternative alternatives for the architecture of the toll gate were presented and demonstrated through 3D modeling. All three alternatives are acceptable according to the historical documents available to the authors. In future

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Table 10. Visual documents showing the shape of comparative studies. Source: Authors.

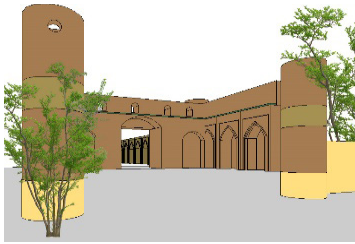
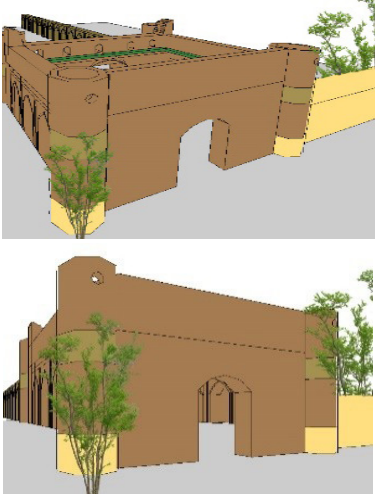

Research, one of the alternatives should be chosen as the most accurate through a deeper investigation and possibly more access to historical documents.

NO	Author/Artist	Year	Sketches and historic photos
1	Johance Baptist Apkar	1923	
2	Ernst Hoeltzer (Cropped photo)	1880	
3	Ernst Hoeltzer (Cropped photo)	1880	
4	Vertans Yuzukchian (Cropped photo)	1850	

Endnote

* This article extracted from. thesis of “Negar Jahangard” entitled “A Conservation Plan of Si-O-Se pol Bridge Based upon Illustrative and Descriptive Documents” that under supervision of Dr. Nima Valibeig which has been done at Art University of Isfahan, Faculty of Conservation, Art University of Isfahan, Isfahan, Iran in 2021.

Table 11. Visual analysis of the toll gate and southern landscape with the presentation of three alternative models. Source: Authors.

NO	Alternative	Representation
1	Alternative 1 Landscape model (north side)	
2	Alternative 2 Landscape model (north side)	
3	Alternative 3 Landscape model (north side)	

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