THE ROLE OF THE GREAT ISFAHAN BRIDGE IN MAKING A LANDMARK AND ACHIEVING "WHOLENESS" FOR URBAN DESIGN

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Contents

Introduction 2
Section 1: The theory of wholeness in urban design 3
Section 2: The concept behind the Great Isfahan Bridge 4
Section 2.1: History 4
Section 2.2: Comparison between the Khaju Bridge and European bridges 6
Section 2.3: structure 7
Section 2.4: Functions 7
Section 3: The Khaju Bridge from a technical point of view 9
Section 3.1: Water-inspired architecture 9
Section 3.2: detail and structure of Khaju bridge 14
SECTION 3.3: POSITION OF KHAJU BRIDGE IN ISFAHAN 15
Section 4: design of Water channels in Khaju bridge 15
Section 4.1: adjustment of changes TO the river flow 17
Section 4.2: Visions 21
Section 5: comparison of Khaju bridge in the 17th century and the 21st centery in urban design 23
Section 5.1: Zayandeh Rud River in the 21st century 25
Section 6: Conclusion 25
REFERENCES 26

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Introduction

The concept of beauty in urban design can lead humans to building constructions and urban design based on the past (Alexander, Neis, Anninou and King, 1987).This is because the concept of beauty comes from a feeling of "organicness", which is based on the accurate vision and quality of a structure that comes from old and historical buildings and towns, however, this phenomenon is not related to a vague sensation of a relationship with biological forms (Alexander[1], Neis[2], Anninou[3] and King[4], 1987).

This concept of beauty was particularly important in urban design in the American context. The sense of a need for aged buildings was captured by the well-known writer and activist Jane Jacobs who, in 1961, had a primary interest in urban planning as a criticism of modernism. This was because many old structures were demolished in New York during the 1950s and 1960s. The idea of using old and historical structures created a phenomenon and even a new organized fashion for architecture and the city in urbanism (Jacobs, 1961).

The aim of this paper is to use Jacobs' criteria to identify architectural landmarks in a case study in Iran. The question that this paper addresses is whether or not an old construction has the potential to be a landmark in a city. This is, in the 21st century, a controversial subject in urban design. Surely, not all old structures are in good enough condition to be a landmark in modern urban design. The use of historical buildings as landmarks has been made by many countries, such as the UK (London Bridge, London), France (Les Halles, Paris) and Iran (The Great

[1] Christopher Alexander is an English architect and theorist.
[2] Professor Hajo Neis is an architect and faculty member of the Department of Architecture School at the University of Oregon
[3] Artemis Anninou is an architect and the author of 'A new Theory of Urban design'.
[4] Ingrid King is an architect and was a professor of architecture at the Norwegian University of Technology.

Bridge, Isfahan region). This paper will focus on the latter building. This bridge was built in the mid-17th century and it was constructed as a landmark. It is an aged and multi-functional structure. However, one of the main reasons for analysing the Great Isfahan Bridge is that the bridge has changed overtime. The condition of this bridge in the 21st century is significantly different to the original built in the 17th century. The contemporary bridge may have lost its "wholeness" affecting the urban design in the Isfahan region altogether.

Section 1: The theory of wholeness in urban design

Some architects have argued that the meaning of "wholeness" in urban design can be connected to the mathematics and sequence of numbers in a proposal. For instance, consider the mathematical sequence of previous increments in numbers, such as q1, q2, q3… leading to qn in a logical sequence (Alexander, Neis, Anninou and King, 1987). However, if this logical sequence changes and assumes the wrong order, it will change the proposal itself. Comparisons between sequences of numbers in mathematics and buildings have been developing in urban design, which can lead to the concept of wholeness in urban design (Alexander, Neis, Anninou and King, 1987). Following this concept, it is possible to understand the benefit of aged buildings in urban design and to achieve the idea of wholeness. For this reason, to achieve wholeness, therefore, cities require aged buildings, without which the growth of vigorous streets and districts would be impossible (Jacobs, 1961).

In addition, according to Rossi (1984), cities can be described as a theatre of human events, however, instead of being a place of representation, it is asserted as a place of actual events. This reality absorbs events and feelings, of which any new event brings a concept of a memory of the past and carries a potential memory of the future (Rossi, 1984). In addition, a city is presented or shown as a responsibility of a culture, which has contemporaries in the past and also contemporaries to come (Rossi, 1984).

It is possible to draw a connection between the concept of wholeness and Rossi's idea of memories of the past and future. The key point here is that to achieve wholeness, architects are required to create a harmony between memories of the past and future via urban design, without which vibrant streets and cities are not realised.

Following the above considerations, old structures can be used in urban design as landmarks to achieve a harmonic balance between past and future. Furthermore, some old buildings are also able to play a role as a multi-functional structure for urban design. These two concepts of the culture and multi-functional characteristics of some aged buildings can be integrated into the idea that "Old ideas can sometimes use new buildings. New ideas must use old buildings" (Jacobs, 1961).

Section 2: The concept behind the Great Isfahan Bridge

Section 2.1: History

One of the most significant periods in the history of Iran was seen during the rule of the Safavid dynasty (c. 1500-1722) (Foran, 1992). Around this time there was a rebirth of Iranian architectonic works of art and its architecture is currently considered to be revolutionary in Iran. Safavid architecture combines Persian arts with Islamic culture during this period (Blaser, 2010).

The Great Isfahan Bridge is located on the Zayandeh Rud River in the Isfahan region. It is also called the "Khaju Bridge" and it was built on the foundations of an ancient bridge built at the time of the Timurid dynasty. Khaju Bridge was built by Shah Abbas II during the mid-17th century. This structure is considered to be the last remnant of the Persian tradition (Michell, 1978). For two main reasons, this structure is significant for Isfahan's landscape: first, the decoration of the tiles in this structure is much more artistic than on other bridges on the Zayandeh Rud River in Isfahan (Barihi, 2011) (Figure 1). Second, the bridge has two storey platforms and its octagonal pavilion rests on a platform on the bridge. The bridge also includes shops, tea rooms and restaurants, and for this reason it is a multi-functional bridge (Blaser, 2010) (Figure 2).

Figure 1. The Khaju Bridge's tiling details on its façade (photograph by the Cultural Heritage Organization of Iran, 2010).

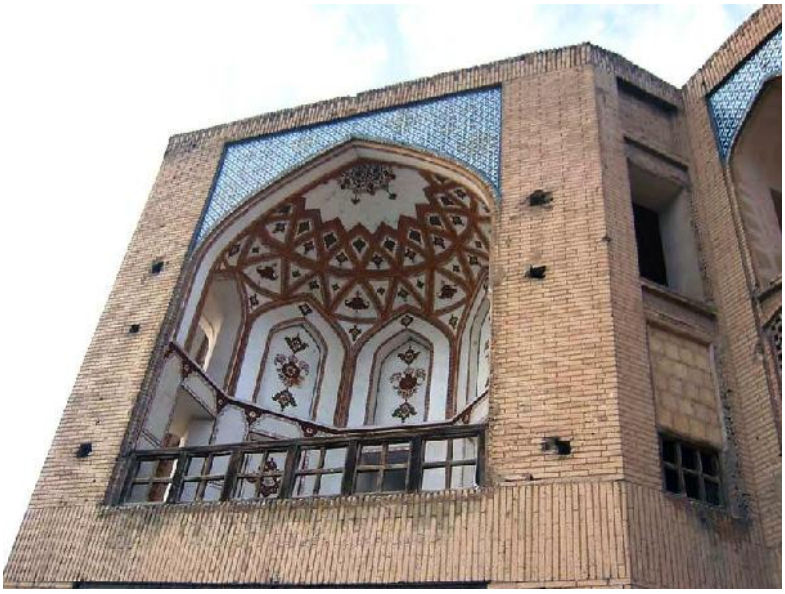

Figure 2. The central part of the bridge's structure. It has an octagonal pavilion called "Byglrbygy", which was designed for the king and his successors. The main purpose behind the pavilion is to create a special space for watching important celebrations, such as the New Year and traditional Persian festivals (General Department of Isfahan State, NA) (photograph by Tabian, 2009).

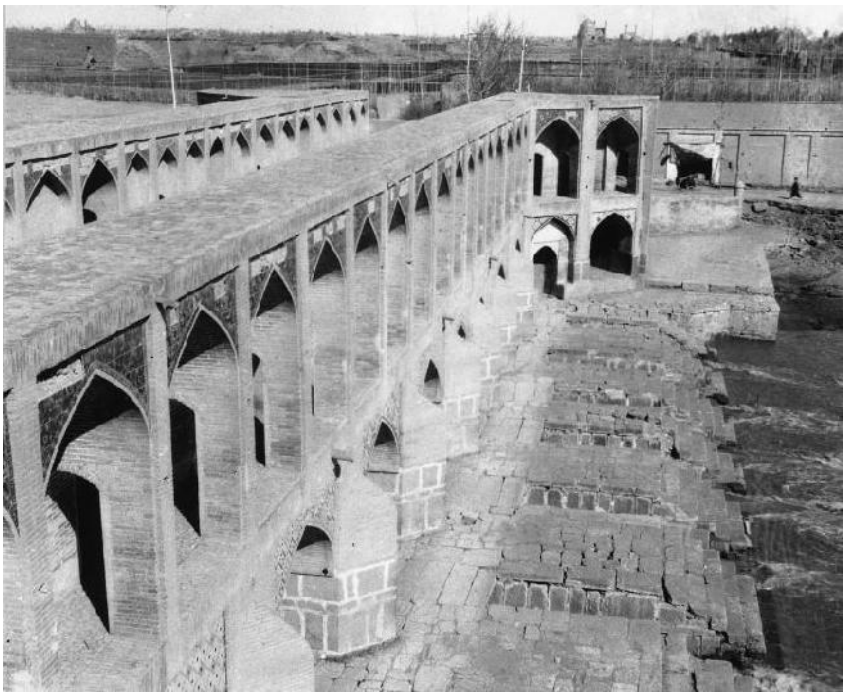

Figure 3. Arcade and water channels (photograph by Robert Byron [1905-1941], 1933-1934)

Section 2.2: Comparison between the Khaju Bridge and European bridges

There are some similarities between European bridges built around the time of the 17th century and the Khaju Bridge. For example, European bridges included houses and shops inside them during the Middle Ages (Campbell, 2003), however, European bridges were made of stone and were timber-framed - their upper sections and the rivers acted as open sewers in some European countries during the Middle Ages (Campbell, 2003). By way of contrast, the Isfahan River (Zayande Rud) was used as a water source, supplying Isfahan city and finding use for irrigation in agriculture (Salami, Mamanpoush, Miranzadeh, Akbari, Torabi, Toomanian, Murray-rust, Droogers, Sally and Gieske, 1998). Moreover, The Khaju Bridge was conceived of as a symmetrical bridge, in keeping with Islamic design aesthetics (Campbell, 2003). (Figure 3)

Section 2.3: structure

From the design point of view the Khaju Bridge is not an ordinary bridge. As a structure it is both enormous (110 metres long and 20 metres wide) and elegant, allowing the passage of caravans. It was built between 1642 and 1667, within 5 years (Vessal and Saidi, 2008). This structure has two storey high viaducts. On the top level, the size of the road allows caravans to pass, while beneath pedestrians may traverse. The lower level is used as a refuge for camels and horses (Campbell, 2003) (Figure 4).

Section 2.4: Functions

According to the different architects who have visited and studied the Khaju Bridge, it has three main functions as follows. First, crossing the Zayandeh Rud River and connecting two city districts it serves as a defence (Blaser, 2010). This means that the bridge plays an important role in providing accessibility for people, since accessibility is a significant component of the functionality of both individual structures and groups of structures (Temple, 2004).

Secondly, the main purpose of this bridge was as a liveable place where people could tarry and enjoy the site. Finally, as the Zayandeh Rud River is not navigable, this bridge acts as a weir, the downstream level being far lower, along with dispensing water above a sequence of steps (Michell, 1978). Accordingly, the closing of the bridge openings from the western part creates an artificial lake in the river (Barihi, 2011).

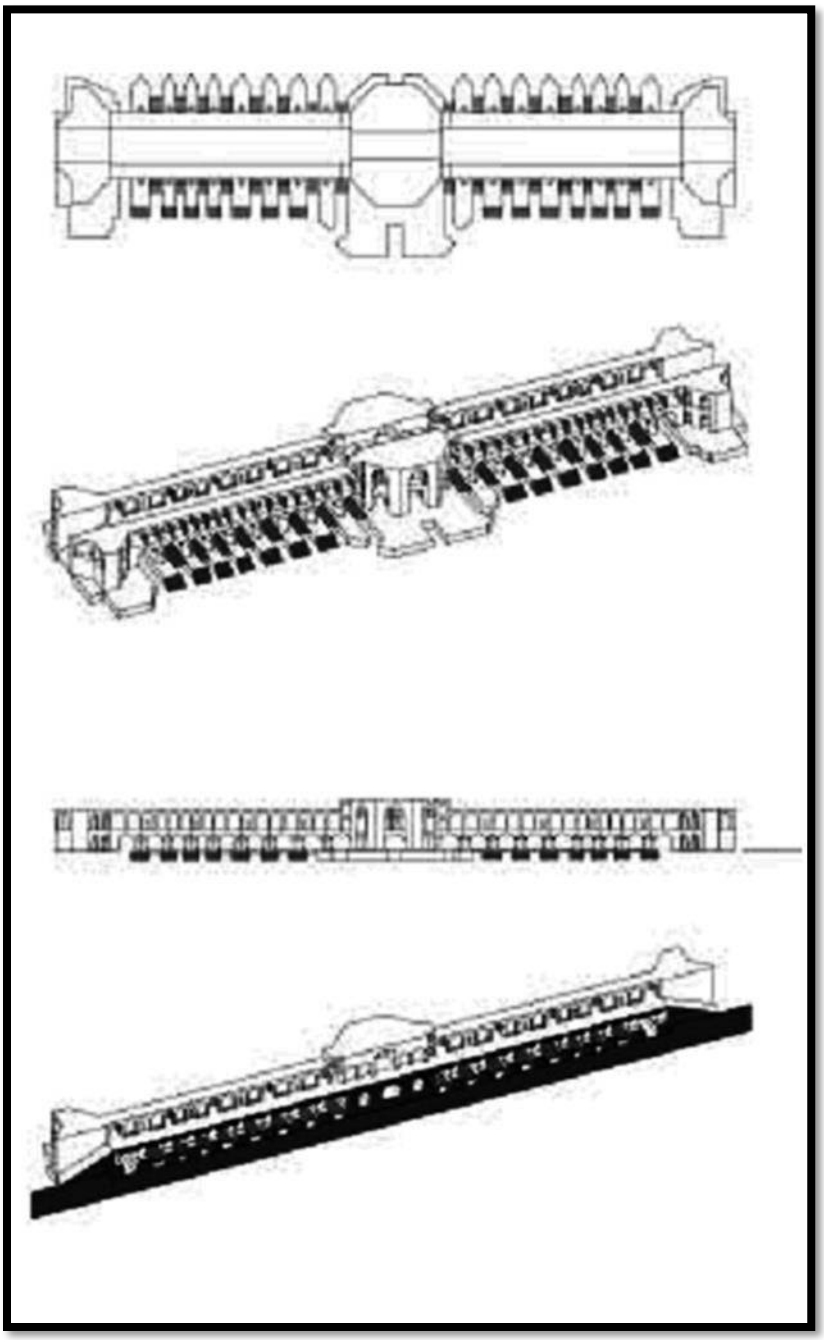

Figure 4. Plan, axonometric, elevation and axonometric sections of the Khaju Bridge in Isfahan (photograph by Michael, Gharleghi, 2012).

Section 3: The Khaju Bridge from a technical point of view

Section 3.1: Water-inspired architecture

Water has a special meaning in Persian culture, causing architects to combine structures with the needs of water. Owing to the fact that water and life were dependent on each other in Persia, the concept is a symbol of hope and it has endowed urban design projects with life (Upham Pope, 1969).

One of the main reasons for designing the Khaju Bridge was to combine the features of the river and water. The architect of this bridge wished to combine the concept of water with the characteristics of the bridge for urban design. Furthermore, the architect designed the bridge as a place of enjoyment, making multiple uses of the water, where the people of the city could live and play nearby, both on and in the water (Alexander, Neis, Anninou and King, 1987). The use of the water in this structure brings the concept of harmony with nature to this bridge. In addition, the river breeze helps to cool the air in the atmosphere of the platform and so control the temperature in the summer heat (for more details please refer to Figures 5, 6, 7).

Picture A Picture B

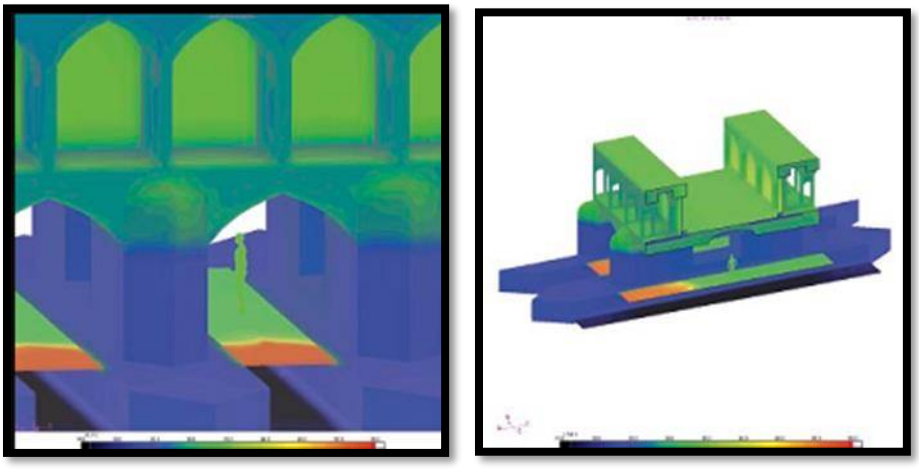

Figure 5. Picture A shows an axonometric of the bridge and Picture B shows the section of Khaju Bridge. Analyses of heat transfer shows that surface temperature of Khaju Bridge during the summer time is cool owing to the fact that the special design of the structure brings about a comfortable environment on this bridge. (Hensel, Gharleghi, Craig, Hensel, 2012) (photograph by Hensel, Gharleghi, Craig, Hensel, 2012).

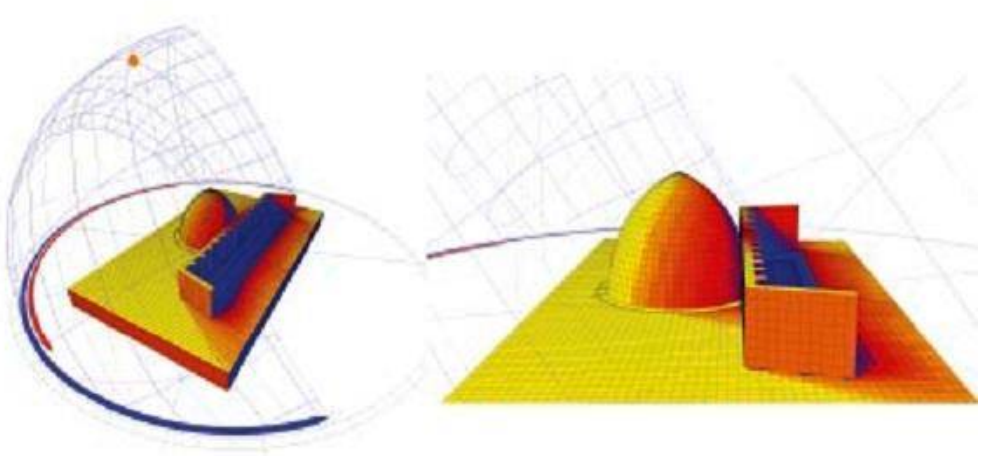

Figure 6. 3D models of Khaju Bridge with solar analyses, the facade of Khaju Bridge protects the water pond from the deleterious effects of the sun and wind. Research shows that during the winter time the pond does not receive any direct sunlight which can mean ice forming in cooler temperatures above 0˚C. (Hensel, Gharleghi, Craig, Hensel, 2012) (photograph by Hensel, Gharleghi, Craig, Hensel, 2012).

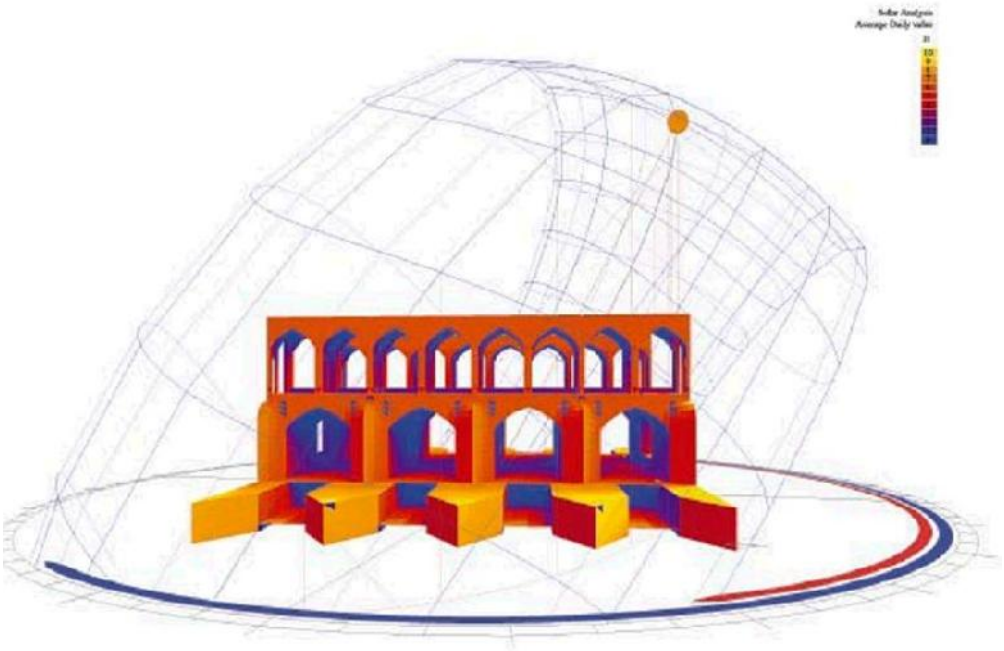

Figure 7. Solar analyses displaying the shaded area of the two floors of Khaju Bridge (photograph by Hensel, Gharleghi, 2012).

Isfahan is located in an arid or semi-arid area and the temperature is high during the summer, reaching an average of 30C in July. During the summer, there is no notable rainfall in this region (Misaghi and Mohammadi, 2003) and for this reason the utilization of natural sources for the purpose of cooling is paramount. The river water can provide better conditions for the people who live in the region. The use of the Khaju Bridge combines the cooling effects of water with hydraulic engineering in a practical design project (Khora Sanizadeh, 2008) (Figures 8 & 9).

Figure 8. The simplicity of the stepping stones across the Zayandeh Rud River in Isfahan (photograph by Shanin, 2006).

Figure 9. The Khaju Bridge in harmony with water and nature (photograph by the Cultural Heritage Organization of Iran, 2010).

Research on the bridge's interaction with the geographical elements shows that the design allows airflow through the bridge (Hensel, Gharleghi, 2012). Computer fluid dynamics (CFD) show that in terms of design, the shape and the façade of the bridge changes the geographical airflow in the area and bring about a constant breeze through the structure. The effect of the

bridge's intervention in the aerodynamics of the area is that it cools the surface area and creates better conditions for people in the dry summer season (Figures 10 & 11).

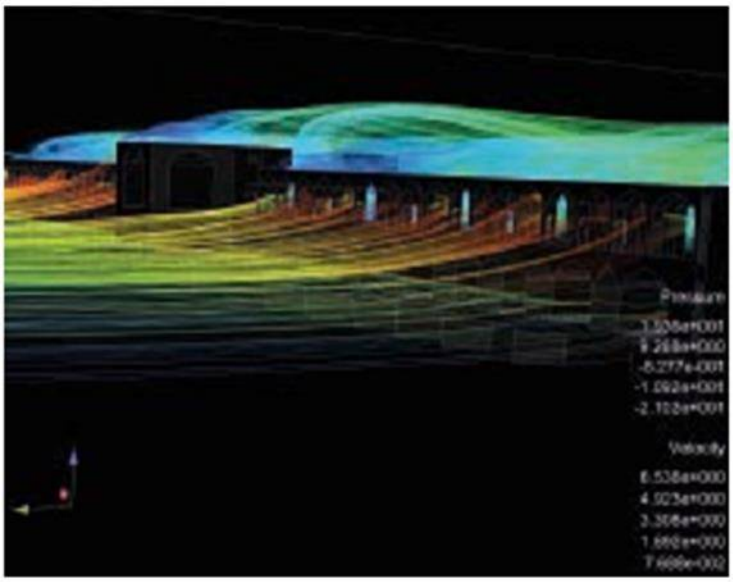

Figure 10. Analysis and modelling of the structure using computer fluid dynamics (CFD) (photograph by Hensel, Gharleghi, 2012).

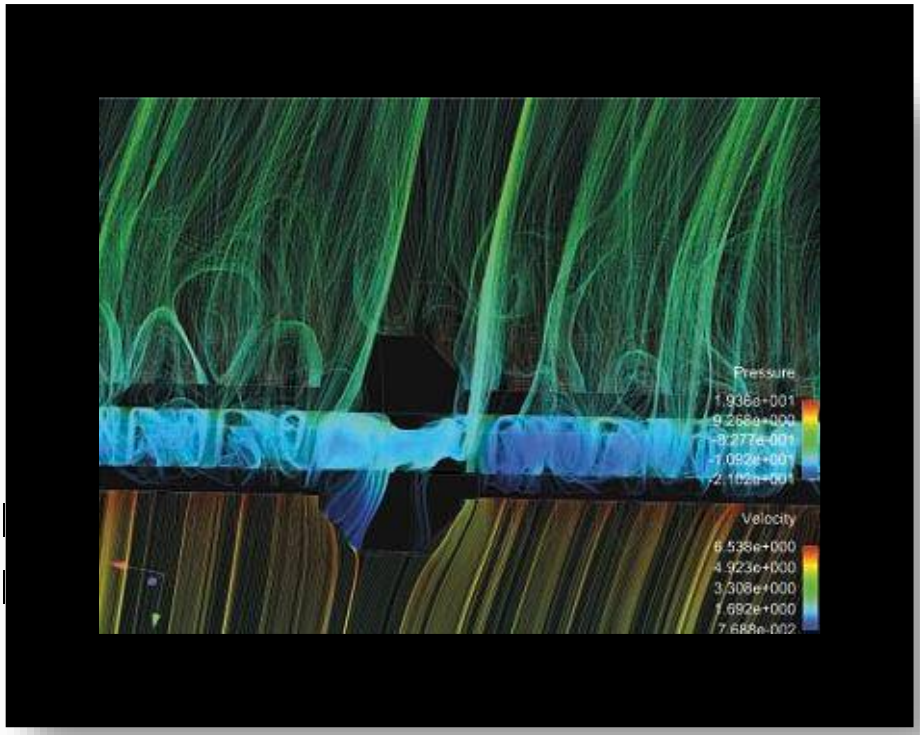

Figure 11. Analysis showing that the evenly spaced arches in this structure change the wind speed bringing a low breeze (3.2 kilometres per second) onto the roadway. This means that the structure brings about a comfortable environment along the path (Hensel, Gharleghi, Craig, Hensel, 2012) (photograph by Hensel, Gharleghi,– Craig, Hensel, 2012).

Section 3.2: detail and structure of Khaju bridge

With regard to the structure and foundation details of Khaju Bridge, until very recently scientists around the world could not ascertain the precise engineering details of its foundations. However, recent research shows that the foundations play a significant role in this structure (Shah Karami, 2006). According to Doctor Shah Karami (faculty member of the Department of Civil Engineering at Amirkabir University of Technology, Tehran Polytechnic), Khaju Bridge's foundations are the key for the variety of functions of the bridge, for instance, the sequence of in-situ piles in the foundations create the multifunctional character of this bridge (Figure 12). This bridge has four main technical roles. First of all, the foundations of bridge protect the bridge from landslides and earthquakes. This is because Iran is located on an earthquake belt which means that the risk of seismic activity is high. Secondly, the foundations of the bridge avoid settlement and cracking in this structure. Thirdly, the engineering of the foundations improves the ground resistance. Finally, this bridge plays a significant role in the water management system for the whole Isfahan region, which means the bridge brings a balance between water and land in this region. In terms of hydrology and geo-hydrology in the Isfahan region, this city does not require a water management system. This is a direct consequence of the existence of the bridge (Shah Karami, 2006).

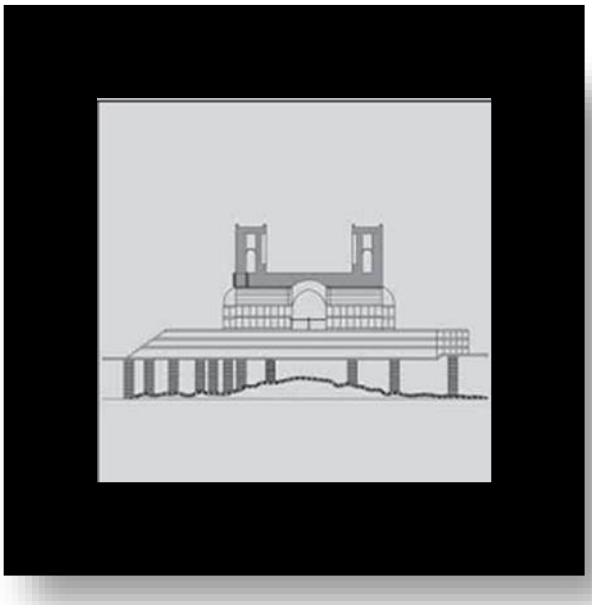

Figure 12. Section of Khaju Bridge and foundations (photograph by Shah Karami, 2006).

SECTION 3.3: POSITION OF KHAJU BRIDGE IN ISFAHAN

Khaju Bridge is a novel way of conceptualising urban design by bringing together the idea of positioning, structure and performance in urban design. The structure and hydraulic engineering of this bridge are in perfect harmony with the natural substrate and Isfahan's geology. For example, the foundations of the bridge play a key role of being an underground dam which provides the underground water tanks for the Isfahan region. This characteristic of the bridge brings three main purposes to the bridge. The first is to provide an underground water table for the Isfahan region. The second is that it is a land drainage system for the region. Thirdly, It manages the groundwater flow directions of the river and the source of water supply for the city (Figure 9) (Shah Karami, 2006, p78, 79).

Section 4: design of Water channels in Khaju bridge

Khaju Bridge has 21 channels on both sides of the Zayandeh Rud River which is divided by the bridge. Each channel has 7 gates on both sides of the bridge. Those channels and gates play a variety of roles for the Zayandeh Rud River. The precise size, height and angles of the gates and channels bring a number of engineering innovations (Figures14 & 15). For instance, they reduce the effect of water erosion on the structure, the ability of the structure to deal with the destructive force of water is then used economically as they create pisciculture ponds downstream of the Zayandeh Rud River (Shah Karami, 2006). The engineering and design of the water channels are decisive in creating nonlinear dynamics and reducing the turbulence of the water flow. The management of the water flow in this bridge creates an exciting landscape for the city and substantially reduces the turbulence of the water (Figure 13).

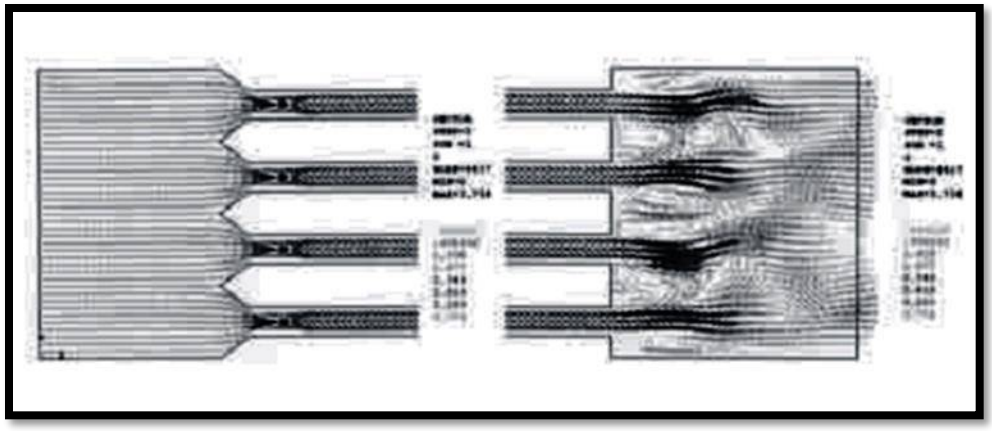

Figure13. The management of the water flow by the bridge's channels in the Zayandeh Rud River (photograph by Shah Karami, 2006).

Picture A Picture B

Figure13. Picture A shows the flooding of the Zayandeh Rud River. Picture B shows the special design of the water channels and the reaction of the structure to the river flooding (photograph by Robert Byron [1905-1941], 1933-1934).

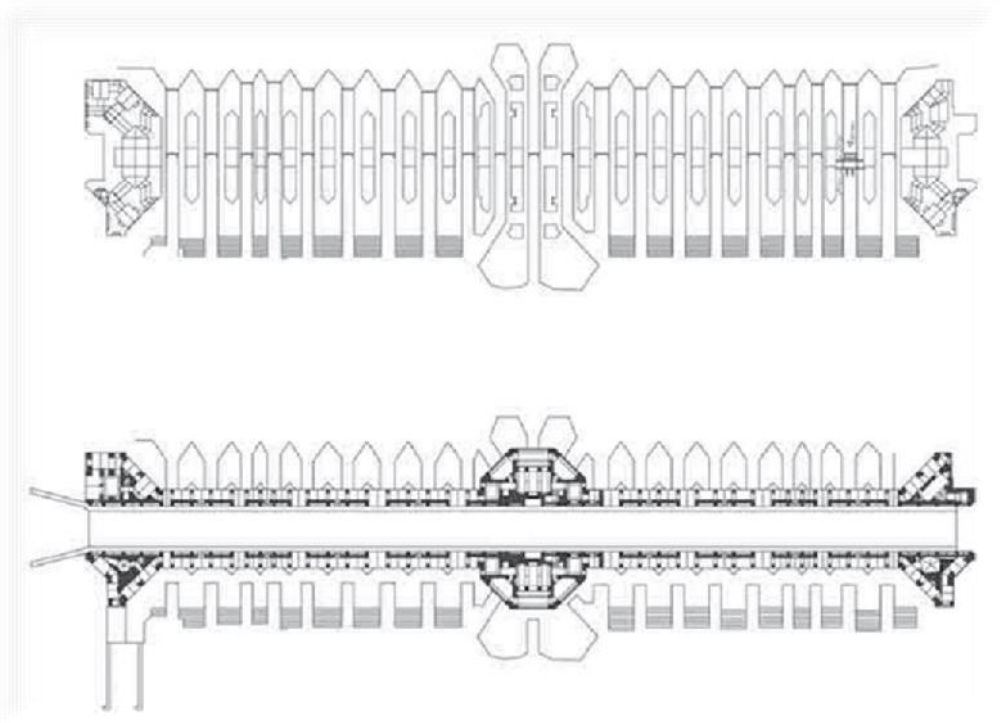

Figure 15. The top plan presents a base balance and channels of Khaju Bridge which are made from rock and the down plan presents the level crossing of the bridge (photograph by Shah Karami, 2006).

Section 4.1: adjustment of changes TO the river flow

One of the significant innovations of the Khaju Bridge is that it adjusts the speed and the direction of the river waters both upstream and downstream of the bridge. This innovation, related to the interaction between the water and the structure, is achieved in four steps, at the entry of the water from upstream, at the entry of water into the bridge, when the water is in the structure of the buildings and at the exit of the bridge (Shah Karami, 2006).

Firstly, the entry of the water from upstream: the material of the base of the bridge is rock and the longitudinal slope of the rocky bottom and the steep angle of the basic bridge create altogether the shape or the geometry of the water. This makes the water run with a minimum of turbulence inside the structure. Immediately after the entry of the water the rock is built at a 40 cm height difference between the river bed and the rocky bottom of the bridge. This creates

the bulge shape of to the structure which directs the water in to the bridge (Shah Karami, 2006) (Figures 16 & 17).

Figure 16. Outside view of the channel. (photograph by Shah Karami, 2006).

Figure 17. The inside view of the channel. Notice the difference in height between the river bed and the bottom of the bridge (photograph by Shah Karami, 2006).

Secondly, upon entry of the water into the bridge each channel has a 185 cm width and 220 cm height. The form of the channels inside has a bulge shape which is made by rock. It is configured as a U ring shape (please refer to Figure 18). This U shape can play two different roles in the bridge. The first is to be a fulcrum for the gate of bridge which can allow the water to rise up to 4 metres in to the river. The second is to protect the channel for erosion of the water (Shah Karami, 2006).

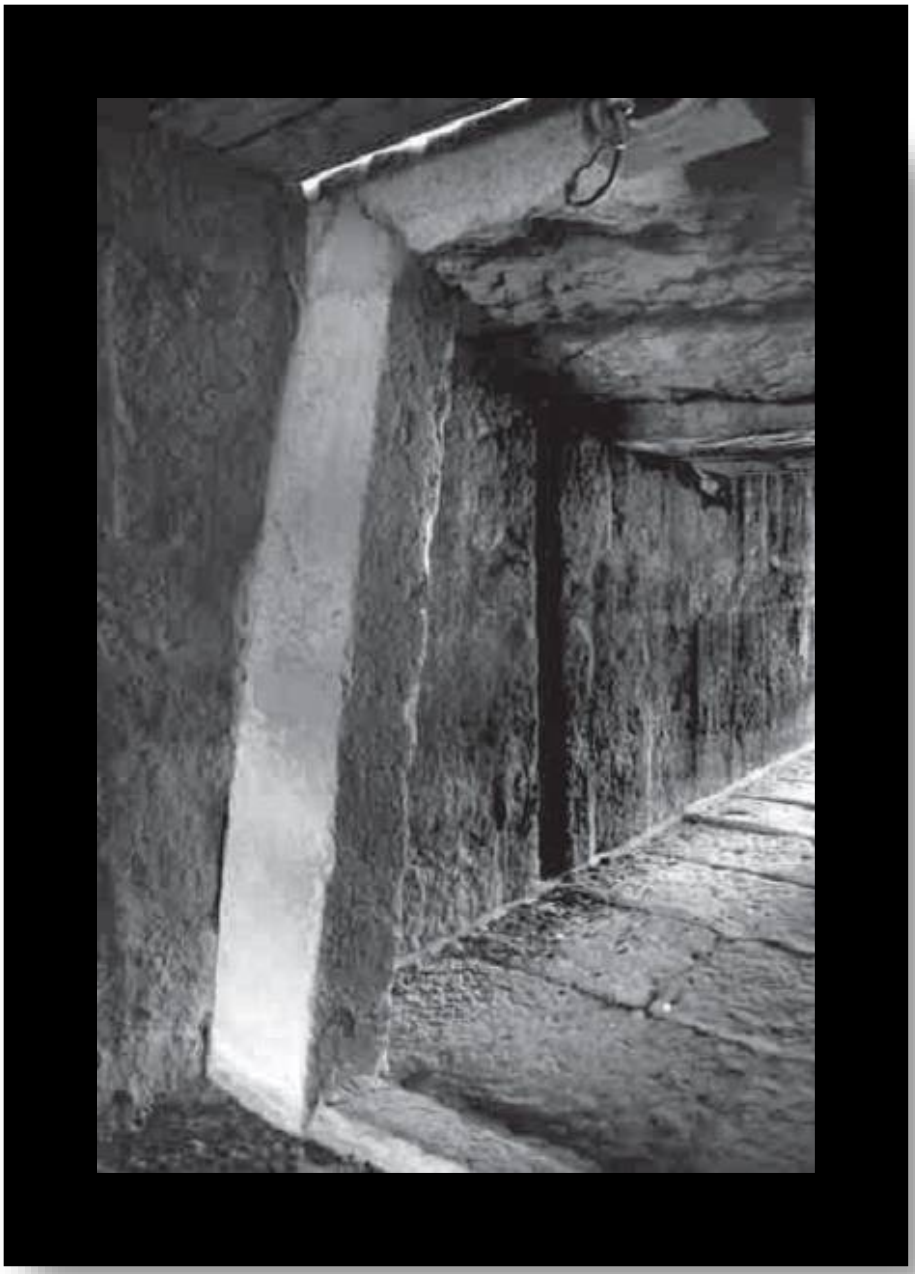

Figure 18. U ring shape inside a channel (photograph by Shah Karami, 2006).

Thirdly, when the water is in the structure the different angles inside the channels and the cross currents of water inside create bubbles inside the bridge. This oxygenises the water for sustaining aquatic life. This makes the water able to sustain fisheries and have an economic purpose, such as pisciculture ponds downstream of the Zayandeh Rud River. (Shah Karami, 2006) (Figure19).

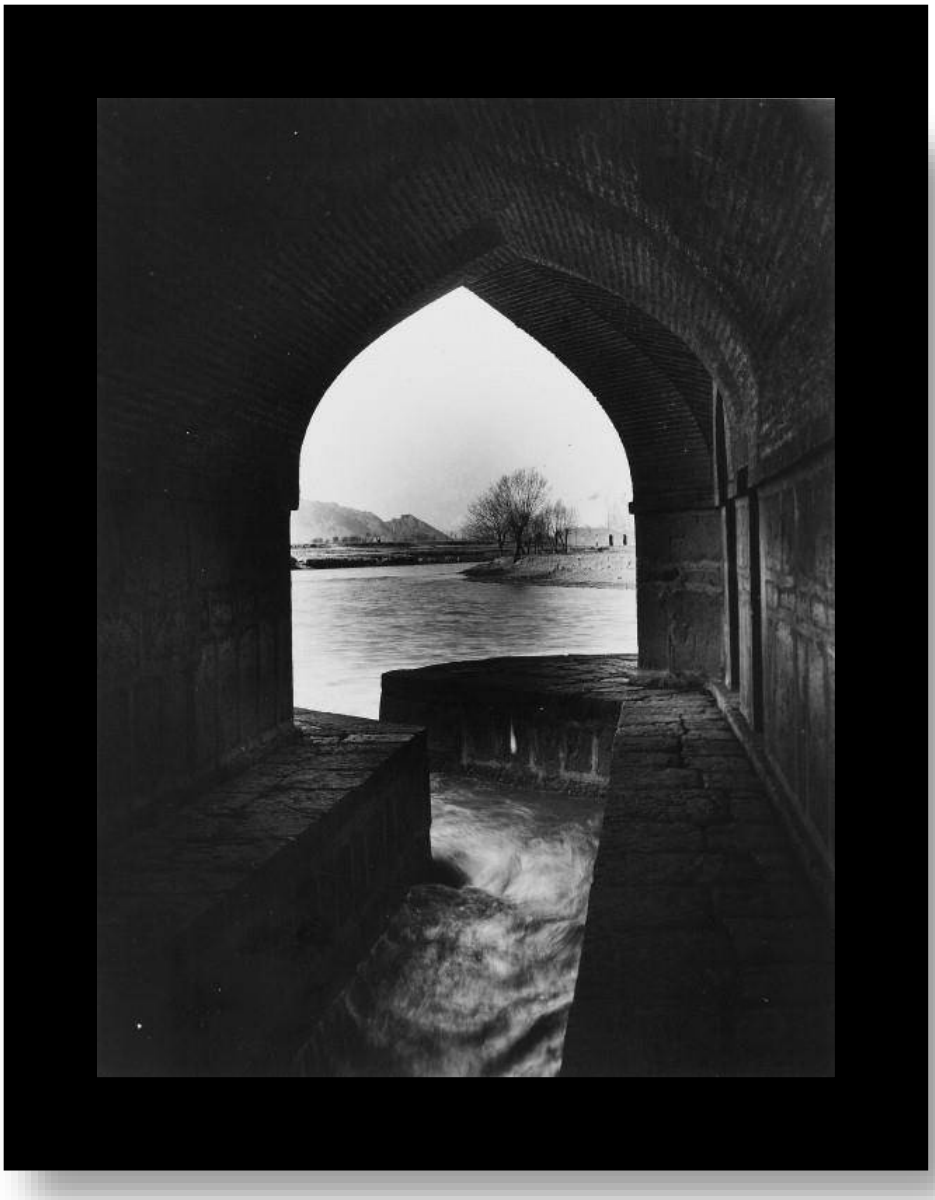

Figure 19. The sluice gate under the bridge. The sluice gate is located under octagonal pavilion called “Byglrbygy” (photograph by Robert Byron [1905-1941], 1933-1934).

Fourthly, at the exit of water, the special design of the channels calms the water wave upstream of the Zayandeh Rud River and changes the waves of the water downstream of the river (Shah Karami, 2006). (please refer to Figure 20).

Figure 20. The contrast between the upstream and downstream water dynamics. Upstream is turbulent and downstream is calm due to the intervention of the bridge.(photograph by Shah Karami, 2006).

Section 4.2: Visions

With regard to the ideas of the wholeness and the visual, the Khaju Bridge has a significant character. In this bridge we can find the meaning of thrust, an excitement and vision, and with these elements brought together it is an undeniably human concept with a sort of dream-like

quality, with direct concern for life and a genuine human vision (Alexander, Neis, Anninou and King, 1987).

This concept of the vision of the Khaju Bridge has already been used in contemporary urban design in Malaysia. There, the Putra Bridge is one of the finest examples. It has three decks and provides vehicle, monorail and pedestrian crossings, in addition to restaurants located at the main pillar of the bridge where people can access them directly (Niroumand, Jamil and Zain, 2011). The Malaysian bridge borrowed its concepts from the Khaju Bridge (Niroumand, Jamil and Zain, 2011).

This example in Malaysia shows how the visionary character of Khaju Bridge can influence architecture in modern urban design in other countries (Figure 21).

Figure 21. The Putra Bridge in Malaysia (photograph by Niroumand, Jamil and Zain, 2011).

Section 5: comparison of Khaju bridge in the 17th century and the 21st centery in urban design

As stated in Dr Canby[5] the Khaju Bridge in the 17th century was located on an axis with *maidan* (the town square). During this period the bridge played a significant role in the urban design of Isfahan. It was connected with the bazaar on the north bank of the river and 'The Zoroastrian quarter' on the south bank (Canby, 2002 p133) (The Zoroastrians lived in the area called *gabr-mahalle* which means 'The Zoroastrian quarter'). This area is located outside the city wall in Isfahan (Rose, 2010,p176). In the 21st century this bazaar and the Zoroastrian quarter have disappeared. According to the municipality of Isfahan in the 17th century Shah Abbas II built palaces , gardens and streets on the south bank of the river. In the 21st century these places still exist. For example, a street in the south bank is called 'Faiz Street', however, nowadays, instead of having a bazaar and the Zoroastrian quarter this bridge brings a connection to 'Faiz Square' on the south bank and 'Khaju Square' on the north bank. So the bridge connects 'Faiz Square' with the Khaju Square (Figures 22 & 23).

[5] Doctor Canby (2002 Sheila R) is head of the Metropolitan Museum's Department of Islamic Art in the USA).

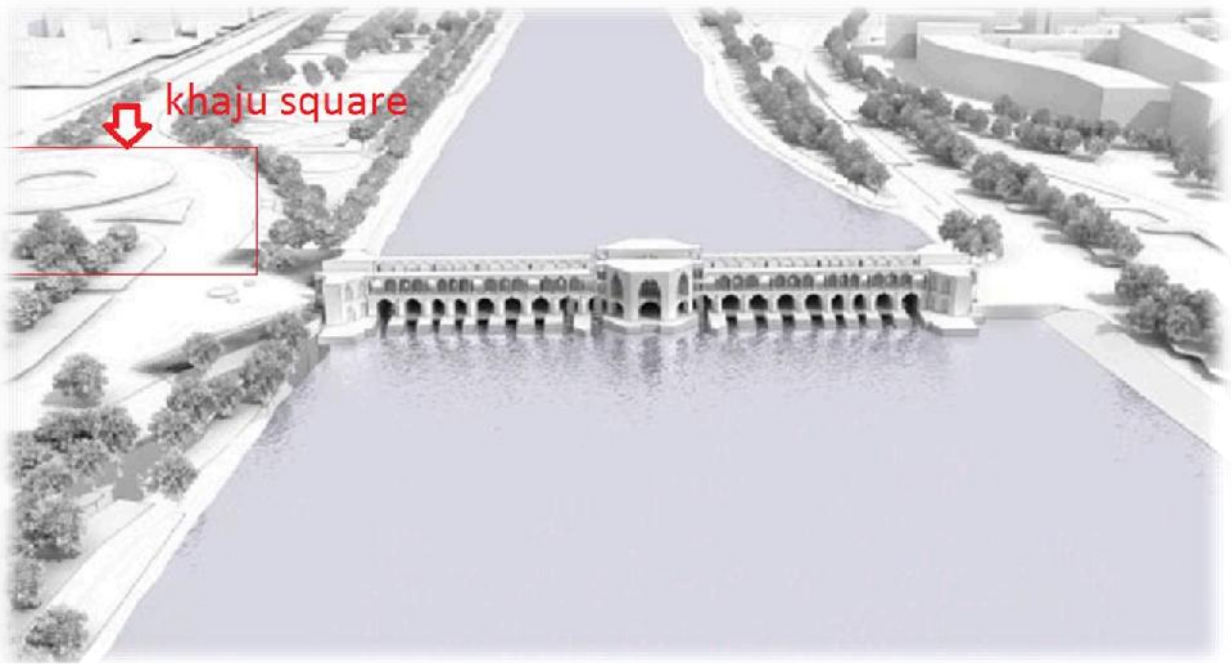

Figure 22. A 3D model of Khaju Bridge in the 21st century connecting Khaju Square on the north bank of the river with Faiz Square on the south bank (photograph by Hensel, Gharleghi, 2012).

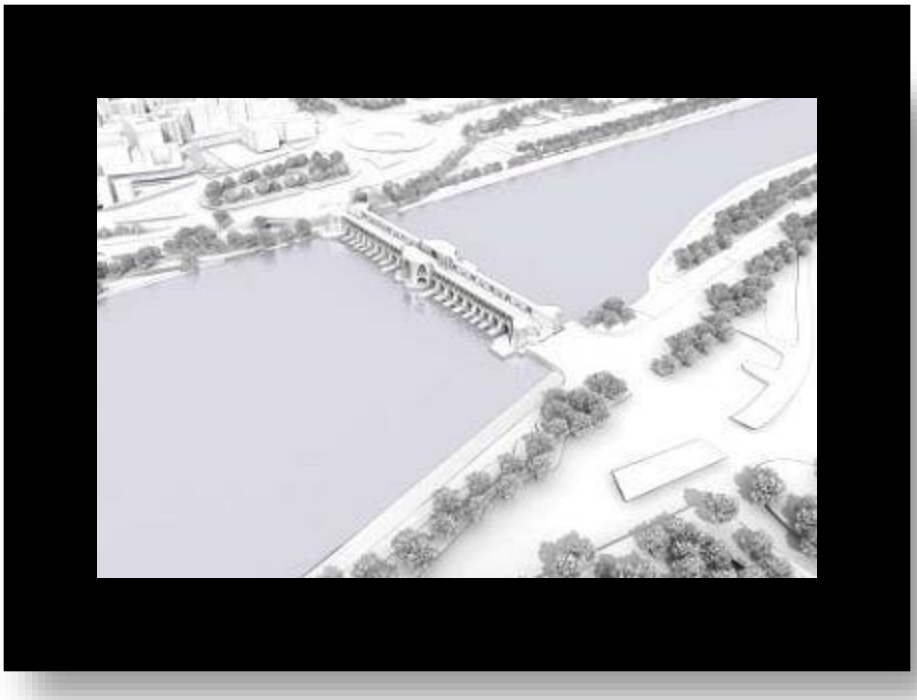

Figure 23. A 3D model of Khaju Bridge (photograph by Hensel, Gharleghi, Craig, Hensel, 2012).

Section 5.1: Zayandeh Rud River in the 21st century

The key functions in this bridge come from its ability to deal with water of the Zayande Rud River as explained in section 4.1. However, in the 21st century the bridge no longer sustains fisheries because of pollution. In the early 21st century pollution of the Zayande Rud River is so high that the bridge cannot sustain aquatic life as in the past.(Shah Karami, 2006).

In the 17th, 18th, 19th and even the 20th centuries the river water was used for agriculture and for drinking purposes, however, in 21st century the pollution of the water not only affects Isfahan but also minimizes the function of the Khaju Bridge as a landmark. As reported by Professor Pourmoghaddas in 2010 (Department of Environmental Health, University of Medical Sciences, Isfahan) the water is extremely contaminated well above the standard level of water quality for drinking purposes. In addition, research shows that downstream of Zayandeh Rud River is not suitable for agricultural and industrial uses. (-Pourmoghaddas, 2010). In addition, highly polluted water has had an extremely negative effect on the structure of the bridge and has affected the old Iranian tradition of visiting the bridge, changing the ancient culture of being in relationship with the water and landmark.

Section 6: Conclusion

In terms of the concept of wholeness, the balance between the past and the future can be crucial in the urban context. Analyses of the Khaju Bridge as one of the most significant cultural heritage sites of Iran show that some old structures can play an important role in a region. This bridge is a key example which shows that an aged structure can bring a novel concept to urban design. Not only do some aged buildings have the potential to be city landmarks, they can also bring with them some sort of conceptual idea for future structures. However, with the high pollution in the eco-system, the Khaju Bridge is constantly under the threat of erosion. Therefore, the concept of “wholeness” that this building brought to the area is in jeopardy along with the concomitant consequences for urban design.

It can be established that with regard to the Khaju Bridge, certain benefits of aged buildings in urban design are always significant. The ideal course of action would be to achieve equality between the requirements of old structures in cities on the one hand, while on the other hand bringing new perspectives of architecture to some old buildings as a piece of heritage reflecting cultural identity rights.

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