MANZAR, 11 (47): 56-67 / Summer 2019
DOI: 10.22034/manzar.2019.182617.1948

Research

Urban Rivers and Resilience Thinking in the Face of Flood Disturbance

The Resilience Planning of the Kan River *

Farshad Bahrami**
University of Tehran, Iran.
Ayda Alehashemi
Imam Khomeini International University, Qazvin, Iran.
Heshmatollah Motedayen
University of Tehran, Iran.

Abstract | Resilience, a new approach to environmental disturbances, has attracted the attention of landscape architects in recent decades. This approach is an appropriate alternative to rigorous engineering approaches and has been extensively used in different landscape projects around the world.

The Kan river, the main river of Tehran, is still vulnerable to flood disturbance even though its infrastructures have been improved to control the flood. Rigid and one-dimensional approaches to flood control not only has failed to control flooding but also destroyed the ecological and structural infrastructures of rivers. This paper seeks to investigate how the environmental resilience approach can affect flood management in urban rivers. It mainly focuses on the role of resilience thinking and its potential contribution to the regularization of the Kan river in response to flood disturbance. To this purpose, in this paper, four successful projects in the world were examined to extract the principles and strategies of resilience in the face of the river flooding. Planning and strategies were proposed based on these principles and guidelines for this chaotic river. Time, trial, threshold, learning, and diversity as the principles and cut and fill as well as wetlands as the strategies were extracted from the projects to address the disturbance of the river. As a variety of disciplines play a key role in flood control, the necessity for multidisciplinary integrated approach and planning is much felt. The integration of principles and strategies, planning, and organization of the landscape lead to a comprehensive and multidisciplinary program. In other words, the Kan river planning management requires a multidisciplinary approach which addresses landscape and ecological issues. This comprehensive and multidisciplinary planning based on flood resilience can serve as a model for other urban rivers that are vulnerable to flood disturbance.

Keywords | Flood; River Management; Resilience; River; Landscape Architecture.

Introduction | Landscape architects face many challenges in managing, planning, and designing environments, landscapes, and exterior spaces. Such challenges that influence different aspects of landscape such as ecological, social, economic are often caused by human intervention or natural disturbances, and can jeopardize urban infrastructure, and impair the process of developing the environment and landscape.

Resilience-based management has received much attention from different disciplines and has been extensively used in urban spaces and landscapes against different disturbances. This approach, which employs the systemic view to adapt urban spaces to possible chaos, has also recently gained the momentum in managing and organizing urban

** Corresponding Author: farshad.bahrami@ut.ac.ir
+ 989398116461

rivers. The importance of this approach lies in organizing and using urban spaces, specifically in urban rivers, in different conditions. In other word, this approach preserves the environmental, ecological, and structural conditions of urban rivers in response to disturbances and enhances the adaptive ability of such spaces to cope with different conditions and disorders.

Urban rivers, especially the ones in Tehran, are increasingly influenced by challenges and disturbances such as floods and droughts. The Kan river, as the main and largest river in Tehran, is highly chaotic. Flooding as the main disturbance of the Kan river incurs many economic and human losses every year (Mashreq News Agency, 2015; Fars News Agency, 2015). So far it has destroyed green infrastructure, human spaces, and architectural spots as well as discouraged people to be in contact with nature. City managers and counselors have adopted different approaches to address the river disturbances. For instance, channels have been built on the riverbank, and this rigorous engineering approach has long been used for controlling the chaos of most of the urban rivers in Tehran. Despite all the efforts, the flood as chaos continues to threaten the rivers, especially the Kan river, and this one-dimensional and rigorous approach has not been able to control the flood disturbance. In addition, channels created for flood control have reduced the ecological efficiency, and over time have destroyed the structure of the river and its inlets (Renault, 2018).

This paper attempts to investigate how the environmental resilience approach can influence flood disturbance management in urban rivers. More specifically, this paper addresses the role and potential impact of this approach on the management of the Kan River, in Tehran, in response to the flood.

To answer these questions, this paper attempts to analyze the sample of urban rivers management project planned and implemented based on resilience, and to identify the indicators and criteria of effective resilience approach in planning urban rivers. By evaluating and examining the current status of the Kan riverbed, the most important and most chaotic river in Tehran, this paper examines the possibility of utilization of these criteria in planning and management of the river. The results of this paper specifically provide guidelines for planning and management of the Kan river based on the resilience approach in environmental science.

Resilience in the face of river flooding

Resilience thinking was first proposed by Holling (1973) in relation to ecology and dynamic ecosystem systems. In Holling' point of view, resilience is the ability of a system to absorb disturbances, while remaining its function. Since then, resilience has been defined in various disciplines and fields such as resilience psychology (Rutter, 1993; Tusaie & Dyer, 2004), resilience engineering (Hollnagel, Woods & Leveson, 2007; Hollnagel, 2011), engineering resilience (Holling, 1973; Ludwig, Walker & Holling, 1997), ecological resilience (Gunderson & Holling, 2002; Walker Holling, Carpenter & Kinzig, 2004), social resilience (Adger, 2000; Langridge et al., 2006), socio-ecological resilience (Folke, 2016), urban resilience (Meerow, Newell & Stults, 2016), and other disciplines. Despite differences in the definitions proposed in various fields, there is a general consensus on this issue. Resilience is an environment related concept or it is conceptually related to systems. Resilience is a way to understand the capability of a system in the face of disturbances (Folke, 2016); or to demonstrate how systems are resistant to disturbances.

In relation to flood, resilience has been conceptualized as the ability and resistance of a system against disturbances or their absorption (such as storms and small clouds); in addition, the system is able to operate in a wide range of disturbances (floods or extreme rainfall) without losing its function (Zevenbergen, 2016). In this definition, the emphasis has been on the function and performance of the system; in other words, this definition emphasizes the stability of the structure and function of the system, its ability to return to pre-disturbance conditions and to maintain its identity against floods. In discussing the resilience of rivers in the face of floods, attention should be drawn to all aspects of landscapes, including social, economic, and infrastructure dimensions. In addition, gaining the maximum benefit of flood in developing and increasing system capabilities can increase the resilience of rivers. Flood is one of the natural features of rivers. However, human intervention and extensive interferences in nature; and consequently, climate change as well as global warming have made a natural disaster out of this natural feature. Despite its damages, the flood has many environmental and economic benefits (Green, 2010). In this regard, reducing the risk of urban river flooding and maximizing the benefits of the flood can increase the resilience of rivers.

Landscape resilience and regularization of urban rivers

Rivers are inherently dynamic. The dynamic structure of rivers is changing for a variety of reasons, including human and natural processes (Liao, 2014). In this regard, the best strategy for living in dynamic spaces and coping with their unpredictable situations is an endeavor to make these places resilient (Gunderson & Holling, 2002; Berkes, Colding & Folke, 2003; Liao, 2014). In fact, any attempts for controlling natural forces are futile, and the evidence pieces for this claim are the Red River of 1997 and the Mississippi River of 1993 in the United States. Instead of letting the river take its natural course, the structures which were built for flood safety exacerbated the situation at the time of the flood

(Bell, 2012). This means that the resilience approach is an appropriate alternative to the flood resistance approach. In addition, it is important that flood is not merely chaos and danger, but rather it is part of the vital processes of nature that include the economic value of ecosystem services (Postel & Richter, 2012; Tockner, Bunn, Gordon, Naiman, Quinn & Stanford, 2008).

In this paper, to identify the principles and extract management strategies, four successful case studies were reviewed and analyzed. This projects, in which (1) Wadi Hanifah river in Saudi Arabia; (2) Mekong Delta river in Vietnam ;(3) Yanweizhou Park in Jinhua City in China; and (4) Yiwu Riverside Green project in China, play a leading role, were drawn upon for generating the theoretical framework and the indicators of resilience in the face of river flooding. The selections of the case studies were guided by a variety of reasons. All the projects have won global awards, have been successful in response to potential disturbances, and have considered the human being as the main component of the landscape. Moreover, they have been based on the indigenous methods and structures. This article attempts to analyze and categorize the actions taken in the projects, and draws inferences about the strategies and principles of the resilient planning.

1. The Wadi Hanifah Project[1]

The Wadi Hanifah river project in Saudi Arabia was a challenging project in the field of landscape architecture and in response to flooding (Fig. 1). The special position of this river in Saudi Arabia, its challenges and disturbances encouraged a group of landscape architects, ecologists, and other experts to design this river. The main challenges of the project were seasonal floods, flash floods, and water pollution. Designing and implementing the project were guided by three basic principles. Available literature highlighted the importance of three principles of "time, threshold, and trial" in the landscape architecture of this project (Moosavi, 2018).

Time: In the process of designing this project, time was the most important principle contributed to its goals. The design team adhered to the principle of "time" to pay particular attention to past geological and human processes that shape the current conditions of the Wadi Hanifah, and to examine the effect of time on ongoing and future processes over a long time. Based on their historical knowledge, the design team examined the changes in the shape of the ground, the natural forms, the previous structure, the forces of nature, and the culture of the past. Designers used a systematic approach to review the process of the project and identify its dynamic processes. In addition, the design team attempted to have a better understanding of the future natural and ecological processes which required a long-term schedule and plan. Additionally, the design team focused on the invisible processes in the Wadi Hanifah river System (Ibid). The invisible processes in this project referred to ecological processes and changes in the dimensions, attributes, and ecological dimensions. Understanding the processes and their observations were possible through the ecologists' accurate assessment of the situation of the river.

Trial: To reduce the risk of flooding, the design team took different measurements based on the shallow depth of the river. The measures, including opening the riparian zone, creating wetlands, and lakes for storing as well as penetrating water into the deep layers of ground (Fig. 2). The lakes

Fig. 1: Wadi Hanifah river. Source: Moosavi, 2018.

were designed for a variety of purposes, including providing recreational facilities. Additionally, slopes along the river were modified according to engineering standards and local stones which were used for building natural lacks to control erosion (Moosavi, 2018). In addition, numerous berms were designed to slow runoffs and floods flow. The designers believed that these vegetation-rich spaces on the islands were important for growing plants and reducing soil erosion. In addition, they can generate biodiversity in the river (Gurnell, 2014).

However, the heavy flood in the river ruined the berms and revealed the nature of the berms in the face of the huge flood (Moosavi, Grose & Walliss, 2015). This trial was a deliberate or unplanned (random, unplanned, and unspecified), it was also known as "in situ testing" based on real-time data and real forces. This trial showed that the berms needed to have a greater resistance to flood speed. The failure of the berms clearly confirmed the high levels of uncertainty of the model and timing issue in the landscape system, and it highlighted the need for a more robust and flexible design. This shows that intra-river modelling through trial and error can create opportunities for designers; however, this is a very tedious and time-consuming issue. There are currently alternative methods for on-site modelling that addresses time and budget constraints. Digital modelling and simulation in environmental design and landscape are new techniques for obtaining more accurate data that make designing easier in the vicinity of flooding rivers and coastal zones (Girot, 2013; Moosavi et al. 2015).

Thresholds: The thresholds in the field of biotechnology refers to turning points at which small changes in environmental conditions caused by human or natural disorders lead to a change in ecosystem status (Sasaki, Furukawa, Iwasaki, Seto & Mori, 2015). Changes in the natural process lead to fundamental changes in the environment and consequently, chaos. In addition to the chaos, the changes can influence the landscape design process of this environment, and the design team will be forced to change the design process or methods to adapt them to the environment. This highlights the importance of understanding the threshold or, in other words, environmental and ecological conditions.

In Wadi Hanifah river project, 2013, the region was stricken by heavy flood, and this resulted in a sudden increase in sediment and organic materials through the flood. This led to an increase in the number of microorganisms in the environment and the population of intrusive fish, especially tibia which feeds on algae. As a result, the number of algae and other aquatic organisms decreased with nitrogen, carbon dioxide, calcium, and other harmful substances in the water. The changes in the system exceeded the threshold of purification capacity, and deteriorated the water quality. To keep the ecological balance in the food chain, environmental engineers were forced to reduce the number of invasive species (Moosavi, 2018). Therefore, identifying environmental threshold systems and using feedback and repetition circles in design can help improve the damaged system (Ibid).

Based on what has been discussed, three basic principles have influenced Wadi Hanifah's project. This analysis shows the importance of "time" as a major component of the process. In addition, "trial" during design and ex-

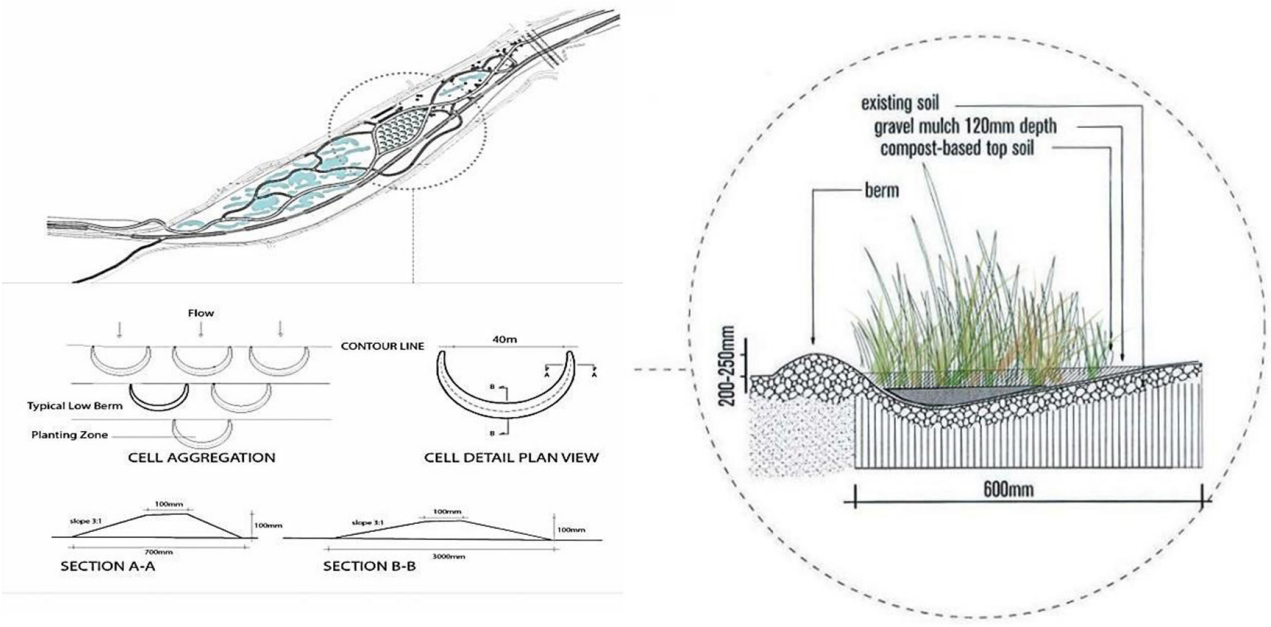

Fig. 2: A number of berms have been used in the river-bed to slow the flood flow and prevent soil erosion. The ground berms are built to reduce the water flow which creates sediments and other organic minerals. They include a curved planting area that gather soil and fertile seeds. (Moosavi et al., 2015). Background figure: (Margolis & Chaouni, 2014 cited in Moosavi et al., 2015).

periments is important to develop a reliable strategy in response to uncertainties and disturbances in designing landscape projects. Moreover, understanding the environmental "thresholds" is also necessary to manage the natural and human changes in landscape projects more effectively.

2. The Mekong Delta river in Vietnam: Traditional resilience in face of flood

Two villages, Vinh An and Ha Bo, in Vietnam are examples of indigenous resilience in the face of the flood. For these villages which are placed on the riverbank, flood disturbance is no longer a destructive element. Over time and in constant flood situations, the villagers have constructed houses and other spaces in the villages which have not been threatened by floods and in contrast they have taken advantages of flood risks (Fig. 3).

The houses of this village used to be made of bamboo and now are made of concrete. The houses are located on pilot spaces, which reduce the force of flood on the houses and results in the discharge of the flood. The empty space below each house is called "sàn". This space is used seasonally and in dry seasons, it is used for storage, rest, and livestock breeding. In flood seasons, the flood flows under the houses and this reduces the risk of flooding. In the spaces between houses, wooden bridges are built to facilitate the movement of people (Liao, Le & Nguyen, 2016).

The interviews conducted by Liao et al. (2016) show that the flood has had two important benefits for the village, and residents of the village accordingly have designed the village and their houses. The villagers have learned through experience that the flood fertilizes the soil of the region and the countryside. It also brings many aquatic animals with itself. Accordingly, the villagers have created seasonal job opportunities for themselves. In the flood season, they go fishing while in the dry seasons, they are engaged in farming (Ibid).

3. Jin Hua River Landscape architecture

The Jin Hua river landscape design project in China, lies at the intersection and convergence of the two rivers—Wuyi River and Yiwu River. This swampy and natural area has long been threatened by the flood. The landscape architect of the project, Kinjwan, has practiced several strategies to address the challenges of the project. Flood as the main challenge of the project has encouraged the landscape architect to search for an adaptation strategy. In addition to the flood, there have been several landscape challenges facing this project which are not the concern of the current study. However, in this paper, the focus is on the flood controlling strategies.

Due to weather conditions, this area (Jin Hua) has been stricken by annual floods. Like any other rivers in the world, several channels and walls, as principles and strategies, were used to control floods. These actions used to disassociate the city and its inhabitants from the river. This rigorous engineering approach used to increase the frequency and power of floods and the damages caused by them. To address this problem, the landscape architect of the project proposed different strategies. The landscape architect of the project created a balance between the river, the edge, and the surrounding area, using the "cut and fill" strategy. This strategy is adaptive with and resilient to environmental conditions (Fig. 4). By creating different terraces on the river-bank, changed the structure of the river from a channel with concrete walls to a natural structure, which in addition enhancing the relationship between the environment and the river, is adaptive with increasing water and river flow. The strategy is based on the flow rate of water. During the flood seasons, this part stays under the water while the other part stands above the water level. These terraced spaces are a very suitable for farming. In fact, flood can fertilize the soil. As a result, spaces and areas sunk in water will be very fertile due to the increased flow rate of water. Thus, flood increases the conditions for local

Fig. 3: Two villages in the Mekong Delta in the flood season. Creating pilots architectural on the flood flow and making the most out of flood for farming, fishing, washing clothes, and dishes. Source: Liao et al., 2016.

Fig. 4: Cut and fill strategy, creation of an agricultural landscape, flood control and places to have the views of the river. Source: Yu, 2017.

plants and tree that do not require irrigation. In addition, this space can also be used as a space for storing the water, strolling, and looking at something. In fact, this strategy, as an ecological solution, is capable of controlling floods and creating landscape spaces (Yu, 2017).

The second strategy which designers of this project adopted was creating spaces at different heights and promoting "spatial and altitude diversity" (Fig. 5). The creation of the dragon bridge as a cultural and social identity in the region is an important task. The bridge, stands at different altitude levels, is able to withstand annual floods and floods with a 200-year period. For example, when a flood occurs, the part of the project goes underwater. In the meanwhile, the bridge, which is over the protected island, allows visitors to be close to nature. Many ramps have been created for easy access to the bridge. The residents from different places in the city have access to the bridge. Landscape architect, in fact, designed the bridge based on the flow rate of water. Creating a spatial and altitude diversity on this bridge has made the project resilient to the flood so much so that in the most critical conditions, the bridge will not lose its core function. In fact, this bridge is connected with the city and nature, past and future (Yu, 2015).

In this project, the landscape architect has employed resilient strategies and approaches in the face of the flood to reduce flooding and maximize the benefits of the flood. The project, as one of the most successful resilience projects, has given a new identity to Jin Hua City.

4. The Yiwu lanscape architecture project in China

This project which was carried out in China was designed by Kunjwan Yu in response to several challenges. The project, an important part of urban green space along the Yiwu river, has been built in the future center of the city. For four main challenges in this project, the landscape architect has used different strategies. The challenges of the project have been: (1) flood, (2) water pollution, (3) semi-built residential buildings, and (4) low budget for maintenance. The challenges have been met by environmental solutions and resilient thinking. To meet the objectives of the project and respond to numerous challenges of the site, the landscape architect has used several strategies, such as resilient mound, wetlands, inner valleys, and farming lands (Yu, 2018). In

Fig. 5: Creating spatial and altitude diversity in the river. Using space in dry seasons and flood seasons. Source: Yu, 2017.

this research, we have just examined the wetlands.

Creating wetlands for cleaning water: Creating wetlands and mounds in the riverbed slows the flood and result in settling suspended particles in the river (Fig. 6). The mounds in the riverbed create a very suitable space for farming and cultivating native crops. Floods and runoffs carry organic materials, and such materials which are stored behind the berms can generate a suitable land for farming (Ibid).

The landscape architect of the project has adopted a resilient approach to the disturbance of the flood. The important point in this project is adaptability. Instead of being resistant to the flood, the architect has been adaptive with it. The use of the wetland in this project has turned flood disturbance to a vital and peaceful element. Examples of ecosystem approaches are flood resilience, water purification and rehabilitation, biodiversity recovery, agricultural production, recreational services, and its aesthetic experience. The Chinese government has officially recognized this project as a successful example for other cities.

Principles and criteria for a resilient landscape in response to floods

Based on selected case studies, principles and guidelines for managing, planning as well as designing chaotic rivers can be presented. Several principles and strategies used in the projects are summarized in Table 1.

The data in Table 1 was deduced from the analysis and classification of the principles and examples of interventions. To this purpose, intervention approaches and the efficiency of resilience approaches in response to disturbance were examined, and the urban resilient design guidelines were categorized and presented as follows:

Designing a resilient landscape for the Kan river based on the resilience principles and design strategies of urban rivers

The Kan river, as the main river of Tehran, has been threatened by seasonal floods every minute. This river has been considered in comprehensive plans of 1968, 1990, and 2007 years since it has the largest water catchment basin in Tehran. In the comprehensive plans of 1968 and 1990, the river has been considered as a means of controlling the flood. In addition to controlling the flood, this river has been introduced as a tourist and recreational area in the master plan of 2007 (Karimi Moshaver, 2013). The actions resulting from the comprehensive plan of 1968 and 1990 have resulted in the creation of channels for flood control. This method of flood controlling which is still in use has been one of the most challenging issues. The reason is that it not only has failed to reduce flooding in the area but also ruined the structure of the river and its ecosystem. Several floods in 2012, 2015, and the flood of April 2019 support this claim that the flood disturbance continue to threaten the Kan river. Boostan-e- Javanmardan which is the operational plan of 2007 (Alehashemi, Bagheri & Akhavan, 2015), has emphasized rigorous engineering approaches. The unsuccessful experiences in managing and designing the rivers of Tehran, including, Boostan-e- Javanmardan and imposing a foreign identity on the natural structure of the rivers, have destroyed the structure of the river and made the citizens stay away from these natural elements

Fig. 6: Creating wetlands for cleaning water, reducing runoffs and flood, creating an agricultural landscape and the architect of the landscape has made human feel close to water (by looking at nature and pondering about it) by creating the means of communication between them. Source: Yu, 2018.

Table 1: The analysis and classification of principles and design strategies in the selected projects in response to flood disturbance. Source: Authors.

Project title	Intervention	Intervention scale	Intervention strategy	Results of the intervention
wadi Hanifah river	Time	A large scale	Studying the changes in shapes of ground, natural forms, past structure, natural forces and culture	Understanding future processes and gaining experience from the past; Planning and designing based on future disturbance and uncertainties
	Threshold	Large and middle scales	Understanding natural and ecological processes and preventing disturbance	Decreasing multiple disturbances; Preserving the ecosystem order; keeping balance in the ecosystem
	Trial	Middle and small scales	Testing flood adaptability on site, or in situ testing and creating berms for flood control	Developing the best strategy adaptive with the flood;
Mekong Delta river in Vietnam	Learning	A large scale	Living in a chaotic environment; Observing and analyzing disturbances as well as gaining experience from it	Maximizing the benefits of the flood; Dynamic village
		A middle scale	Creating lands for the dual purpose of floods: agriculture and fishing	Promoting spatial diversity, functional diversity in different parts of the village; Promoting job diversity for the villagers;Friendly adapted environment;
		A small scale	Creating a "San" (pilot) space in each building; Building bridges between houses above the water level	Promoting dynamism and the adaptability of houses in response to floods and droughts;
Jin Hua river in China	Diversity	A large scale	Building bridges with different heights; Building a dragon bridge in the site	Promoting a dynamic landscape adaptive with disturbance; Creating a relationship between the spaces of the site;
		A middle scale	Creating multiple spaces to touch the water and having a view of nature: places overlooking nature ,artificial, and natural	Creating an adaptive environment with the flood; overlooking nature
	Cut and Fill	A small scale	Creating terraces in the edge of the river	Creating a landscape adaptive with chaos; Creating an agricultural Landscape overlooking nature (water);
Yiwu river in China	wetlands	A small scale	Creating mounds on the bed of the river	Promoting the adaptability with flood and reducing water speed; A strategy for cleaning contaminated water

(Bahrami, 2018). As a result, applying an approach that is consistent with the conditions and structure of the river is essential. Numerous floods and its disturbances in the Kan river necessitates the use of resilience approach in design and planning. Accordingly, designing and planning of the Kan river based on resilient thoughts and successful examples can help us to reduce flooding and restore the structure of the river and its ecosystem. Based on the principles and strategies extracted (Table 2), in planning and designing this river, the following issues should be taken into consideration.

The Impact of "time" on the planning and design process of the Kan river

It is very important to pay attention to the two period returns (i.e., past and future) of the flood in the design process. Studying the flood period and geological processes in the past is helpful to understand the natural process and predict future disturbances. Reviewing Kan river's historical trend, the natural trends in the future and predict different events such as flood, rainfall, climate change, global warming, and their impact on the river can facilitate planning and design process. For example, examining the water flow rate in different seasons, and evaluating previous reports of disturbances from different sources can help to identify the past time returns (e.g., Mashreq News Agency, 2015; Fars News Agency, 2015; Water Research Institute, 2004). In addition, studying the social aspects of the river will help to understand its historical and cultural layers

Table 2: Principles and criteria for a resilient landscape in response to the flood. Source: Authors

1. principles	Description
Time	This component deals with studying and analyzing the processes of time (past and future) in a system (i.e river). Considering this component helps landscape architects to understand, examine, and analyze geological, human, social, cultural, and ecological processes for designing resilience to disturbances.
Threshold	The threshold refers to the ecological turning point in a system. The point at which human and environmental disturbances change the system status in relation to the threshold and ultimately result in changing the system conditions before the disturbance. Understanding the ecological threshold of seach system contributes to the stability of the system in a sustainable condition.
Trial	Trial means the process of examining the conditions of components and designing them in the laboratory or on-site. Carrying out trials on the site (in situ testing) or the laboratory reduces errors and mistakes in the design process or in the event of disturbances.
Learning	Learning as one of the main components of resilience refers to achieving experience of disturbances to improve the adaptability of the system in the face of chaos. In other words, the learning principle allows the system to find ways to adapt itself to the disturbances.
Diversity	Diversity refers to different functional components which protect the system in the face of various disturbances and threats. In this regard, if disturbances influence the functions of one component, other components will contribute to the development of the system and the system will not fail.
2.Strategies	**Description**
Cut and fill	This strategy, which refers to Cut and Fill, can replace the flood control channels in the river. This strategy increases the connection of the river with the environment and human by creating diverse spaces, and it also restores the ecological conditions of the river to its natural state. In addition, creating an agricultural landscape at the edge of the river is another benefit of this strategy.
Wetlands	This strategy refers to creating high mounds in the waterway to reduce its speed. Creating these mounds along the bed of the river leads to purifying water, slowing the speed of water, and creating agricultural landscapes along the river's course.

and how social factors influence its natural structure and its ecosystem. Understanding these aspects expedites the planning and design process. As a result, adopting a systematic approach in studying the Kan river can identify the dynamic trends of factors influencing the river.

The impact of "trial" on the planning and design process of the Kan river

Using trial and error in the design process of the Kan river is inevitably required. This is of great importance because designing the Kan river based on a new and different approach has not been practiced in Iran. The necessity of examining different design methods for selecting the best one is much felt. Although this principle can be very time consuming and costly, it is very effective in reducing flood disturbance and helping to restore natural and ecological structures. In addition, using laboratory models or successful case studies in the world, and recruiting various experts in different fields can reduce the length and cost of the process. Additionally, reviewing and evaluating past efforts in the river can reveal the deficiency of previous methods used in the past. For example, examining and evaluating flood control channels can show that this method not only does fail to control the flood and its disturbance but also increase its frequency and velocity. Investigating Tehran's flood reports and recent floods in the years 2015 and 2019 supports the claim (e.g., Mashreq News Agency, 2015; Fars News Agency, 2015; Water Research Institute, 2004); and reviewing the results of Boostan-e- Javanmardan on different issues related to the Kan river such as the ecological consequences, the landscape (objective-subjective), the structural changes of the river etc., can reveal the past trials and errors in this river (e.g., Alehashemi & Shahsavarg, 2014; Alehashemi et al., 2015; Ghahroudi Thalei , Majidi Heravi & Abdoli, 2016).

The impact of "threshold" on the planning and design process of the Kan river

The natural processes in the Kan river, including the species of fish, plants, birds, animals, and the chemical content of water, can determine the threshold of the ecosystem. Analyzing the processes can be helpful to identify the natural and human disturbances that can disrupt the natural and ecological processes.

Natural chaos and human disturbances disturb the ecosystem of the river and bring about changes in the ecological processes and ecosystem structure of the river. Such changes may have destructive effects on the structure of the river and its entire ecosystem. In this regard, recruiting experts in this field can preserve the ecosystem of the river and let it takes its natural courses. In other words, in the planning and design process, employing ecologists or specialists in natural processes, ecosystems, hydrology, botany, soil science, and zoology will be helpful to identify the threshold and have more accurate planning for this river.

The impact of "learning" on the planning and design process of the Kan river

Learning as one of the main components of resilience provides society and the users of the environment with opportunities to learn and gain experience about disturbances (Gunderson & Holling, 2002). Learning about disturbances and the ways how to deal with them only occurs at the time of flooding in the Kan river. It actually occurs when the channels of the river are removed, and the river has its natural structure. It is important to take action wisely and anticipate measures needs to be taken. Additionally, learning about the native architecture of the area and the way the inhabitants as well as users of the river deal with it also can be helpful to learn from the chaotic Kan river.

The impact of "diversity" on the planning and design process of the Kan river

Diversity is also another main component of resilience. Increasing diversity will increase system resilience and reduce disturbances. Diversity refers to a number of different functional components used to protect the system in the face of various disorders and threats (Godschalk, 2003). The spatial and altitude diversity based on the water level in the river increases its resilience in the face of flood disturbance. The spatial diversity creates diverse spaces in the dry and flood seasons. The altitude diversity occurs when houses, bridges, places, and etc., are built at different elevated points overlooking rivers, and if the river is in flood in high seasons, different levels at higher altitudes would not lose their functions.

The impact of “cut and fill” on the planning and design process of the Kan river

This strategy, which is used in most of the rivers in the world, is a very suitable alternative for the channels of the Kan river. The use of the topographic lines of the river and generating numerous terraces on the edge of the river that cannot reduce flood disturbance but restore the natural, ecological system, and ecosystem structure. In addition, the creation of an architectural landscape at the level of terraces and multiple spaces for harvesting, is another potential of this strategy. Though the Kan river has been disassociated from its surrounding area by flood control channels, using cut and fill strategy can reconnect the river with the surrounding environment and improve the relationship between the river and human.

The impact of "wetland" on the planning and design process of the Kan river

Several benefits of this strategy have been documented in environmental and ecological sciences, for example, reducing water pollution, reducing water velocity, creating climate diversity, agricultural landscape, etc. Applying this strategy to the Kan river will not only reduce the velocity of the water but also increase the environmental diversity of the river. As the high velocity of water flow in the river in recent decades is associated with the structure of the river; therefore, decreasing the speed of water on the river will reduce soil erosion and reduce the risk of flood. In addition to reducing the speed of the water, the wetlands can create a place for the accumulation of organic matter in the river. The organic and nutritious matters which are carried by water or flash floods can enhance soil fertility. As a result, these wetlands can improve and increase the quality of agricultural products in the area.

Designing and implementing the wetlands in the riverbed requires destroying the channels built for flood control and opening the riparian zone by removing channels and architectural spots. This creates a suitable place for small; however, numerous mounds in the riverbed. These mounds with low altitudes, in the river bed, slow the flow of water and flash floods. The important point about the wetlands is the water velocity on some days and seasons that protecting the mounds in the depths of the ground can reduce the risk of being washed off by the flood. Since this strategy is developed based on resilient thinking, they will go underwater in high water seasons while they continue to create diverse spaces in low water seasons.

Discussion

Based on the principles and strategies used in the successful projects of the world, we have detailed the planning and design of the Kan river for flood resilience and restoration of its natural and ecological structure. Table 3, illustrates the more details of this planning.

Conclusion

The Kan river, as one of the main urban rivers in Tehran, has received much attention from landscape architects, urban planners, ecologists, and urban citizens. Though different plans have been implemented to control the flood, the river is in full flood in some seasons and the flood has been destroying its natural and human infrastructure. Hence, examining case studies in the world and using their experiences can help in planning and designing of the Kan river. Examining four successful examples in different countries of the world (i.e., Wadi Hanifah river, Mekong Delta river in Vietnam, Jin Hua river in China, and Yiwu river in China) can present different design principles and strategies in the chaotic environment of urban rivers. These principles and strategies can be used for developing a comprehensive plan for the Kan river In this research, based on the principles and strategies (i.e. time, trial, threshold, learning, diversity, cut and fill, and wetland), strategies for intervention and planning of the river have been offered. This management planning, which is based on resilient thinking, helps landscape architects to have a comprehensive and multidisciplinary plan, including ecological, native, cultural, historical, and morphological issues of land. It can serve as a model for other vulnerable urban rivers in Tehran.

Table 3: Planning of the Kan river based on the principles and strategies for flood resilience. Source: Authors.

1. Principles	Variables	Guidelines
Time	Examining the historical conditions	- Studying cultural components: Understanding how the human being lives; how they farm; how they adapt or resist the flood; how they build houses and what architectural style is.
		- Investigating biological and environmental conditions: identifying return period of the flood; identifying the flow rates in different seasons; - examining the old inlets of the river.
	Examining the future conditions	- Predicting future disturbances; - Predicting ecological processes.
Trial	Using the laboratory	- Testing multiple methods in terms of its adaptability to flood in the laboratory; - Creating simulated models to predict and measure flood adaptability.
	Examining Successful examples in the world	- Examining adaptability and flood resilience of case studies.
Threshold	Examining the ecosystem order	- Using the knowledge of ecologists and specialists.
	Identifying natural processes	- Investigating natural processes and preventing multiple disturbance in this environment.
Learning	Living in the environment	- Providing an informative and secure environment for local people and professionals.
	Using the knowledge of the local	- Using the knowledge of the region and the experience of the local.
	Gaining experience from past disturbance	- Investigating the losses and disturbances of past years to increase the knowledge and experience from its historical trend.
Diversity	Creating a spatial diversity	- Creating diverse spaces at various altitudes based on the flow rate of water; - Creating diverse spaces based on different seasons ; - Creating diverse spaces in a linear form along the river.
	Creating altitude diversity	- Creating a spatial diversity at various altitudes based on the flow rate of water; - Creating various terraces based on the amount of water in different seasons.
2. Stratgies	**Variables**	**Guidelines**
Cut and fill	Creating river terraces based on the river level	- Promoting adaptability based on the topography of the river; - Creating an agricultural landscape; - Creating a place overlooking water to promote people' connection with water and to promote ; - flood resilience; - Promoting the relationship between the river and the surrounding area.
Wetlands	Creating resilient mounds on the path of the river	- Reducing water speed; - Creating a place for accumulating soil organic matter; - Increasing diversity.

Footnote

* This paper presents the part of findings of Farshad Bahrami's Master thesis titled "Designing the landscape architecture of the Kan River, in Tehran, in the face of flood and drought disturbances, based on resilience thinking" at the Faculty of Fine Arts, University of Tehran, under direction of Prof. Heshmatollah Motedayen (as a supervisor) and Prof. Ayda Alehashemi (as an advisor).

1. The three components of the Wadi Hanifah river project which are used in this paper are the results of Sareh Moosavi's article entitled "Time, Testing and Threshold: Revealing the Design of Repetitive Nature in the Rehabilitation of Dry Rivers".

Reference List

• Adger, W. N. (2000). Social and ecological resilience: are they related? *Progress in Human Geography*, 24(3): 347-364.

• Alehashemi, A. & Shahsavargar, M. (2014). Artificial Nature. *Journal of MANZAR*, 5 (24): 44-47.

• Alehashemi, A., Bagheri, Y., & Akhavan, E. (2015). Imposed or Natural Identity? Javanmardan Park, Landscaping in Kan Valley. *Journal of-*

MANZAR, 7(31): 94-103.
• Bahrami, F. (2018). Darakeh Valley as the Iranian Sharbagh. *Journal of MANZAR*, 10 (43): 34-41.
• Bell, S. (2012). *Landscape: Pattern, Perception and Process*. London: Routledge.
• Berkes, F., Colding, J. & Folke., C. (2003). *Navigating social–ecological systems: building resilience for complexity and change*. UK: Cambridge University Press.
• Fars News Agency. (2015). *The Fars report of the last night flood in Kan and Sulqan*. available from: www.farsnews.com/news/13940429000144. (Accessed May 2019).
• Folke, C. (2016). Resilience (Republished). *Ecology and Society*, 21 (4): 44.
• Ghahroudi Thalaei, M., Majidi Heravi, A. & Abdoli, E. (2016). Urban Flood Vulnerability (Case Study: Tehran, Derakhshan). *Geography and environmental hazards*, 17 (4): 21-35.
• Girot, C. (2013). *The Elegance of Topology*. In Girot, C. Freytag, A. Kirchengast, A. and Richter, D. (ed), Topology: topical thoughts on the contemporary landscape (pp. 79-116). Berlin: Jovis Verlag.
• Godschalk, D.R. (2003). Urban Hazard Mitigation: Creating Resilient Cities. *Natural Hazards Review*, 4 (3): 136-143.
• Green, C. (2010). Towards sustainable flood risk management. *International Journal of Disaster Risk Science*, 1 (1): 33-43.
• Gunderson, L. H. & Holling, C. S. (2002). *Panarchy: understanding transformations in human and natural systems*. Washington D.C.: Island Press.
• Gurnell, A. (2014). Plants as river system engineers. *Earth Surface Processes and Landforms*, 39 (1): 4-25.
• Holling, C. S. (1973). Resilience and Stability of Ecological Systems. *Annual Review of Ecology and Systematics*, 4 (1): 1-23.
• Hollnagel, E., Woods, D.D. & Leveson, N. (2007). *Resilience engineering: Concepts and precepts*. Ashgate Publishing, Ltd.
• Hollnagel, E. (2011). *Prologue: the scope of resilience engineering*. London, United Kingdom: Taylor & Francis Ltd.
• Karimi Moshaver, M. (2013). River Valleys Potentials in City Development. *Journal of MANZAR*, 5 (22): 52-55.
• Langridge, R., Christian-Smith, J. & Lohse, K. A. (2006). Access and resilience: analyzing the construction of social resilience to the threat of water scarcity. *Ecology and Society*, 11(2): 18. [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art18/
• Liao, K.H. (2014). From flood control to flood adaptation: a case study on the Lower Green River Valley and the City of Kent in King County, Washington. *Natural Hazards*, 71 (1): 723-750.
• Liao, K.H., Le, T. A. & Nguyen, K.V. (2016). Urban design principles for flood resilience: Learning from the ecological wisdom of living with floods in the Vietnamese Mekong Delta. *Landscape and urban planning*, 155: 69-78.
• Ludwig, D., Walker, B. & Holling, C. S. (1997). Sustainability, stability, and resilience. *Conservation ecology*, 1(1): 7. URL: http://www.consecol.org/vol1/iss1/art7/
• Mashreq News Agency. (2015). *Tehran's flood statistics since 1333*. available from: mshrgh.ir/476461 (accessed May 2019).
• Margolis, L., & Chaouni, A. (2014). *Out of Water-Design Solutions for Arid Regions*. Boston: Birkhäuser.
• Meerow, S., Newell, J. P. & Stults, M. (2016). Defining urban resilience: A review. *Landscape and urban planning*, 147: 38-49.
• Moosavi, S., Grose, M. & Walliss, J. (2015). Performative Design for Restoration of Dryland Rivers. Paper presented at the History of the Future. *52nd World Congress of the International Federation of Landscape Architects*. Saint-Petersburg, Russia: Polytechnic University Publishing House.
• Moosavi, S. (2018). Time, trial and thresholds: unfolding the iterative nature of design in a dryland river rehabilitation. *Journal of Landscape Architecture*, 13 (1): 22-35.
• Postel, S. & Richter, B. (2012). *Rivers for life: managing water for people and nature*. Island Press.
• Renault, P. (2018). Restoration Plan for the Kan River in Tehran. (PP: 137-142). *Paper presented at the International Workshop Water and City Hydraulic Systems and Urban Structures*, Yazd, Iran.
• Rutter, M. (1993). Resilience: Some conceptual considerations. *Journal of Adolescent Health*, 14 (8): 626-631.
• Sasaki, T., Furukawa, T., Iwasaki, Y., Seto, M. & Mori, A.S. (2015). Perspectives for ecosystem management based on ecosystem resilience and ecological thresholds against multiple and stochastic disturbances. *Ecological Indicators*, 57: 395-408.
• Tockner, K., Bunn, S. E., Gordon, C., Naiman, R. J., Quinn, G. P., & Stanford, J. A. (2008). *Flood Plains: Critically Threatened Ecosystems*. In Polunin NVC (ed) Aquatic ecosystems. (pp: 45–61). Cambridge Cambridge University Press.
• Tusaie, K. & Dyer, J. (2004). Resilience: A historical review of the construct. *Holistic nursing practice*, 18(1): 3-10.
• Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, adaptability and transformability in social–ecological systems. *Ecology and Society*, 9 (2): 5.
• Water Research Institute. (2004). *The report of water and the rate of flow of the Kan river*. the Ministry of Energy of Iran.
• Yu, K. (2015). A resilient landscape. *Topos*, 90: 84-89.
• Yu, K. (2017). *A Resilient Landscape: Yanweizhou Park in Jinhua City*. available from: https://www.turenscape.com/en/project/detail/4644.html. (Accessed May 2019).
• Yu, K. (2018). *The Yiwu Riverside Green*. available from: https://www.turenscape.com/en/project/detail/4653.html. (Accessed May 2019).
• Zevenbergen, C. (2016). Flood Resilience. In *IRGC resource guide on resilience* . Lausanne: EPFL International Risk Governance Center (IRGC).

HOW TO CITE THIS ARTICLE
Bahrami, F., Alehashemi, A. & Motedayen, H. (2019). Urban Rivers and Resilience Thinking in the Face of Flood Disturbance, The Resilience Planning of the Kan River. *Journal of MANZAR*, 11 (47): 56-67.
DOI: 10.22034/manzar.2019.182617.1948
URL: http://www.manzar-sj.com/article_89029_en.html