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A Study on Proposed Urban Highways Landscape Design Elements and Indicators with a Landscape Resilience Enhancement Approach*

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ABSTRACT

The urban highways landscape is one of the most important components of the urban landscape, enhancement of sustainability and resilience of which is of great importance. Studying the urban highways landscape design elements and indicators with a landscape resilience enhancement approach is a useful tool to promote the quality of urban life and support making the landscape sustainable to cope with current and future environmental changes. Despite the important advancements made in the field of identification of highway landscape indicators, investigation of the designing elements and indicators from the landscape resilience point of view has been neglected. Therefore, the provision of elements and indicators for the highway landscape design is still required to enhance its resilience. Thus, the present study aims to, first, investigate the principles and rules of highway landscape design, and then, explain the factors affecting its resilience. In this regard, to formulate the theoretical framework, relevant studies and theories were collected, and analyzed by library studies and reviewing library resources, internet resources, and articles. Then, the relevant elements and indicators to urban highways design were investigated at two human and natural levels, with a focus on the landscape resilience aspect through content analysis of relevant studies. Findings indicate that designing urban highways landscape with a resilience enhancement approach can be designed with a focus on the creation of diversity (biodiversity) and complexity, connectivity, and interconnection of urban ecological networks, redundancy, modularity, multi-functionality, adaptability, visual quality, and aesthetics. These elements are proposed with the provision of the related definitions and design components.

Keywords: Urban Landscape, Urban Highway Landscape, Resilient Landscape, Design Elements.

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1. INTRODUCTION

"The cities are the main centers of human population in the present world", and among their important issues is the fundamental effects of vehicular access networks due to their effective role in the vital and basic services of urban life (Taghvaei and Hashemzadegan 2017). Urban highways, which are among the most important components of the urban landscape, "create the meaning and identity of the landscape, connect various elements of the city, and play an important role in the perception of the city as a whole" (Mohtadi and Shahbazi 2018).

Today, the increase in population and the expansion of urbanization, have led to the irregular development of the hierarchical network of urban highways (Masnavi and Fathi 2012). Designing urban highways with merely traffic-based one-dimensional approaches disregarding the landscape design principles alongside the car-independency and wrong decisions on land use have led to environmental concerns such as climate change and the increase in greenhouse gases which are rooted in ecological and urban planning (Masnavi 2013). It has led to the fragmentation, isolation of natural habitats, and the change in normal ecological cycles and landscape of ancient cities (Testa 2015; Taghvaei and Hashemzadegan 2017; Parivar, Vakili, and Sotoodeh 2016). The collection of these factors has led to the decrease in resilience on various spatial scales, the unsustainability of human and urban habitats, and the formation of a new resilience approach to the landscape and urban planning based on the consideration of the complex relationship between man and environment (Khansefid 2016; Hemmati and Amiri 2017; Alehashemi and Mansouri 2018). In this regard, the concept of resilience has been introduced to be a proper method for urban ecosystems management that can survive and adapt in the long term by perceiving the dynamism and non-linear relationships and focusing on the creation of powerful systems in complex systems such as cities (Beller et al. 2015).

The resilience of ecosystems was first defined by Holling (1973) as a measure of the ability of an ecological system to absorb the changes and survive after the disturbance (Folke 2016). Brand and Jax (2007) have considered the focus of the resilience-related research on advanced ecological resilience at the end of the 1970s to 1990s to be the ground for interdisciplinary and transdisciplinary research in the human systems dominated by urban ecological-social resilience (Levin et al. 2013; Amirzadeh 2017), which is an opening for the application of the resilience term for a wide range of social, economic, and infrastructural systems besides the ecological systems. However, despite the current advancements in the field of urban resilience and its resilient landscape (Cockburn et al. 2015; ASLA 2019a; Beller et al. 2019; Movahed and Tabibian 2019; Asadi and Sharghi 2019), fewer studies have dealt with the investigation of the principles of urban highways design (Masnavci and Fathi 2012; Khansefid 2016; Moghadasi and Haghighatbin 2016; Taghvaei 2017; Entekhab 2018; Ghanbari et al. 2019) from the resilient landscape (Ahrami and Hemmati 2020; Beller et al. 2019; Cockburn et al. 2015) or resilient landscape design point of view (Kwak, Deal, and Mosey 2021).

The review of related literature indicates numerous questions concerning the elements and indicators of resilient urban highways design. The present study aims to further clarify these elements and indicators. Urban highways are among the important indicators of urban resilience revealing the importance of urban highways design in the framework of urban landscape resilience based on the strong correlation and overlap of the resilience of ecological functions, ecosystem services, and urban infrastructures (Beller et al. 2019; Masnavi and Fathi 2012; Khansefid 2016).

The present study has emphasized ecological resilience on the landscape scale or landscape resilience as one of the dimensions of resilience in urban ecological-social systems and seeks to investigate the fundamental elements and indicators effective in urban highway landscape design to enhance its resilient landscape by investigating and reviewing the previous studies This is considered a foresight study done for improving the quality of urban life and expanding options for enhancing the city's systematic ability to encounter and cope with the changes with least. Therefore, the present study aims to compile a framework of urban highways design elements and indicators with a resilience enhancement approach, and tries to answer the following questions:

1. What are the principles and rules for urban highway landscape design?
2. What are the effective factors in urban highway landscape resilience?

2. METHODOLOGY

The present study is qualitative and is conducted based on an analysis of the previous studies and texts. In the first step, to formulate the theoretical framework, the studies by the experts in the field have been reviewed, citing the online articles and sources and using the library and documentary studies, and searching authentic scientific databases. The content analysis method was used in the next step. The concepts of the urban landscape, highway landscape, landscape resilience, the relevant indicators and criteria, the principles for urban highway landscape design with a focus on the principles of ecological landscape design as well as the indicators and elements of the resilient landscape were scrutinized. Then, the indicators and elements of urban highways landscape design have been extracted and expanded with an emphasis on the resilience dimension of the

landscape at two natural and human levels with a focus on the creation of diversity (biodiversity) and complexity, connectivity, and interconnection of urban ecological networks, redundancy, modularity, multi-functionality, adaptability, visual quality, and aesthetics by reviewing relevant scientific fields and studies. Figure 1 presents the conceptual model of the study.

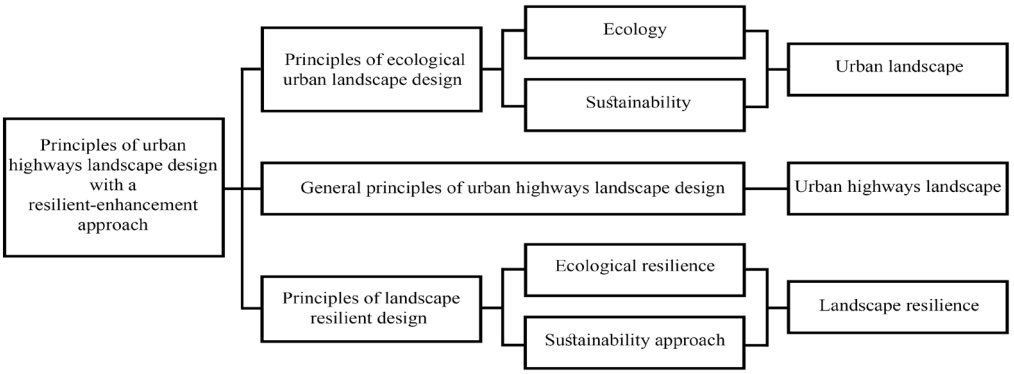

Fig. 1. Conceptual Model

3. CONCEPT OF URBAN LANDSCAPE

The urban landscape is a fundamental platform for the urban structure. It is also a complex concept, an evolving concept, and the only element that is able to connect the city components and create sustainability by creating integration (Masnavi and Soltani Fard 2007). The emergence of the concept of sustainability, the formation of the concept of landscape ecology, the emergence of the resilience theory (chaos), and its introduction into the field of ecology in the late 20th century created a new window in urban landscape design (Erfani, Bahrainy, and Tabibian 2019) and made various definitions for it. Generally, the urban landscape is the interface and surface of human contact with the phenomenon of the city (Mansouri 2005) under the influence of which the emotions of the citizens are formed. The importance of the urban landscape as an interface between man and the phenomenon of the city is to the extent that Golkar (2007) has considered urban landscape management to be equal to and in line with urban design (Golkar 2009).

In this regard, the urban landscape can be considered to be a merely objective reality based on tangible and mainly visual components that create the space or can be influenced by the citizens, a view of the city and its cultural-historical, nostalgic, and identity dimensions. Many scholars also consider both subjective and objective aspects to be among the prominent components of the urban landscape (Mansouri 2005). A regionally sustainable landscape is defined to have the highest ecological improvement to simultaneously meet the basic needs of all human generations (Allahyari, Balist, and Khodakaram 2017). A sustainable view of the landscape and the visual urban environment is the product of a "sustainable urban design", i.e., it is the product of the maturity of the urban design which emerged after ecological issues such as climate change and sustainable development (Golkar 2009). The most important ecological issue of sustainable development is also the creation of a sustainable urban landscape in the city (Alikhani Zamani and Salehi 2014). And by influencing the designers' and planners' approaches, it has led to sensitivity in the ecological dimension and the focus on finding some ways to enhance the sustainability of the urban landscape (Makhzumi 2016; Asadi and Sharghi 2019).

In the late 20th century, and with the development of the science of sustainability and the introduction of the chaos theory into the discussion of ecological sustainability (Ahern 2011), a change in the systematic attitude toward the city occurred (from a static view to a dynamic one) which paved the way for the formation of the newly-emerged concept of landscape resilience with its introduction into the urban planning and landscape literature (Hemmati 2016; Hemmati and Amiri 2017; Beller et al. 2019; Bahrami and Hemmati 2020; Alehashemi and Mansouri 2018). Generally, resilience, which is used in various scientific disciplines and fields (Folke 2016), has sustainability, recovery, and transformation approaches (Bastaminia, Rezaei, and Saraei 2017), and based on its concept, characteristics, and context, it is divided into three categories of engineering resilience, ecological/ecosystem resilience, and social-ecological resilience (Folke 2006). Therefore, the resilient landscape approach is formed from the concept of ecological resilience with a focus on sustainability (Folke 2006; Beller et al. 2015) in social-ecological systems, adapting to the uncertainties and changes mankind is facing (Cockburn et al. 2015). The nature of the sustainability approach to resilience has been expanded from the ecological studies that define resilience as the ability to return to a previous state (Folke 2016). This concept was first introduced as a way to understand the non-linear dynamism in

ecological systems with the provision of the concept of "domain or basins of attraction" in the ecosystems (Golverdi 2018; Folke 2016). It later converted the concept of resilience and sustainability into two sides of a coin in the discussions related to these two concepts (Hemmati 2016), since sustainability creates the goals of a system, and resilience concepts are used to reach these goals (Anderies et al. 2013). Therefore, landscape sustainability depends on its resilience and its resilience is also the result of the revision of previous concepts of sustainability (Hemmati 2016).

However, since the emergence of the concept of landscape resilience, few studies have dealt with this subject (Bahrami and Hemmati 2020). Based on the review of relevant literature, existing definitions of resilient landscapes have generally emphasized the element of nature instead of opposing it as well as enhancing biodiversity, improving physical processes and ecological functions, stability and strength in the field of multiple balance and sustainable landscapes concerning environmental, socio-economic, cultural, and historical values, and providing the necessary ecosystem services to overcome the disturbances human is faced with (Folke 2006; Cockburn et al. 2014; Beller et al. 2015; Gross et al. 2017; Local Land Services Central West 2016; Mock and Salvemini 2018; Lafortezza et al. 2018; ASLA 2019a; Chambers, Allen, and Cushman 2019).

For example, Beller et al. (2015; 2019) have defined "landscape resilience" to be the landscape's ability to maintain the native biodiversity (diversity of life at all levels from genes to ecosystems which are supported by ecological functions and physical processes), ecological functions (which means all existing ways by which the ecosystems support the life processes since supporting the native food complex networks, supply of food resources, function as movement corridors, providing the shade and the nesting locations), and critical landscape physical processes overtime against the climatic changes, urbanization, and other stressful factors (Beller et al. 2015). Cockburn et al. (2014) believe that a resilient landscape should continue functioning, provide a range of ecosystem services, recover itself from the shocks such as flood and drought, adapt itself to them, and provide various ecological, social, and economic advantages (Cockburn et al. 2015). Cockburn et al. (2014) believe that in the resilient landscape approach, ecological/ecosystemic resilience should support production and life resilience and take into accounts the integration of the ecosystem including the water cycle, food, biological cycle, carbon, and high values of environmental protection such as promoting biodiversity, improving ecosystem services, paying attention to cultural and social values, participation of stakeholders and native communities, and economic development into consideration (Cockburn et al. 2015). In the present study, we mainly focus on the protective values approach (Fig. 2).

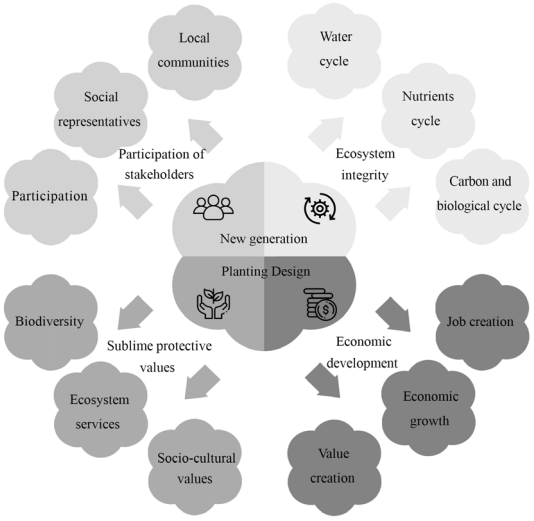

Fig. 2. Common Approaches to Resilient Landscape
(Cockburn et al. 2015)

In another study, the Local Land Services Central West of Australia (2016) defines landscape resilience to be the ability of natural landscapes and ecosystems to recover from chaos and disturbances such as purging, cattle grazing, windstorms, landslides, fire, drought, flooding, climate change, chemicals, weed invasion, or hunting (Local Land Services Central West 2016). Chamber, Allen, and Cushman (2019) have also defined the ecological resilience of ecosystems and the general resilience of landscapes to be a function of environmental features, disturbance regimes, ecosystem characteristics and processes, and ecological memory (Chambers, Allen, and Cushman 2019). What is obvious in the existing definitions is that the resilient landscape approach considers the landscape to be a set of ecosystems that, with the assumption of promotion of diversity and revision of its common functions and processes, seeks to enhance the system resilience (here, the landscape) before the change in the system from a state to another, to absorb the disturbance and chaos.

In the meantime, the interdisciplinary concept of "urban landscape ecology" also emphasizes a comprehensive understanding of urban landscape with a holistic approach to the relationship between man and nature due to the development of an "interconnected science between landscape processes and patterns" (Nassauer and Opdam 2008), as a method to examine the quantity of "landscape resilience" with the final goal of the creation of "sustainability" in the city (Hajghani and Ahmadi 2016; Makhzumi 2016; Taghvaei and Simiari 2018). According to Forman and Godron (1998), from an ecological point of view, the city is a set of disturbed ecosystems, and the structures, functions, and processes related to an urban landscape can be defined with this approach (Forman and Godron 1998). In this regard, the urban landscape is a mosaic of ecosystems, a network

of relationships between organic and non-organic communities and built elements in spatial-temporal scales with three basic features of landscape structure, function, and dynamism (Forman and Godron 1986) that is able to develop in the interaction between the environment and other units, over time (Masnavi and Soltani Fard 2007).

In this approach, the landscape is a complex and multi-layered concept that includes nature and culture. It has a spatial-temporal hierarchy and at the same time, it has non-objective values and beliefs (Makhzumi 2016). The term "ecology" is the same as the science of environment that deals with studying the ecosystems that constitute the urban landscape. The ecosystem is also a collection of organisms interacting with the surrounding environment in a specific region. Under the influence of this mutual relationship, they are producing and exchanging food and energy (Hajghani and Ahmadi 2016).

In these definitions, the ecosystems that constitute the urban landscape include the natural systems, terrestrial and aquatic ecosystems, forests, pastures, lakes, built environments, agricultural lands, and urban areas (Wu 2008). Ahern (2007) also defines the elements of the urban landscape based on Forman's patch/corridor/matrix model in the form of urban patches (parks, gardens, forests, sports fields, cemeteries, wetlands, and urban open spaces), urban corridors (rivers, streams, estuaries, urban utility channels, paths, and roads, railway tracks, and power transmission lines), and urban matrices (residential, commercial, administrative, industrial, and mixed urban areas) (Ahern 2007).

Table 1. Natural and Built Urban Ecosystems in the Patch/Corridor/Matrix Model

		Model	Ecosystem
Natural Urban Ecosystems	Terrestrial Ecosystems	Patch	Natural forests-animal habitats
		Corridor	Natural wildlife pathways
		Matrix	Green and natural open areas
	Aquatic Ecosystems	Patch	Wetlands-natural lakes
		Corridor	Rivers-estuaries-valleys-waterways (streams)
		Matrix	Natural bodies of water
Urban Built Ecosystems		Patch	City parks-sports fields-public and private gardens-cemeteries-open and green urban spaces-urban forests
		Corridor	Channels of urban facilities-urban routes (highway, freeway, main and side streets)-pedestrian routes-cycling routes-railway routes-power transmission lines
		Matrix	Residential areas-Industrial areas-Commercial areas -Mixed urban areas-Urban waste disposal areas

Obviously, there is a strong correlation and overlap between landscape resilience concepts and landscape ecology, and this correlation can be a proper criterion to use and expand the principles of these two cases to achieve landscape sustainability in a way that in recent developments, it has been tried to integrate these concepts through the concept of spatial resilience (Chambers, Allen, and Cushman 2019; Allen et al. 2016). Allen et al., (2016) consider spatial resilience to be an important component in the resilience theory and the frontline of the efforts to quantify the resilience concepts. They also view the concept of landscape spatial resilience to be the manifestation of recent conceptual advancements in the area of the explanation of resilience and the possibility to change heterogeneous and dynamic systems (Allen et al. 2016). In this regard, and based on theoretical science, spatial resilience can be defined as "the share of spatial features in the feedbacks that lead to the creation of resilience in ecosystems and other complex systems, and vice versa" (Allen et al. 2016).

3.1. Effective Factors in Resilient Landscape Design

A city is considered fully resilient when all the indicators, components, and dimensions of resilience in that city are in a better condition and in a state of growth and improvement (UNISDR 2012).

Therefore, several related articles in the field of ecological and landscape resilience have been examined, the indicators and the principles of landscape resilient design are discussed and identified to emphasize the creation of ecologically active landscapes with high biodiversity, and relevant ecosystem services under the influence of climate change, and other human stressors (Table 2).

Ahern (2013), one of the first scientists to provide resilience principles, based on the landscape ecological approach, considers five indicators of

biodiversity, modularity, and redundancy, connectivity of urban ecological networks, adaptive design, and multifunctionality to be among the interdisciplinary strategies to design and achieve urban sustainability and resilience (Ahern 2013). Mowahed and Tabibian (2019) consider the strengthening of urban ecological networks based on the principles of landscape ecology to guarantee the improvement of the system's ability to deal with environmental pressures and increase ecological resilience (Mowahed and Tabibian 2019). However, other indicators in the field of landscape resilience- with an emphasis on biodiversity and ecological performance- have been proposed in the studies of Beller et al. (2015; 2019) based on the seven dimensions of setting, process, connectivity, diversity/complexity, redundancy, scale and people (Beller et al. 2015).

Reviewing the articles revealed that the most emphasis in the field of urban ecological resilience and its landscape is laid on the attention to the principles of 1. (biological) diversity and complexity, 2. connectivity and interconnection of ecological networks, 3. modularity, 4. redundancy, 5. compatibility and adaptation capacity, 6. multifunctional design, 7. paying attention to the dimension of scale (Beller et al. 2015; 2019; Parvaresh 2014; Amiri et al. 2018), 8. strength while being flexible (Parvaresh 2014; Qaraei, Masnavi, and Hajibande 2018), 9. Innovation (Allan and Bryant 2011; Folke 2016; Asadi and Sharghi 2019), 10. Paying attention to the geographical characteristics and context (Beller et al. 2015; 2019; Amiri et al. 2018), 11. Processes and regimes of disturbance (Beller et al. 2015; 2019; Amiri et al. 2018), 12. Restoration of biological functions and ecosystem services (Allan and Bryant 2011; Asadi and Sharghi 2019), 13. Ecological sustainability and a combination of different knowledge (Folke 2016). 14. Management plans (Asadi and Sharghi 2019; Parvaresh 2014), and 15. Paying attention to the people's dimensions and social capacities (Asadi and Sharghi 2019; Beller et al. 2015; Beller et al. 2019). Among these indicators, the first six indicators have been used since they had the most references and were in line with the research subject. The definitions of these indicators are presented in Table 2.

4. EXPLANATION OF THE CONCEPT OF URBAN HIGHWAYS LANDSCAPE

Urban highways are the most important element of the urban landscape, and the rest of the landscape elements are either dependent on them or organized according to them. Pakzad (2007) believes that, in addition to being a communication network, the highways are like the skeleton of the city which strengthens the permeability of the arteries and the visibility of the landscapes (Pakzad 2007). Mohtadi and Shahbazi (2018) consider the urban highway as one of the main physical elements that form the meaning and identity of the city as well as the structure of the city and connect different elements in the city, and play an important role in the perception of the city as a whole (Mohtadi and Shahbazi 2018). The urban highway is also a built corridor which is defined as an example of the structural elements of the urban landscape in Forman's patch/corridor/matrix model (Taghvaei 2017). The problems related to urban highways can be investigated from the ecological and landscape resilience points of view. In this regard, highways, as urban infrastructures and movement corridors, function as natural and green corridors and significantly affect the ecological sustainability of the city and its landscape (Sabunchi, Abarghouei, and Motadayen 2019). It makes the need for the development and design of the landscape with a sustainable and resilient approach.

The relationship between the highway and its landscape is a two-way relationship. As a built corridor, the highway provides the interconnection between the patches in the landscape and is a passage for the flow of ecological processes and living organisms between different patches (Taghvaei 2017). On the other hand, it is the urban highway landscape that is a part of the everyday landscape of urban communities for commuters, cyclists, and pedestrians (NZ Transport Agency 2014) and significantly affects the functional, visual-aesthetic, and environmental characteristics (sustainable landscape components) of the highway and the surrounding environment (Taghvaei 2017).

Table 2. Effective Indicators in Urban Landscape Resilience

Row	Ecological-Landscape Resilience Index	Definition	Scholars
1	Biodiversity and Complexity	Diversity (variety of landscape features) and complexity (including spatial configurations and interactions between features) are defined as describing the physical and biological variability at the scales present in the landscape, as well as the interactions between different components. Biodiversity directly supports ecosystem services and processes.	(Allan and Bryant 2011; Ahern 2013; Folke 2016; Beller et al. 2015; 2019; Parvaresh 2014; Parivar, Vakili, and Sotoudeh 2016; Hemmati 2016; Gharaei, Masnavi, and Hajibandeh 2018; Amiri et al. 2018; Asadi and Sharghi 2019)

Row	Ecological-Landscape Resilience Index	Definition	Scholars
2	Connectivity and Interconnection of Urban Ecological Networks	Connectivity refers to the links between habitats, processes, and populations across a landscape. This definition includes both the distribution of resources and habitats relative to each other and the possibility of the movement of organisms in the landscape (permeability). Connectivity enables the movement of individuals and the rearrangement of species collection at different scales and connects physical processes such as sediment transport in habitats.	(Ahern 2013; Beller et al. 2015; 2019; Parivar, Vakili, and Sotoudeh 2016; Hemmati 2016; Gharaei, Masnavi, and Hajibandeh 2018; Mowahed and Tabibian 2019; Asadi and Sharghi 2019)
3	Redundancy	Redundancy refers to the presence of multiple similar or overlapping elements or functions within a landscape that promotes diversity and provides insurance against destruction.	(Ahern 2013; Beller et al. 2015; 2019; Parvaresh 2014; Gharaei, Masnavi, and Hajibandeh 2018; Asadi and Sharghi 2017)
4	Adaptability and Compatibility	The supervision of the land in a coordinated, flexible, and conscious manner; Learning from monitoring, research, and pilot projects and management of specific stressors that must be controlled to maintain optimal ecological function and biological processes.	(Ahern 2013; Folke 2016; Beller et al. 2015; 2019; Hemmati 2016)
5	Modularity	Modularization is created through different elements or components with similar and supporting functions. Modularization causes the risk to be divided, both in time and in place, and the probability of risk occurrence is reduced.	(Allan and Bryant 2011; Ahern 2013; Parivar, Vakili, and Sotoudeh 2014; Hemmati 2016; Asadi and Sharghi 2019)
6	Multifunctionality	It can be achieved by combining applications, compressing them, or using them in turn.	(Ahern 2013; ASLA 2019b; Hemmati 2016; Asadi and Sharghi 2019)

4.1. Recognition and Expansion of Principles of Urban Highway Landscape Design

As a main and internal feature of highway infrastructure landscape design, several principles, criteria, and considerations should be considered (Khansefid 2016), which is far from possible to examine all of them due to being rooted in various scientific topics. Therefore, to extract the general principles of highway landscape design, the general principles and strategies that have a higher level of success in the design and implementation of sustainable highway landscapes have been investigated.

According to the American Society of Landscape Architects (ASLA), transportation infrastructure is an important part of the landscape, whose resilient and sustainable design depends on paying attention to the following principles: 1. low carbon, 2. being active, 3. being safe, 4. being justice-oriented, 5. being resilient, 6. being ecological, and 7. being beautiful (ASLA 2019b).

The principle of low carbon and being active in sustainable transportation systems is proposed to encourage reducing the effects of climate change. The use of low-carbon transportation is combined with the development of transit axes such as public transportation, biking, or walking, and it aims to create a healthy lifestyle for the workforce. A report by the Victoria Transport Policy Institute (2016), which assessed the benefits of public transport, also found that communities that are pedestrian-oriented and based on public transport have higher physical fitness and mental health. The safety principle can be implemented through traffic calming, such as speed and lane width restrictions and the use of protected refuges. In the principle of being justice-oriented, access to sustainable transportation options, as a right for all residents- regardless of their income, race, age, disability, religion, or nationality- and based on cheap, safe, accessible, and multimodal transportation options, is emphasized. In the principle of resilience, emphasis is placed on the resilience of the landscape and the standardization of highway construction, taking into account the consequences of climate change and the creation of multimodal and green transportation networks. Being ecological is one of the other basic principles that are put forward through the construction of green infrastructure

to strengthen biodiversity (supporting pollinator species and wildlife populations), trapping and filtering surface sewage, and reducing floods. As an important component of our landscape and public realm, transportation infrastructure must be beautiful, inviting, and livable, intelligently designed to foster community identity, equity, and ownership (ASLA 2019b).

In another study on the principles of landscape design of New Zealand state highways (2014), to improve the quality and resilience, and sustainability of their landscape, the following are emphasized: 1. Using a location-based and setting-sensitive approach, 2. Helping to create green infrastructure and landscape integration, 3. Understanding physical conditions, 4. The right plant in the right place, 5. Promoting biodiversity and building resilience, 6. Supporting low-impact design, 7. Providing visual quality and quality user experience, 8. Low cost (low maintenance) and inclusion of all life values, 9. considering safety in design, and 10. facilitating social interaction and having a collaborative approach (NZ Transport Agency 2014).

Khansefid (2015) also, referring to the concepts of sustainability and resilience, has considered the construction of the landscape of transportation infrastructure during the rapid global changes in urban environments to be based on ecological landscape-oriented urban planning, and focused on the principles of accessibility, connectivity, multi-functionality, multi-scale functions, and maintainability of the project on different stages of planning, design, construction, and post-construction, and multiple scales (Khansefid 2016).

Hemmati and Amiri (2017) also, by examining examples of successful resilient landscapes, believe that in addition to ecological functions, cultural and aesthetic functions should also be included in the design of resilient landscapes (Hemmati and Amiri 2017). Therefore, in the examination of the highway landscape, parallel with paying attention to the ecological dimension and resilience, the creation of visual quality and beauty has also been emphasized (Taghvaei 2015; Moghadasi and Haghighatbin 2017). The principles of visual design in the design of roads, highways, and freeways can be listed as greenness, minimal intervention, neutral design, use of native materials, optimal alignment of the road, replacement of technical elements with more natural elements, creation, and indexing of milestones, etc. Based on the studies by Kevin Lynch, Moghadasi and Haghighatbin (2017) also emphasized the clarity of the beginning and end of the road, the direction of the road, the continuity of the road, tree lines, and paving of the road, the presence of signs on the side of the road, the scale and enclosure of the road, markings, and nodes (Moghadasi and Haghighatbin 2015).

Referring to the principle of resilience, in line with paying attention to the aesthetic component and creating visual quality, has revealed paying attention to the objective and subjective aspects of the urban landscape in creating a resilient landscape (Bahrami and Hemmati 2020). It was also indicated that the landscape of future highways is highly dependent on the adaptation to the current and future conditions, and a wide range of issues related to their construction or renovation.

Examining the related articles shows that it is important to use ecology, in addition to paying attention to the principles of resilience, for the design of dynamic and sustainable landscapes.

In this regard, to integrate the ecological sciences related to urban systems, the principles of ecological design of the urban landscape have been used as a directing axis in the design.

Cadenasso and Pickett (2008) propose the principles of ecological landscape design as follows:

- Cities are a set of ecosystems and consist of four components of living organisms, physical conditions and environment, social structures, and the built environment, and the design should be done to influence all four components.
- Urban spaces are heterogeneous and the design should take steps to promote heterogeneity and ecological functions.
- Urban systems are dynamic, and the dynamic quality of cities is related to the acceptance of changes and design according to internal and external changes.
- There is an interaction between the components of urban systems (humans and natural processes), as design should take steps to recognize and create feedback between social and natural processes (Çelik 2013).
- Recognition of the ecological processes in cities is of great importance and the management and design of landscapes should help to maintain and develop the fundamental biological processes to shape human health and well-being (Kamyab Teimouri 2018; Çelik 2013).

The first three principles focus on the structure of the urban landscape and its change over time, and the remaining two principles focus on ecological processes and performance in cities (Çelik 2013).

The structure of the urban landscape is based on a network of natural and built components known as the components of the urban spatial organization (Gharaei et al. 2016). It includes the most important ecological patches in Forman's model, parks and natural resources, local remains or planted patches from Green space, natural or built wetlands, and urban areas. Hydrological flows, large and small streams and rivers, main and side streets, and their patterns, alternative ways of transportation such as walking and biking paths, and public transport lines and railways also create significant corridors in the overall ecological structure of the highway landscape.

5. FINDINGS

Making the urban highways landscape resilient and sustainable should be done based on the principle of landscape dynamism and the relationship between the organic and non-organic elements in landscape ecosystems. Overcoming the challenges faced by the highways is only possible through adaptive management and continuous monitoring. The highway landscape design is a wide-ranging discussion. Therefore, the design process should be associated with the use of past experience, examination of the present time, and continuous monitoring in the future. It is viable by qualitative and quantitative examination of all components related to the highway landscape in multiple scales and various intervals.

In this regard, some urban highways landscape design elements and indicators have been proposed with a focus on the creation of biodiversity and complexity, connectivity and interconnection of urban ecological networks, redundancy, modularity, multifunctionality, adaptability and compatibility, and beauty and visual quality, as indicated in Figure 3. These elements and indicators have emphasized the urban landscape design based on the landscape resilience principles, using the structural elements of landscape proposed by Forman, and focusing on the creation of an integrated green-blue-gray infrastructure.

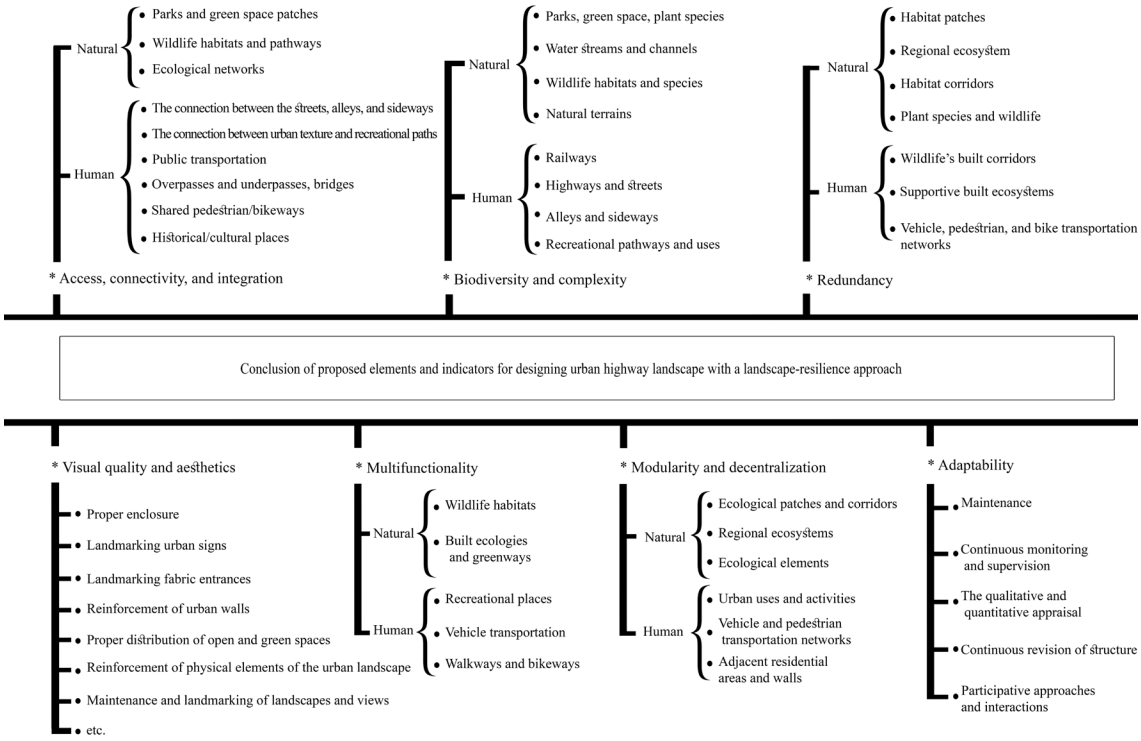

Fig. 3. Proposed Elements and Indicators for Designing Urban Highway Landscape with a Landscape-Resilience Approach

The structural elements of the urban landscape include the natural and built patches and corridors. Among the natural patches, the green and open patches and remaining natural wetlands can be named. Also, among the built green patches, the urban forests and parks can be named. The green and open patches are the main factor in the ecological balance of the cities that play an important role in the creation of landscape resilience and sustainability. The extent of influence of these patches depends on their vastness, shape, diversity (biodiversity), and connectivity.

Natural corridors include valleys, estuaries, natural streams, and their surroundings, as well as linear parks. Greenways, green space on the roadsides and highways, tree-lined pathways, channels and water streams, and accesses including public transportation paths, pedestrian paths, and bikeways are also among the built corridors. The collection of natural and built patches, combined with natural and built corridors can create green-blue-gray infrastructures such as urban highways with a resilient landscape.

- Landscape diversity (biodiversity) and complexity can be enumerated in the framework of the biological reactions, diversity of species, and diversity of ecosystems. This diversity can be achieved by the creation of diversity in biological patches (open and green spaces) on the landscape scale, diversity of plant species, water resources, structures and height, and physical heterogeneity in micro-habitats and natural features, and sub-climates on the site or habitat

scale. Also, the landscape diversity should include the diversity of uses, recreational places, and all kinds of built and natural highway landscapes.

- Connectivity of ecological networks: Connectivity of the urban highways landscape depends on the connectivity of natural and built transportation, communication, and energy flow corridors. In urban highway landscapes, connectivity is achieved through connecting multifunctional networks such as greenways, ecological networks, blue-green networks, river paths, and garden paths. Connectivity of the wildlife-exclusive pathways and connected transportation and pedestrian paths are also among the important issues in the creation of a resilient highway landscape. Concerning connectivity, physical and non-physical connectivity should be emphasized which requires a separate study due to the wide scope of the subject.
- Redundancy: In the urban landscape, redundancy includes the redundancy in structures, populations, and functions and can be achieved through a multiplicity of habitat patches and corridors such as green and open spaces, pathways, and estuaries. The presence of natural and built patches and corridors in highway landscapes is among the main factors in landscape survival against stressors and disturbances, and the creation of resilience.
- Modularity and decentralization: Modularity and decentralization can be achieved through the creation of green and open space patches or similar ecological and supporting corridors all over the landscape. Also, by the creation of supporting ecosystems, various uses on the side of the highways are no exception.
- Multifunctional design: Multifunctionality can be achieved through the combination of the applications, compressing them, or using them in turn. For example, greenways can act as wildlife pathways at night or in addition to the provision of ecosystem services, can be useful in encountering disturbances such as climate change.
- Learning and adaptability: Adaptive design turns the risk of facing incidents and disturbances we are not fully aware of, into opportunity. The requirement for such an occurrence is the creation of a continuous learning process in which the system continuously revises itself with the feedback it receives. For adaptability, the use of resilient materials alongside paying attention to their maintenance is important. The collection of natural and built landscape structures and ecosystems requires continuous monitoring through qualitative and quantitative examinations besides their continuous revision in the face of disturbances.
- Focus on beauty and visual quality in the landscapes can be achieved through the creation of biodiversity, the use of vegetation and durable materials, proper lighting, revitalization of cultural-historical and religious places, a pathway system with the possibility of safe and comfortable and continuous access for pedestrians, bikers, and the wildlife in the region, the use of signs and boards in the right place, and having a good and wide view inside and outside the landscape.

6. DISCUSSION AND CONCLUSION

Urban highway landscape design is a new subject, especially from the resilience point of view. In the present study, it was tried to provide a correct definition of the elements and indicators of each component and to pave the way for further studies in this regard by expanding the conceptual elements and indicators related to the subject at two levels of natural and built components of the urban landscape with a focus on the ecological resilience of landscape. The ecological systems are a significant part of our surrounding nature and recognition of its processes and mechanisms as well as understanding the relationships between its components can be a proper approach to how complex systems such as highway landscapes work. In this regard, further studies are required to comprehensively deal with this subject.

Various aspects of the highway, ecological landscape, and resilient landscape have been emphasized in some recent studies. The present study tried to recognize and combine various frequent and effective principles and aspects regarding the resilient design and highway landscape. For example, Lak (2012) has considered ecological resilience to be under the influence of biodiversity and redundancy, while Parivar, Vakili, and Sotoudeh (2016) emphasize the examination of general resilience from the diversity, connectivity, and modularity points of view. Hemmati (2016) considers resilient landscapes to include cases such as diversity, modularity and decentralization, multifunctionality, adaptive planning and design, and strengthening the connectivity of networks. Also, Hemmati and Amiri (2017) consider the importance of aesthetic patterns to achieve a resilient landscape. Mowahed and Tabibian (2019), to increase ecological resilience, put forward the strengthening of urban ecological networks and enumerate suggestions such as the diversity and redundancy of green patches and water corridors, the proximity of patches, the connectivity of patches and corridors, the modularity, heterogeneity, and multifunctionality of patches and corridors, and finally, the creation of large patches. Jack Ahern, a landscape ecologist (2012), has examined the principles of diversity, modularity, and redundancy, the connectivity of urban ecological networks, adaptive design, and multi-functionality. Beller et al., (2015; 2019) consider seven dimensions to be important in landscape resilience, including setting, process, connectivity, diversity/complexity, redundancy, scale, and people. Masnavi and Mohtadi (2012) considered the way out of environmental concerns and issues caused by the uncontrolled expansion of cities and highways to be the use of non-motorized transportation facilities in the form of walking and biking with the help of building greenway

networks. Khansefid (2017), in his studies, examines the landscape of transportation infrastructure at two natural and human levels based on the principles of accessibility, connectivity, multi-functionality, being multi-scale, and maintenance. The ASLA believes that the transportation infrastructure is an important part of the landscape and the resilient and sustainable design of the highway should pay attention to the principles of 1. low-carbon, 2. being active, 3. being safe, 4. being justice-oriented, 5. being resilient, 6. being ecological, and 7. being beautiful.

In the present study, the proposed elements and indicators for urban highways design as well as their operational definition have been extracted by analyzing the previous studies and focusing on concepts and elements of the resilient landscape, the highway landscape, the principles of ecological design of urban landscape, and paying attention to the subjective and objective aspects of the urban landscape.

Findings indicate that urban highway landscape design has been proposed with a resilience-enhancement approach focusing on the creation of diversity (biodiversity) and complexity, connectivity, and interconnection of urban ecological networks, redundancy, modularity and decentralization, multifunctionality, adaptability and compatibility, beauty, and visual quality, and finally, paying attention to natural and human components of landscape structure.

It should be noted that the reviewed studies have only focused on the objective aspect of urban resilience. Thus, the present study has aimed to take a step to fill the gap regarding the evolutionary concept of resilient landscape design by putting together a collection of objective and subjective components of the resilient design of urban highways landscape.

Also, due to the multiplicity of criteria and indicators, those criteria and indicators with the greatest number of cites in the literature have been presented.

On the other hand, considering the concept of the city as a socioecological system is itself an implication of the urban design to meet the natural and human needs of its landscape, connect the organic and non-organic environment, and examine the possibility of multipurpose uses of the landscape along with the enhancement of ecosystem services.

To recognize all principles of resilience, in further studies, besides paying attention to the suggestions provided in the present study, it is suggested to consider components regarding the constituent elements of urban objective/subjective landscape. It is also suggested to examine the structure of the land, soil, diversity of topographies, dominant ecological groups, and historical-cultural context and resources of the site, pay attention to dynamic relationships between landscape elements, climate, and land use, the connectivity between the biological patches, processes, spaces, wildlife pathways, recreational, transportation, and pedestrian pathways, biological and species diversity, decentralization at the structure, population, and functions levels, and the role of people and stakeholders in the creation of adaptability with the conditions.

Finally, the precise recognition of the challenges and risks over time and consideration of a proper scale in the urban landscape are among other important points that require a separate study, since the evaluation of landscape resilience is possible only through awareness of the resilience of some specific urban elements against existing challenges and risks and based on the accessibility of the data and the possibility of examination of the data and main natural and structural components constituting the urban space.

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