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Using the Component Model of Sustainable Landscape for the Quality Assessment of Urban Natural Public Spaces: A Case Study from Tehran's River-valleys

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ABSTRACT: Ecological destruction in human-dominated landscapes has significant impacts on environment sustainability internationally. Landscape planning can play a role in mitigating the effects of human-related activities. One element of landscape planning involves the analysis of the biological, spatial and social arrangement of areas in an urban environment and identifying characteristics that are underrepresented in urban natural public spaces. In this study, the quality of public spaces resulting from the regeneration of Tehran's river-valleys' natural environment is assessed in relation to landscape ecology principles. We use the components of Bio-spatial-social Logic, Eco-environmental-societal Function, Mind-experiential-aesthetic Logic and Eco-environmental-societal Excellence, as the components of a framework, to examine the quality of existing urban natural public spaces and to define deficiencies in the current urban landscape system. Based on multivariate ecological, environmental and societal space, the evaluation made by this component model indicates that the principles of landscape ecology have been disregarded in Tehran's River-valleys land development and various ecological problems have been evolved from its river-valleys' regenerating projects. Our criterion is based on the alteration of landscape's content composition and spatial configuration variables to eco-environmental-societal excellence features. The analysis provides a systematic, function evaluation of urban natural public spaces, in three hierarchical levels of Environmental Equilibrium, Geographical-anthropological Sustainability and Eco-environmental-societal Excellence features. Some strategies are introduced for Tehran's river-valleys' landscape variables change.

Keywords: *Landscape Ecology Principles, Landscape Planning, Urban Ecology, Natural Environment, the Analytic Network Process.*

INTRODUCTION

Tehran is located in a plain between Alborz Mountains and the northern border of the Central Desert of Iran. Among the geographical features of Tehran's landscape are the foothill areas at the north, which are of high ecological importance in terms of water resources, plantation and mountain climate. Environmental conditions of these regions directly influence Tehran's landscape. Any ecological damage or the pollution of these areas has direct consequences for the rest of the landscape. Changes in the use of environment and natural corridors of these regions and in general any land structure whose biological function is defined to be the origin of landscape ecological services is the main concern of Tehran's landscape planning to maintain and improve its ecological, urban and societal quality. In order to evaluate the quality of Tehran's urban public spaces resulting from the recreation of urban natural environments, we need to provide a conceptual model with comprehensive components and criteria, with which the quality of urban natural public spaces can be assessed. Accurate evaluation of urban natural public spaces and an assessment of their current deficiencies will help towards the development of highly qualified urban environment. By scrutinizing existing conceptual models, the study provides a new conceptual model to assess the quality of Tehran's river-valleys' natural

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Fig. 1: Tehran’s Velenjak River-valley: regeneration area, before and after Source: Google Earth 2000 and 2011

environments (Fig. 1).

In planning for urban natural environment, we need to look at a multilateral management of landscape and human activities from an urban landscape point of view, referring to a geographical unit characterized by a specific pattern of ecosystem type and formed by interactions of geographical, ecological and human-induced forces (Forman, 1995; Steiner, 2000). Mentioned by Linehan and Gross (1998), landscapes change, form and transform anthropocentrically. Every human activity, such as building the environment, takes place in one or more ecosystems. Establishment and continual sustainability of complex environmental ecosystems requires coexistence and balanced relations of their elements with each other and also with larger environments. Opdam refers to landscape as

The Place Diagram is one of the tools PPS has developed to help communities evaluate places. The inner ring represents key attributes, the middle ring intangible qualities, and the outer ring measurable data.

Fig. 2: The component model of PPS (Project for Public Spaces) Source: www.pps.org, received: 8/25/2011

a unit of planning, with considerable attention paid to human activities that influence the transformation and dynamics of the ecological balance (Opdam et al., 2006). Since natural environments are heritage of our cities and their maintenance and protection is necessary for continuation of urban life, it is very important to give special attention to the principles of landscape ecology in a model provided for investigating the quality of urban natural public spaces. Landscape ecology focuses on structures, functions and transformations of the environment, attempting to find patterns and interactions between landscape elements, patches, corridors and the matrix (Forman, 1995; Ingeognoli, 2002). As any urban ecosystem consists of a whole set of landscapes that are more or less sustainable, any planning and design strategy, especially in large scale landscapes, should consider the principles of ecological networks to integrate ecology into sustainable land development. These are the reasons that necessitate the proposal of a comprehensive component model for investigating the quality of urban public spaces that have been born out of regenerating urban natural environments.

By analyzing existing component models, this study has attempted to provide a comprehensive component model for the application of landscape ecology principles to the regeneration process of urban natural environments and the continuous process of sustaining ecosystem, environment and human interactions in urban natural public spaces. In providing a new comprehensive model, the integration of the fundamental concepts for the evaluation of the quality of space used by models such as PPS (Project for Public Spaces) (Fig. 2), CABE Space (Commission for Architecture and the Built Environment) (Table 1), and Socio-spatial Sustainability (Maghsoudi, 2007) (Table 2) has been implemented. PPS is the result of investigating the quality of urban spaces in more than 1000 public spaces; CABE Space is a proposed model with a prominent comprehensive idea in order to create public spaces with a high standard of quality and value; and Socio-spatial Sustainability gives a conclusion for the collective ideas of modernism, formalism, radicalism and naturalism to urban planning specialists in order to analyze the quality of urban public spaces. In these models the necessity of landscape ecology principles for evaluating the interconnecting process of social and natural systems is identifiable: PPS is planning oriented; CABE Space ignores many criteria; and Socio-spatial Sustainability only considers the timeframe of project construction, while disregarding the value of spatial built systems. For introducing the component model of Sustainable Landscape, in the level of system ecology, aspects of nature and bio system on the one hand, and manmade program and idea system on the other hand, are identifiable. By their mutual interactions, components of ecological structure, ecological function, thought structure and ecological equilibrium are definable (Fig. 3 and Fig. 4). In the level of urban ecology, aspects of environment and built system on the one hand, and human activity and form system on the other hand, are identifiable. By their mutual interactions, components of spatial structure, environmental function, mold structure and environment sustainability are definable (Fig. 3 and Fig. 4). And finally, in the level of human ecology, aspects of landscape and human system on the one hand, and social behavior and ideal system on the other hand, are identifiable and by their mutual interactions, components of social structure, social function, meaning structure and social excellence are definable

Table 1: The component model of CABE Space (Commission for Architecture & the Built Environment)
Source:www.cabespace.org.uk, received: 10/8/2011

Criteria for Evaluating the Quality of Public Space	
The Value of Public Space	The Economic Value of Public Space
	The Impact on Physical and Mental Health
	The Benefits for Children and Young People
	Reducing Crime and Fear of Crime
	The Social Dimension of Public Space
	Movement in and Between Spaces
	Value from Biodiversity and Nature

Table 2: The component model of Socio-spatial Sustainability Source: after Maghsoudi, 2007

	Criteria for Evaluating the Quality of Public Space		Scholars
Socio-spatial Sustainability	Technologic	**Maximum Use of Technology**	(Le Corbusier, 1971); (Giedion, 1961)
		Efficiency	(Le Corbusier, 1971); (Giedion, 1961)
	Aesthetic	**Connectivity**	(Sitte, 1945); (Cullen, 1971); (Zucker, 1970); (Hillier & Hanson, 1984); (Tschumi, 1983); (Mitchell, 1994)
		Oneness	(Ardalan & Bakhtiar, 1975); (Bacon, 1975); (Zucker, 1970); (Alexander et al., 1987); (Kreier, 1979); (Trancik, 1986); (Kostof, 2004); (Rapoprt, 1971); (Venturi et al., 1972); (Appleyard, 1976); (Jenckes, 1986); (Ellin, 1996); (Loukaitou-sideris & Banerjee, 1998)
		Character	(Hiedegger, 1969); (Appleyard, 1976); (Norberg-schulz, 1980); (Lynch, 1981); (Rossi, 1982); (Jackson, 1994); (Arefi, 1999); (Lawson, 2001); (Jiven & Larkham, 2003)
		Human Scale	(Sitte, 1945); (Mumford, 1961); (Zucker, 1970); (Bacon, 1975); (Jacobs, 1984); (Rapoprt, 1977); (Tibbalds, 1992); (Urban Task Force, 1999); (Moughtin, 2003); (Gehl & Gemzoe, 1996)
	Sociability	**Access**	(Lynch, 1981); (Mitchell, 1999); (Benn & Gaus, 1983); (Calthrope, 1993); (Madanipour, 1995); (Tibbalds, 1992); (Akkar, 2005); (Whyte, 1980); (Carr et al., 1992); (Newman, 1995); (Jacobs, 1984); (Trancik, 1986)
		Social Inclusion	(Harvey, 1973); (Rapoprt, 1977); (Whyte, 1980); (Jacobs, 1984); (Sennett, 1994); (Madanipour, 2004)
		Security	(Trancik, 1986); (Carr et al., 1992); (Jacobs, 1984)
		Wants	(Healy, 2002); Gehl & Gemzoe, 1996); (Arnestein, 1969); (Lynch, 1981), (Carr et al., 1992); (Tibbalds, 1992); (Sennett, 1994)
	Sustainability	**Ecological Awareness**	(Katz, 1994); (Urban Task Force, 1999); (Leccese & McCormick, 2000); (Carmona et al., 2003)
		Compact Shape	(Mumford, 1961); (Rapoprt, 1977); (Lynch, 1981); (Tibbalds, 1992); (Katz,1994); (Urban Task Force, 1999); (Hilderbrand, 1999); (Carmona et al., 2003); (Moughtin, 2003)
		Mixed Use	(Mumford, 1961); (Rapoprt, 1977); (Jacobs, 1984); (Gehl & Gemzoe, 1996); (Urban Task Force, 1999); (Carmona et al., 2003); (Moughtin, 2003)
		Best Use of Technology	(Arendt, 1958); (Mumford, 1961); (Tibbalds, 1992); (Urban Task force, 1999); (Katz, 1994)
		Stability	(Tibbalds, 1992); (Urban Task Force, 1999); (Katz, 1994); (Carmona et al., 2003)

(Fig. 3 and Fig. 4).

Four components of Bio-spatial-social Logic, Eco-environmental-societal Function, Mind-experiential-aesthetic Logic and Eco-environmental-societal Excellence are introduced by mutual interactions of above dimensions in hierarchical levels. By introducing these components, the component model of Sustainable Landscape is proposed for evaluating the quality of urban natural public spaces resulting from the regeneration of urban natural environments (Fig. 3 and Fig. 4). For these components, some considerations are suggested in Table (3). Also, Table 4, Table 5 and Table 6 introduce some criteria for landscape variables change based on “Environmental Equilibrium”, “Geographical-anthropological Sustainability”, and “Eco-environmental-societal Excellence” features.

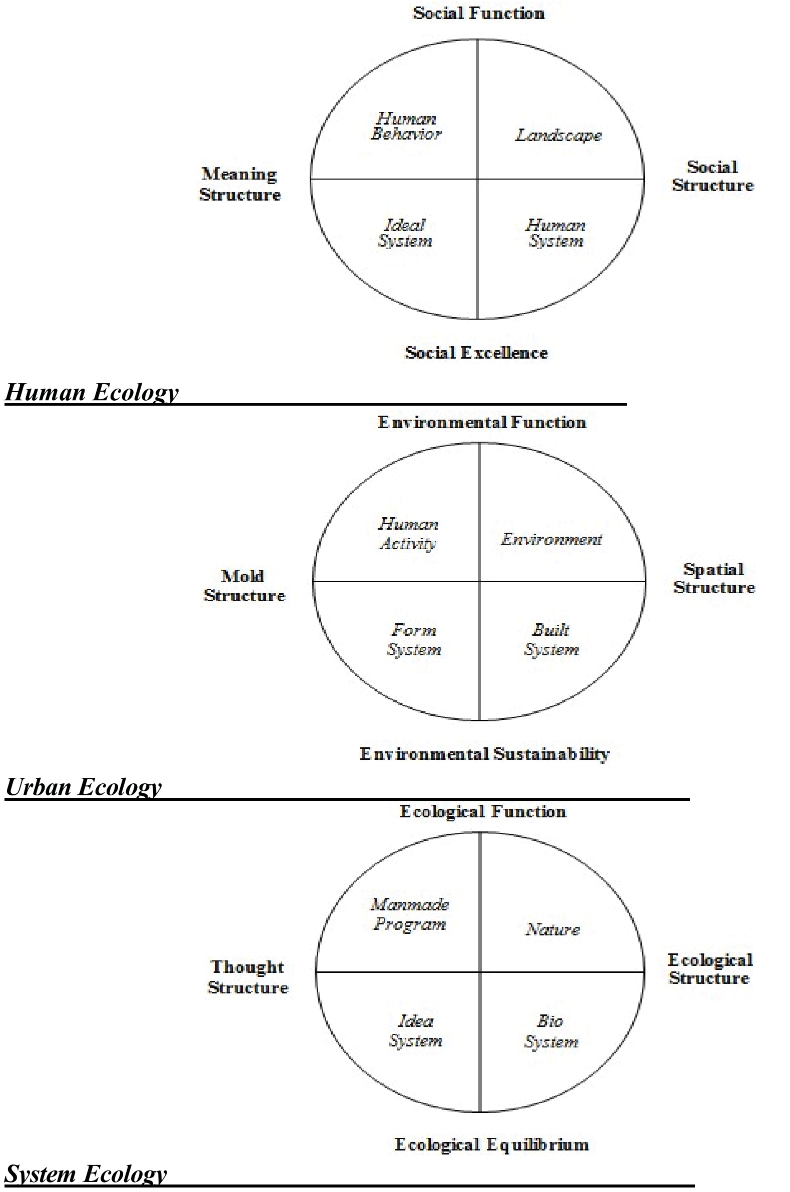

Fig. 3: The component model of Sustainable Landscape (extended)   Source: Authors

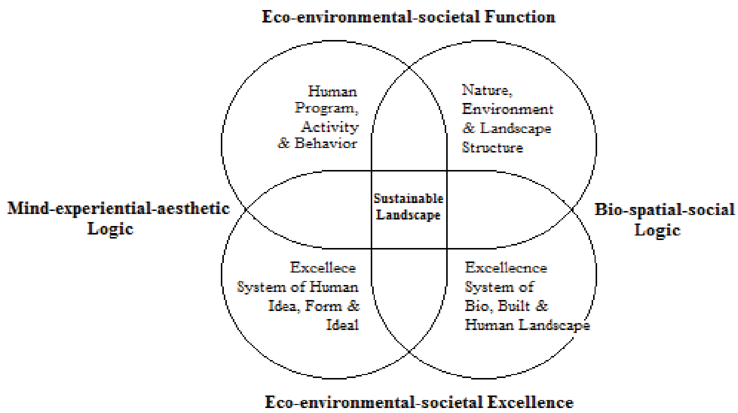

Fig. 4: The component model of Sustainable Landscape Source: Authors

Table 3: Criteria for component model of "Sustainable Landscape" based on ecological, environmental and societal principles
Source: Authors

			Criteria	Appropriate Content Composition	Appropriate Spatial Configuration
Bio-spatial-social Logic	Ecological Structure	**Nature** & Bio-system	**Geography, Living components, Man-made products** - macro- & micro-climate, natural sources - tectonic condition, slope, land slip - soil coverage, plants, animals	- Eco patches, preserving living conditions (Noss and Harris, 1986)	- Eco corridors, preserving ecological connections: cycle of matter & energy, linking nature reserves, cultural features and historical sites (Little, 1990)
	Spatial Structure	**Environment** & Built-system	**Environmental proportion, permanence & Health** - consumption of local materials - eco compatible construction & repairs - consumption of non-pollutant materials - eco compatible locations of storing pollutants	- Intra- & extra-habitat structural equilibrium, preserving species diversity	- Intra- & extra-habitat relation-isolation equilibrium, preserving patch heterogeneousness
	Social Structure	**Landscape** & Human-system	**Social health** - sociological processes, maintaining natural elements & environmental equipment - public cooperation, continuous maintenance-supervision of nature & manmade environments		- Eco corridors, preserving natural & manmade patch heterogeneousness, natural patch abundance, environmental positions and socio-economic functions (Ahern, 1991)
Eco-environmental-societal Function	Ecological Function	**Nature** & Manmade	**Cycle of matter & energy** - optimum cycle of matter & energy	- Spatial-temporal perspective of eco corridors, preserving unified system of ecosystems and place and interconnected system of climate and territory (Forman 1995; Zonneveld, 1995)	- Spatial connectivity and integrity of eco corridors, preserving balanced function of eco-anthropological processes (Jongman and Pungetti, 2004; Forman, 1995)
	Environmental Function	**Environment** & Human Activity	**Spatial comfort, access & compatibility** - optimized ecological conditions (climate, landscape ...), environmental conditions (noise, smell, view ...), and sociological conditions (collective memory, social consensus ...) - access for disabled use, public transport and parking areas … - capacity for different activities;various ages and nature-related activities	- Land dispersion of species - Ecological connectivity of habitat patches - Ecological connectivity of natural & manmade systems	- Spatial connectivity of species - Spatial connectivity of habitat patches - Spatial connectivity of natural & manmade systems
	Social Function	**Landscape** & Human Behavior	**Social compatibility** - capacity to meet the needs of different land uses, to fulfill the converse requirements of different land uses, and to fulfill the requirements of multi-functional spaces **Nature-human interaction** - capacity to meet the needs of nature-human interactions	- Multifunctional network of eco corridors, integrating social & ecological objectives at the same time (water quality protection, erosion and flood control, recreational-aesthetic facilities, etc.) (Walmsley, 1995; Erickson and Louisse, 1997; Jongman and Pungetti, 2004)	- Spatial network of eco corridors preserving multiple eco-societal purposes such as environmental, recreational, cultural, aesthetic, etc. (Ahern, 1995); and preserving species diversity, tourism opportunities and regional characteristics (Linehan et al., 1995)

Continue of Table 3: Criteria for component model of “Sustainable Landscape’’ based on ecological, environmental and societal principles
Source: Authors

			Criteria	Appropriate Content Composition	Appropriate Spatial Configuration
Mind-experiential-aesthetic Logic	Thought Structure	**Idea** & Manmade Program	**Sensational richness** - principles of space memorability - principles of enjoying of being in the space	- Ecological integrity of urban and non-urban units - Ecological integrity of natural environments, urban spaces and residential areas …	- Spatial integrity of recreational potentials and ecological attractions - Spatial integrity of ecological elements: ground waters, forest, parks, agricultural areas
	Mold Structure	**Form** & Human Activity	**Safety & Security** - principles of space security - principles of space safety	- Eco-socio boundary network of eco hydraulic corridors - Eco infrastructural network of roads, rivers, canals, sewage networks, etc.	- Socio-economic network activity of multi-purpose greenways - Eco network of walking roads, bicycle routes, local traffic, etc.
	Meaning Structure	**Ideal** & Human Behavior	**Visual beauty** - aesthetic principles of space design	- Natural urban sceneries formed by local materials	- Aesthetic needs satisfaction preserved by landscape’s natural features
Eco-environmental-societal Excellence	Ecological Equilibrium	**Idea** & Bio-system	**Honoring space & time** - ecological equilibrium, honoring nature, environment, and society	- Eco corridors content compatibility, fulfilling the requirements of the excellence trend of social programs: “ecological preservation’’ and “social development”, resulting from the corridors’ new specie, patch &ecosystem prioritization	- Eco corridors spatial compatibility, fulfilling the requirements of the excellence trend of ecological networks: integrated networks of ecosystems, connecting biotic processes and interactive trends of landscape infrastructure networks to a comprehensive spatial system
	Environment Sustainability	**Form** & Built-system	**Sociability & Public cooperation** - promotion of social interactions with regard to different uses of space - presence of people’s demands and comments in regard to construction and use of space	- Bio steps’ hierarchy of natural and manmade patches, urban and geographical patches and different geographical phenomena	- Spatial living sequences of natural & manmade patches, urban & geographical patches and different geographical phenomena
	Social Excellence	**Ideal** & Human-system	**Identity** - space identity - place identity - eco, space and societal excellence	- Genuineness of natural resources, cultural-historical elements and human behavior	- Genuineness of natural environment, cultural-historical relations and human function

Table 4: Criteria for landscape variables, based on Environmental Equilibrium Features Source: Authors

Performance Indicator	Content Composition	Spatial Configuration
	Trend for increased quality of biological structure	*Trend for increased quality of spatial structure*
Environmental Equilibrium: / Natural patch preservation / **Landscape's resource allocation**	***Increased patch diversity equilibrium***	***Increased patch heterogeneity equilibrium***
	Ecological corridor's patch composition: *Patch richness, Number of patch, Class area proportion, Mean patch size*	***Ecological corridor's patch configuration:*** *Mean proximity index, Mean nearest neighbor distance, Proximity*

Table 5: Criteria for landscape variables, based on Geographical-anthropological Sustainability Features Source: Authors

Performance Indicator			Content Composition	Spatial Configuration
Geographical-anthropological Sustainability:	Ecological network preservation	**Landscape networks' socio-spatial network rogram**	*Trend for increased quality of biological function*	*Trend for increased quality of spatial function*
			Increased biological isolation-relation sustainability	***Increased spatial isolation-relation sustainability***
			Ecological network's corridor composition: *Intra & extra habitat isolation-relation*	***Ecological network's corridor configuration:*** *Intra & extra spatial isolation-relation*

Table 6: Criteria for Landscape variables, based on Eco-environmental-societal Excellence Features Source: Authors

Performance Indicator			Content Composition	Spatial Configuration
Eco-environmental-societal Excellence:	Ecological-anthropological network Excellence	**Landscapes' bio-spatial-social network management**	*Trend for biological excellence*	*Trend for spatial excellence*
			Increased eco hierarchy of biological stages	***Increased environmental sequences of habitat spaces***
			Ecological-anthropological network's patch & corridor composition: *Necessary extent and relation of natural and man-made patches & corridors*	***Ecological-anthropological network's patch & corridor configuration:***

MATERIALS & METHODS

In this study, the analytic framework of the component model of Sustainable Landscape is used for assessing the content composition and spatial configuration of landscape's variables in the regeneration process of Tehran's River-valleys. In the environmental planning of Tehran's landscape, some river-valleys have undergone regeneration, and some parts of their areas have been set aside for urban greens and gardens. This plan has been confirmed to resolve Tehran's various urban problems such as high pollution, social insecurity, shortage of cultural places, etc. This study evaluates all considerations related to proposed comprehensive component model of Sustainable Landscape regarding Farhzad River-valley - Nahjolbalagheh Garden. This garden, located at District 2 of Tehran Municipality, the northwest of Tehran's landscape, has been formed in the process of regenerating a part of Farahzad River-valley. The area is approximately 1200 meters long, and 300 meter wide with a height difference of approximately 40 meter (from the lowest to the highest part) and an area of approximately 35 hectares (Fig. 10 and Fig. 11).

Tehran's Landscape Network - Natural and Manmade Potentials and Restrictions:

Being situated at the foothills of Alborz Mountains, Tehran has several river-valleys running from North to South. There are also a number of canals and seasonal rivers that absorb additional rainfall in the area. The rivers and streams that run through these mountain valleys and inside the city are among the advantages of Tehran's landscape, and their ecological potential creates desirable urban patches within the manmade urban fabric. In addition to the provision of open spaces, concentration of main views and circulation of pure air, these natural corridors are among the major elements of Tehran's comprehensive plan to revive its landscape. In order to create continuous and expansive natural patches and assure spatial interconnection between natural greens and manmade spaces, these corridors are considered the main natural elements of Tehran's sustainability development plan (Fig. 5).

Among other landscape features are natural and manmade patches, which give Tehran its unique characteristics and

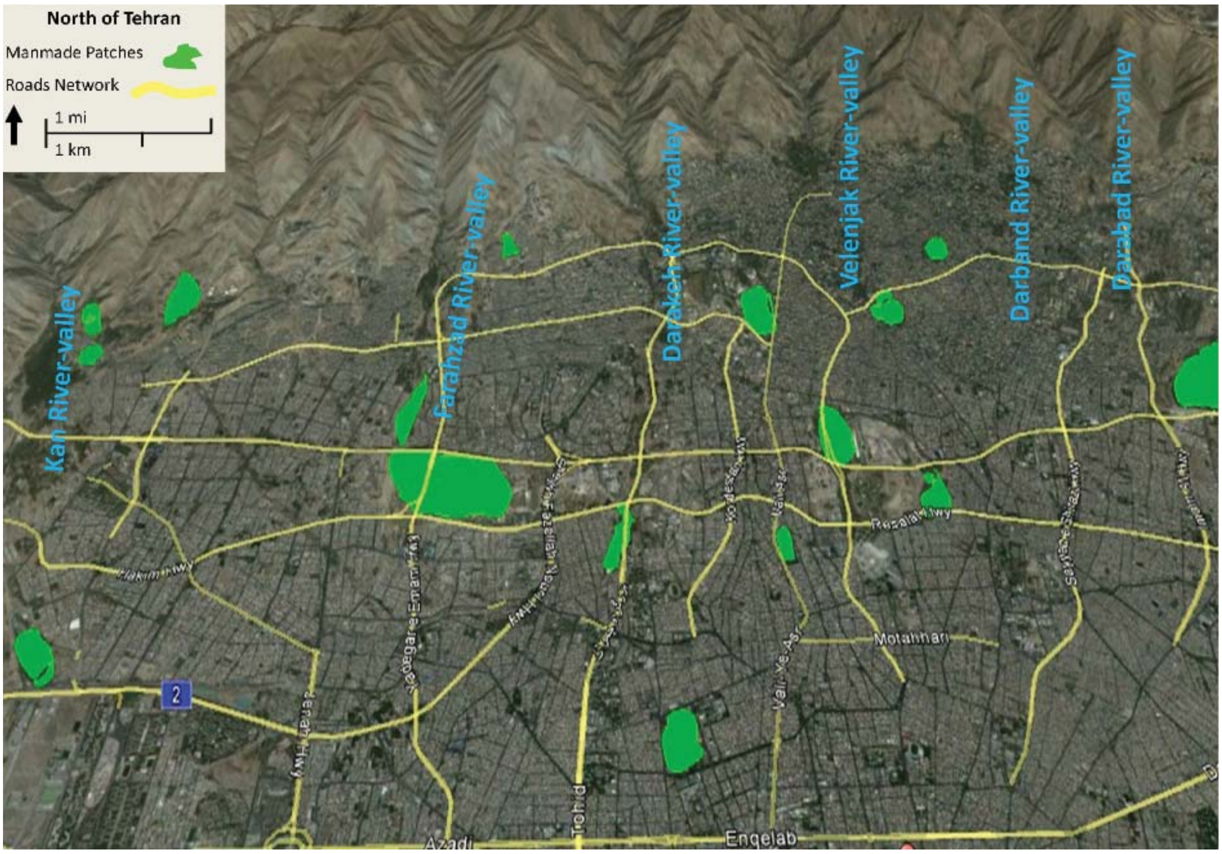

Fig. 5: Tehran's landscape network: natural & manmade corridors and patches Source: Google Earth 2011

residential and touristic values. One of its most important natural patches is northern heights which endow the city with a special natural characteristic. Today, Tehran has lost many of its natural patches due to rapid growth. Urban constructions have also caused the gradual destruction of natural patches, which were situated along geological corridors, near local water resources. The development of manmade natural patches has also shown that even though the number of parks and green patches has been increased, these newly natural patches have not been made sustainable. They have shown a little efficiency due to their small size and lack of ecological integration. These patches have been made without paying attention to landscape capabilities and water and soil resources. As a result, most of the newly-established green patches have been built on uncultivated hills and lands without suitable water and soil resources. In Tehran, there has always been a shortage of water, and because of this, water has often been taken from other areas, thus causing the eventual destruction of more natural landscapes. Unfortunately, the newly-established green patches have not been able to perform as ecological substitutions.

Therefore, with the increase of urban constructions and the continuous destruction of landscape's natural resources, there are no more valuable areas in Tehran that can be considered as natural patches. Except for large patches dispersed in the northern foothills and the margins of the city, which are ecologically disconnected, natural patches within the landscape are small ones. It is worth noting that patches near the natural corridors are ecologically historic as well as valuable in terms of extent. These areas are not only considered as landscape's micro-scale ecological patches, but due to their expanse and

Fig. 6: Tehran's Darakeh River-valley Source: Google Earth 2011

Fig. 7: Tehran's Velenjak, River-valley Source: Google Earth 2011

Fig. 8: Tehran's Darband River-valley Source: Google Earth 2011

Fig. 9: Tehran's Darabad River-valley Source: Google Earth 2011

the presence of hydro-corridors, they are also able to act at the landscape's macro-scale ecological activities. These patches are also important in terms of having access to city's recreational potentials as well as different urban land uses and functions. These characteristics and capabilities add to the ecological importance of these patches.

Tehran's natural corridors, which run in main routes, do not have ecological boundaries and as a result their ecological characteristics as connecting routes have no use (Fig. 6, Fig 7, Fig. 8 and Fig. 9). Even, constructed urban corridors (including riverside corridors and greenways) have urban functions due to being connected to urban zones. Thus, these corridors have special characteristics in terms of having important ecological and societal advantages in different landscape scales. The recreational potentials of these landscapes are also considerable. They are remarkable areas not only because they are rich ecological resources providing large green patches, but also because they are important cultural sites that provide the landscape's historic identity. Sometimes these areas along with their manmade urban elements benefit from the landscape's natural characteristics and become considered historic urban elements that define cultural functions. However, other times they remain poor in terms of plantation, and though they have the spatial capability to benefit from landscape's natural patches and corridors, nonetheless, they remain in need of good ecological connectivity. The vicinity of historic urban structures with valuable natural sites helps to protect the socio-ecological identity of the landscape. All these factors allow the manmade identity of the landscape to be in harmony with its natural and historic characteristics. Table (7) concludes Tehran's landscape characteristics, based on its content composition and spatial configuration features.

Nahjolbalagheh Garden - Natural and Manmade Potentials and Restrictions:

The analytic framework of the component model of Sustainable Landscape is used for assessing the landscape's content composition and spatial configuration variables based on "Environmental Equilibrium", "Geographical-anthropological Sustainability", and "Eco-environmental-societal Excellence features (Table 4, Table 5 and Table 6). According to the principles of landscape ecology, the quality assessment of nature-made public spaces needs to consider the importance of constituent elements of landscape structure (natural and manmade corridors and patches) and the consistent need of their organization in the form of different alternatives and plans. The importance of landscape planning alternatives in creating and preserving green corridors lies in their capability for maximum ecological protection of landscape's potential resources: 1) integration of spatial elements, capable of circulating matter and energy; 2) integration of natural patches and corridors, capable of developing ecological functions; 3) integration of natural patches, capable of division into manmade units; 4) integration of natural corridors, capable of developing infrastructure networks; 5) integration of urban activities, capable of developing multipurpose ecological networks, etc.

In the following, the component model of Sustainable Landscape is used to assess the quality of Nahjolbalagheh Garden, as a part of the regeneration process of Tehran's Farahzad River-valley (Fig. 10 and Fig. 11). According to this assessment, although ecological principles have been observed in the construction of Nahjolbalagheh Garden and efforts have been made in using compatible materials and environmental standards for repairs and waste disposal, there are nevertheless some weaknesses in intra- and extra-habitat structural equilibrium for preserving

Table 7: Tehran's landscape features: Content Composition and Spatial Configuration Source: Authors

Content Composition	Spatial Configuration
Patch diversity equilibrium - Reduced structural complexity of habitat patches - Reduced patch diversity of intra-habitat relations - Reduced species diversity of extra-habitat relations	**Patch heterogeneity equilibrium** - Reduced structural complexity of habitat relations - Reduced patch heterogeneity of intra-habitat relations - Reduced species heterogeneity of extra-habitat relations
Biological isolation-relation sustainability - Reduced biological relations between habitat patches - Reduced species distributions between land patches - Reduced biological relations between natural & manmade systems	**Spatial isolation- relation sustainability** - Reduced spatial relations between habitat patches - Reduced spatial distribution of species between land patches - Reduced spatial relations between natural & manmade systems
Eco hierarchy of biological stages - Lack of ecological hierarchy between natural & manmade patches - Lack of ecological hierarchy between urban & geographical areas - Lack of ecological hierarchy between different geographical phenomena	**Environmental sequences of habitat spaces** - Lack of spatial hierarchy of natural & manmade patches - Lack of spatial hierarchy of urban & geographical areas - Lack of spatial hierarchy of different geographical phenomena

species diversity, and intra- and extra-habitat connectivity equilibrium for preserving patch heterogeneity. For example, grass has no ecological relation to the other species of this region. As a result, the need of grass for large quantities of water has made it difficult to maintain this decorative species efficiently and therefore, even underground water resources of other regions are being used for its irrigation. Another example is the concrete structure of the riverbed, which has impaired the relation/isolation balance of ecosystem for establishing the intra- and extra-habitat heterogeneity of the region.

The spatial arrangement of the environment also indicates the excessive interference of the human in nature. The river valley, as a natural corridor, cannot adequately preserve the area's heterogeneity by balancing the need for socio-economic functions on the one hand and the connections between habitat patches and possibility of access to environmental opportunities on the other. Moreover, considering the water shortage of the region, the vast cultivation of the plants that need ample irrigation, the use of underground water resources and the use of electrical energy for underground water-pumps, all indicate that almost no attention has been paid to the optimal use of matter and energy. Although the garden is used by almost all age groups, the activities are not nature-related. Since land dispersion and spatial connectivity of species and ecological and spatial connectivity of habitat patches are ill-suited, there are also disorders in the region's biological and spatial connectivity of natural and manmade patches. Although the place is within a natural environment, there are no usable activities to enable people to interact with nature. The resultant space is like a beautiful painting that only allows the users to view decorative natural sceneries. Therefore, the planning of landscape has not been successful in achieving its multiple eco-societal ambitions: from ecological goals to environmental, recreational, cultural or aesthetic.

Application of the ANP to Nahjolbalagheh Garden: In assessing the quality of Nahjolbalagheh Garden, the Analytic Network Process is used based on the framework proposed by the component model of Sustainable Landscape. Within multi criteria analyses, a very remarkable role is played by the Analytic Hierarchy Process - or AHP (Saaty, 1980; Saaty and Vargas, 1990) – and by its more generalized evolution, i.e. the Analytic Network Process – or ANP (Saaty, 2006). Many decision-making issues cannot be structured hierarchically, because they imply interactions and dependences between the highest elements with respect to the lowest. In fact, not only does the importance of the criteria cause the importance of the alternatives, as in a hierarchy, but also the importance of the alternatives does cause the importance of the criteria (Bottero et al., 2007). The Analytic Network Process (ANP) is a generalization of the Analytic Hierarchy Process (AHP), by considering the dependence between the elements of the hierarchy. Many decision problems cannot be structured

Fig. 10: Nahjolbalagheh Garden: region's intra- and extra-habitat heterogeneity
Source: Google Earth 2006

Fig. 11: Nahjolbalagheh Garden: region's intra- and extra-habitat heterogeneity
Source: Google Earth 2011

hierarchically because they involve the interaction and dependence of higher-level elements in a hierarchy on lower-level elements. Therefore, ANP is represented by a network, rather than a hierarchy (Saaty, 2008). The ANP model consists of control hierarchies, clusters and elements, as well as interrelations between elements. The ANP allows interactions and counter-interactions between clusters and supplies a network structure able to connect clusters and elements in any manner in order to obtain priority scales from the distribution of the influence between elements and clusters (Bottero et al., 2007). The ANP requires a network structure to represent the problem, as well as pairwise comparison to establish relations within the structure. There are two possible modeling approaches to ANP: the BOCR (Benefits, Costs, Opportunities, Risks) approach, suggested by Saaty (Saaty and Vargas, 2006), which allows to simplify the problem structuring by classifying issues into traditional categories of cost and benefit; and a free-modeling approach, which is not supported by any guide or pre-determined structure. The first approach is often inadequate because it falls into reductionism; while the second one is often difficult to be applied in complex decision making problems (Lombardi et al., 2007). The analytical tools provided from ANP are very useful for supporting the decision making process; nevertheless, it is always very important to feed a great deal of information or a lot of experts to the model in order to come to a better solution (Bottero et al., 2007). The model is divided into four main stages:

1) The structure of the decision-making issue must be defined through the recognition of its main objective. Such objective must be later divided into groups (clusters), constituted by various elements (nodes), and alternatives or options where to choose. Then, the relationships between the different parts of the network must be identified. Each element can be a source, which is an origin of path influence, or a sink, that is a destination of path influences (Fig. 12).

2) A series of pairwise comparisons are made to establish the relative importance of the different elements with respect to a certain component of the network. In the case of interdependencies, components with the same level are viewed as controlling components for each other. In pairwise comparisons, a ratio scale of 1-9 is used to compare any two elements (Table 8). The numerical judgments established at each level of the network make up pair matrixes. Through pairwise comparisons between the applicable elements, the weighted priority vector is calculated. This vector corresponds to the main eigenvector of the comparison matrix (Saaty, 1986).

3) The supermatrix elements allow for a resolution of interdependencies that exist among the elements of the system. It is a portioned matrix where each sub-matrix is composed of a set of relationships between and within the levels as represented by the decision maker's model (Step 1) (Bottero et al., 2007). The general form of the supermatrix is described in Table (9) where C_N denotes the N^{th} cluster, e_{Nn} denotes the n^{th} element in the N^{th} cluster, and W^{ij} is a block matrix consisting of priority weight vectors (w) of the influence of the elements in the ith

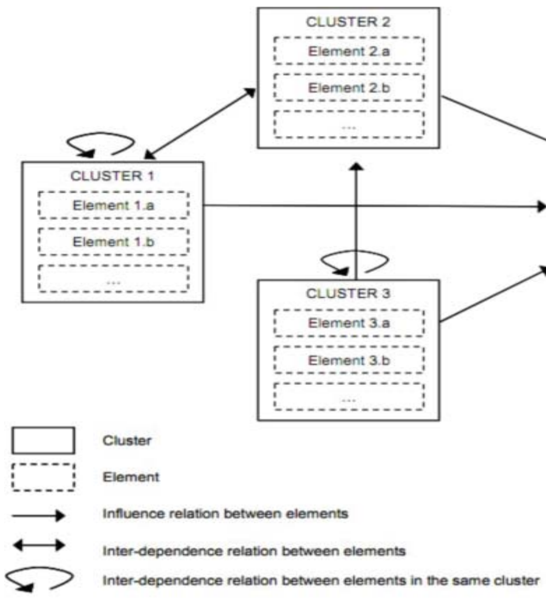

Fig. 12: Example of network structure with clusters and elements Source: Bottero et al., 2007

cluster with respect to the jth cluster. If the ith cluster has no influence to the jth cluster then $W^{ij} = 0$. The matrix obtained in this step is called the initial supermatrix (Piantanakulchai, 2005). The eigenvector obtained from cluster level comparison with respect to the control criterion is applied to the initial supermatrix as cluster weight. This results in the weighted matrix.

4) The weighted supermatrix is made to converge to obtain a long-term stable set of weights. The supermatrix is raised to limiting power such in equation (1) to get the global priority vector. In this research all steps are done by the Super Decision Software, the ANP's software.

Figure (13) represents the network application of the study for assessing the quality of Nahjolbalagheh Garden based on the framework proposed by the component model of Sustainable Landscape. Three clusters are introduced for the structure of ANP: Goal; Components; and Alternatives. The clusters and elements of the ANP application are described in Table (10). Based on the criteria, developed by the component model of Sustainable Landscape, inner and outer dependences of element components are strongly interconnected. Five chosen alternatives are: Excellent; Good; Intermediate; Bad; and Very Bad. The information regarding the assessment are collected through observation, interviewing, questionnaires and statistics/information gathered from relevant organizations. In this investigation, the users of the space form the statistical population of the research. The required number of questionnaires is calculated using the Cochran Formula. The questionnaires have 22 items and the test subjects, who are selected randomly, are asked to give 1 to 5 points to each item based on the Likert Spectrum.
Once the average score of each component is calculated, they are placed in pairwise comparisons. The following scores are achieved: "Eco-environmental-societal Function" score of 2.21, "Mind-experiential-aesthetic Logic" score of 1.53, "Eco-environmental-societal Excellence" score of 2.63, and "Bio-spatial-social Logic" score of 2.8. For dual comparisons, each element of the cluster of components is compared with the only element of the cluster of goal. Each element of the cluster of alternatives is also compared with each element of the cluster of components. Each elements of the cluster of components that possess an internal relationship with other elements of the same cluster is also compared with each other. An example of each of these comparisons is shown in Figure (14), Figure (15) and Figure (16).
Once all the pairwise comparison matrixes is compiled, the totality of the related priority vectors forms the unweighted supermatrix (Table 11). As described before, the unweighted supermatrix has to be multiplied for the cluster matrix (Table 12) in order to obtain the weighted supermatrix (Table 13).

Table 8: Fundamental scale of Saaty Source: Saaty, 2008

1	equal importance
3	moderate importance of one over another
5	strong or essential importance
7	very strong or demonstrated importance
9	extreme importance
2,4,6,8	intermediate values

Table 9: General structure of supermatrix
Source: Piantanakulchai, 2005

		C_1: e_{11} e_{12} … e_{1n_1}	C_2: e_{21} e_{22} … e_{2n_2}	…	C_N: e_{N1} e_{N2} … e_{Nn_N}
C_1	e_{11}, e_{12}, …, e_{1n_1}	W_{11}	W_{12}	…	W_{1N}
C_2	e_{21}, e_{22}, …, e_{2n_2}	W_{21}	W_{22}	…	W_{2N}
⋮		…	…	…	…
C_N	e_{N1}, e_{N2}, …, e_{Nn_N}	W_{N1}	W_{N2}	…	W_{NN}

Table 10: Clusters and elements Source: Authors

Clusters	Elements
Goal	Q= Quality of Nahjolbalagheh Garden
Components	1= Eco-environmental-societal Function 2= Mind-experiential-aesthetic Logic 3= Eco-environmental-societal Excellence 4= Bio-spatial-social Logic
Alternatives	A= Excellent B= Good C= Intermediate D= Bad E= Very Bad

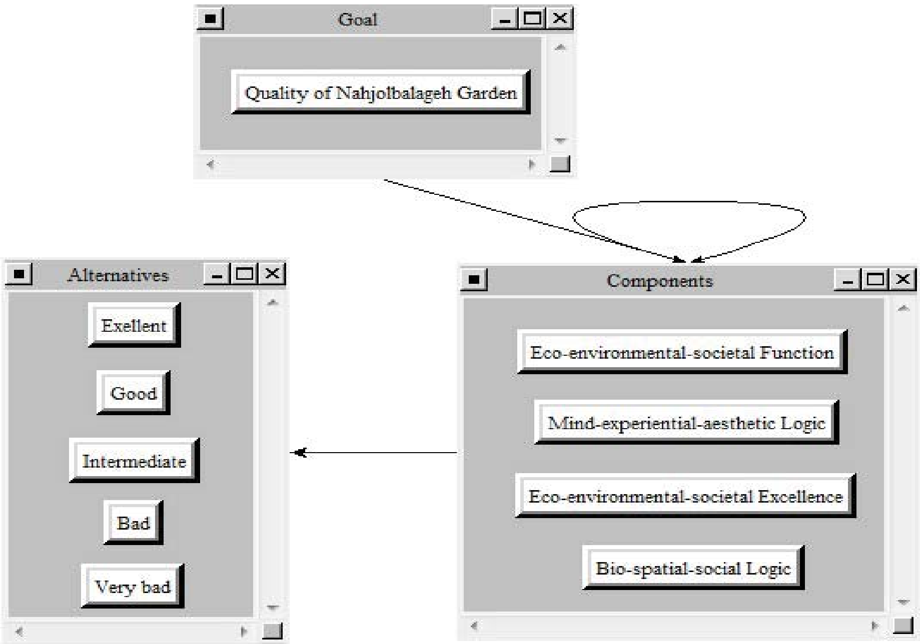

Fig. 13: Network structure Source: Authors

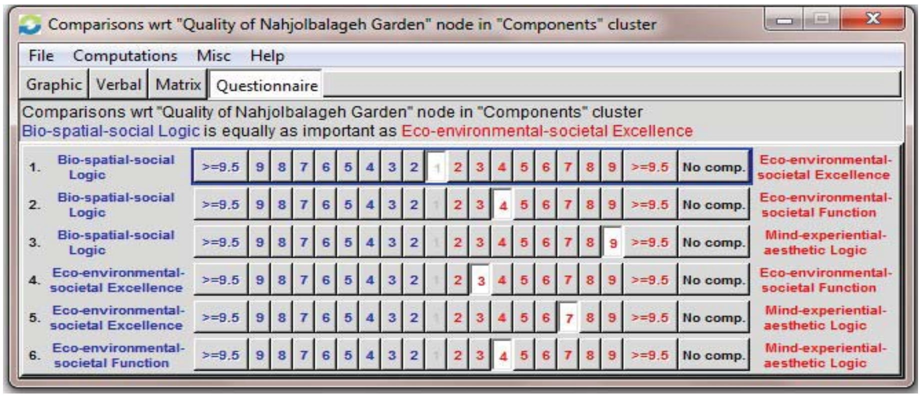

Fig. 14: Comparisons with respect to ‘Quality of Nahjolbalagheh Garden’ node in ‘Components’ cluster
Source: Authors

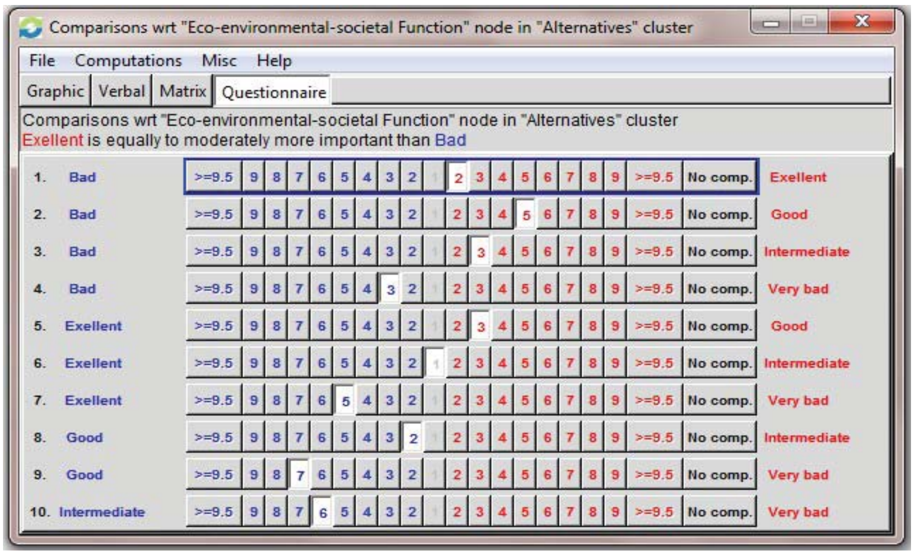

Fig. 15: Comparisons with respect to ‘Eco-environmental-societal Function’ node in ‘Alternatives’ cluster
Source: Authors

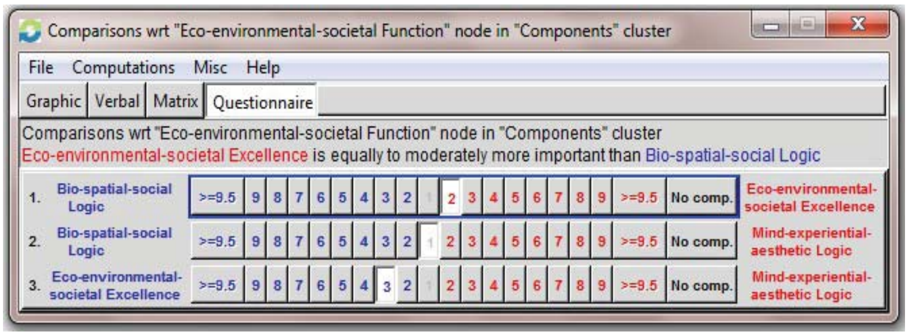

Fig. 16: Comparisons with respect to 'Eco-environmental-societal Function' node in 'Components' cluster Source: Authors

Table 11: Unweighted supermatrix Source: Authors

	A	B	C	D	E	1	2	3	4	Q
A	0.00	0.00	0.00	0.00	0.00	0.19046	0.33737	0.10980	0.06769	0.00
B	0.00	0.00	0.00	0.00	0.00	0.44117	0.35390	0.32107	0.23234	0.00
C	0.00	0.00	0.00	0.00	0.00	0.23178	0.18180	0.38041	0.47331	0.00
D	0.00	0.00	0.00	0.00	0.00	0.09465	0.08301	0.13702	0.17188	0.00
E	0.00	0.00	0.00	0.00	0.00	0.04194	0.04391	0.05171	0.05478	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.63371	1.00000	0.00	0.21311
2	0.00	0.00	0.00	0.00	0.00	0.20981	0.00	0.00	0.00	0.64609
3	0.00	0.00	0.00	0.00	0.00	0.54992	0.19193	0.00	0.00	0.07513
4	0.00	0.00	0.00	0.00	0.00	0.24027	0.17436	0.00	0.00	0.06567
Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 12: Clusters matrix Source: Authors

	Alternatives	Components	Goal
Alternatives	0.000000	0.500000	0.000000
Components	0.000000	0.500000	1.000000
Goal	0.000000	0.000000	0.000000

Table 13: Weighted supermatrix Source: Authors

	A	B	C	D	E	1	2	3	4	Q
A	0.00	0.00	0.00	0.00	0.00	0.09523	0.16869	0.05490	0.06769	0.00
B	0.00	0.00	0.00	0.00	0.00	0.22058	0.17695	0.16053	0.23234	0.00
C	0.00	0.00	0.00	0.00	0.00	0.11589	0.09090	0.19020	0.47331	0.00
D	0.00	0.00	0.00	0.00	0.00	0.04732	0.04150	0.06851	0.17188	0.00
E	0.00	0.00	0.00	0.00	0.00	0.02097	0.02196	0.02586	0.05478	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.31686	0.50000	0.00	0.21311
2	0.00	0.00	0.00	0.00	0.00	0.10491	0.00	0.00	0.00	0.64609
3	0.00	0.00	0.00	0.00	0.00	0.27496	0.09597	0.00	0.00	0.07513
4	0.00	0.00	0.00	0.00	0.00	0.12014	0.08718	0.00	0.00	0.06567
Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

In the end, the columns of limiting matrix provide the final priorities (Fig. 17). The priority list for the alternatives gives a great deal of relevance to Good with respect to the other possibilities (Fig. 18). The second priority –Intermediate – indicates that the continuation of the current process, gives worth position to the quality of public space.

RESULTS & DISCUSSION

Though favorable conditions of this natural public space with respect to the variables of the component of Mind-experiential-aesthetic Logic, has met the users satisfaction, but its unfavorable conditions with respect to the variables of the other components, Bio-space-social Logic, Eco-environmental-societal Function and Eco-environmental-societal Excellence, will seriously challenge the quality of this public space in the near future. This research shows that in the process of regenerating Tehan's river-valleys' natural environment, including Farahzad River-valley, the principles of landscape ecology have been disregarded. In effect, no attention has been paid to the natural and ecologic potentials of these landscapes. In the case of Nahjolbalagheh Garden, the project has been completed as if its only purpose has been to establish a beautiful garden. The disregards for the microclimate, the plant and animal diversity, the non-local plant cultivation incompatible with the context, unfavorable and non-sustainable cycle of matter and energy, infiltration of pollutants into the ecosystem (especially the ecosystem of river-valleys), and finally the absence of ecological connectivity to other urban landscapes are issues that may cause serious local problems and even the ecological destruction of Tehran's landscape in the not so distant future.

Super Decisions Main Window: q.mod: Priorities

Here are the priorities.

Icon	Name	Normalized by Cluster	Limiting
No Icon	Bad	0.12454	0.071336
No Icon	Exellent	0.15147	0.086762
No Icon	Good	0.34767	0.199147
No Icon	Intermediate	0.32831	0.188053
No Icon	Very bad	0.04801	0.027500
No Icon	Bio-spatial-social Logic	0.14559	0.062198
No Icon	Eco-environmental-societal Excellence	0.30707	0.131180
No Icon	Eco-environmental-societal Function	0.43943	0.187725
No Icon	Mind-experiential-aesthetic Logic	0.10791	0.046099
No Icon	Quality of Nahjolbalageh Garden	0.00000	0.000000

Fig. 17: Final vector with global priority deriving from limited matrix Source: Authors

Name	Graphic	Ideals	Normals	Raw
Bad		0.358206	0.124539	0.071336
Exellent		0.435667	0.151470	0.086762
Good		1.000000	0.347675	0.199147
Intermediate		0.944288	0.328306	0.188053
Very bad		0.138087	0.048009	0.027500

Fig. 18: Synthesized priorities for the alternatives Source: Authors

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CONCLUSION

To attain more qualified natural public spaces in Tehran's urban environment, it is necessary to stop the continuous ecological destruction of Tehran's river-valleys' potentials, and to take steps to improve urban landscapes' ecological connectivity. Based on the potentials and the restrictions of the landscape, the solutions for enhancing the ecological connectivity of urban natural public spaces are provided through the hierarchy of landscapes' Environmental Equilibrium, Geographical-anthropological Sustainability and Eco-environmental-societal Excellence features (Table 14). By monitoring Tehran's river-valleys' content composition and spatial configuration variables, the function quality of Tehran's natural resources is restored.

According to the hierarchical levels of ecological features, Tehran's river-valleys are valued as an ecological matrix of recreational areas citywide for the inhabitants of the regions as well as attractive residential areas. This will contribute to the improvement of the urban environment, the quality of life and general health of urban inhabitants, and even the strengthening landscape's ecological and economic potentials. The main focus is the application of the concept of eco-hydrology through the rehabilitation of the Tehran's river-valleys as an ecological network linking the landscape's highly attractive ecological, recreational and residential areas. The key element is the ecological management of the Tehran's river-valleys as the spatial link between geomorphology, vegetation, hydrology and land use, and as the integrated network between major natural corridors and patches within and outside the city, connecting natural and manmade green patches in order to

Table 14: Strategies for Tehran's river-valleys' landscape variables Source: Authors

Performance Indicator			Content Composition	Spatial Configuration
Environmental Equilibrium:	Natural patch preservation	**Landscape's resource allocation**	- Distribution of small natural patches (Increased extent & number of natural patches) - Distribution of large manmade patches (decreased extent & number of manmade patches) - Distribution of large & small decorative-planting patches (decreased extent & number of ecologically non-related patches)	- Ecologically related patch distribution (increased spatial relation of natural patches) - Spatial relation of natural patches in gaining ecological positions (non-spatial break of natural systems by manmade patch & corridor interferences) - Spatial isolation of natural patches in gaining anthropological positions (improved natural systems' spatial relation with manmade patches & corridors)
Geographical-anthropological Sustainability:	Ecological network preservation	**Landscape's socio-spatial network program**	- Natural corridors' disconnection (increased length & number of ecological corridors) - Distribution of manmade corridors (decreased length & number of traffic corridors) - Distribution of decorative-planting corridors (decreased length & number of ecologically non-related corridors)	- Ecologically related corridor distribution (increased spatial relation of natural corridors) - Spatial relation of natural corridors in gaining ecological positions (non-spatial break of natural corridors by manmade patch & corridor interferences) - Spatial relation of natural corridors in gaining anthropological positions (natural corridors' spatial relation with manmade patches & corridors) - Spatial relation of manmade corridors in gaining ecological positions (manmade corridors' spatial relation with natural patches & corridors)

Continue of Table 14: Strategies for Tehran's river-valleys' landscape variables

Performance Indicator			Content Composition	Spatial Configuration
Eco-environmental-societal Excellence:	Ecological-anthropological network Excellence	**Landscapes' bio-spatial-social network management**	- Using ecological-anthropological boundaries of green corridors - Stabilizing ecological potentials of interrelated urban inner and outer natural units - Distributing natural patches next to the densely urban patches - Stabilizing ecological bed of landscape to interact with decorative-planting small patches - Making tourism opportunities and possible access to ecological attractions - Aggregating different recreational types in forming different ecological activities along with green corridors (multipurpose greenways) - Using native materials in forming land views proportioned with climate - Forming habitual-cultural identity of ecosystems in reviving eco-historical identity of landscape - Stabilizing native natural resources in stabilizing landscape's cultural-historical properties	- Spatial integration of ecological elements: surface waters, forest, parks, agriculture lands, villages - Spatial interconnection of infrastructure elements: roads, rail routes, rivers, water canals, sewage networks - Ecological zoning of access networks: tourism walkways, biking routes, local traffics - Ecological interconnection of tourism regions and urban transportation networks - Successive natural perspectives of urban spaces and Residential neighborhoods

improve the ecological networks citywide.

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