ISSN: 2008-5079 / EISSN: 2538-2365
DOI: 10.22034/AAUD.2023.334522.2645

The Role of Various Ecological Criteria in Different Seasons of Residential Buildings located in Mashhad City*

Hamid Hamed Sardar[a]- Saeed Tisghalam Zonouzi[b]- Shooka Khoshbakht Bahremani[c]**

[a] Ph.D. Candidate, Department of Architecture, Central Tehran Branch, Islamic Azad University, Tehran, Iran.

[b] Assistant Professor, Department of Architecture, Central Tehran Branch, Islamic Azad University, Tehran, Iran (Corresponding Author).

[c] Assistant Professor, Department of Architecture, Central Tehran Branch, Islamic Azad University, Tehran, Iran.

Received 17 March 2022; Revised 22 January 2023; Accepted 07 February 2023; Available Online 22 September 2023

ABSTRACT

High-rise residential buildings in natural environments are an emerging phenomenon in many countries, particularly in developing countries. Many buildings may cause irreversible damage to their environment due to incompatibility. Designers and constructors would build some buildings in line with sustainable development based on their training and principles for environmental preservation; however, sustainability criteria in the design are also responsive for some seasons and cannot cover all seasons. This study aims to examine the effect of ecological criteria in different seasons by extracting shortcomings of the ecologic design of high-rise residential buildings. The research method is a mixed qualitative-quantitative method. In the qualitative step, Delphi's future study with three brainstorming, limitation, and selection is used then the Kendall coefficient is applied for variable refining in case studies. In the quantitative step, the questionnaire is formulated based on the Likert scale and then distributed among 384 stakeholders during four different seasons. Data analysis is done through JMP and Sigmaplot software, and moving averages and graphic correlation charts are finally extracted. The results show that ecological architecture' variables have a correlation rate of 0.73 during summer and winter. The highest correlation is observed between summer and winter seasons, while the lowest correlation (0.0004) is seen between spring and summer seasons, and designers have paid attention to both seasons in their designs.

Keywords: Ecological Architecture, Various Seasons, High-Rise Residential Buildings in Mashhad City, Mixed Method.

* This paper is derived from the Ph.D. thesis by the first author titled "Reading Components of Ecosystem Architecture for Improving Building and Environmental Quality of Case Study: Multifunctional Buildings in Mashhad City" which is guided by the second and third authors.

** E_mail: arch.szonouzi@yahoo.com

1. INTRODUCTION

Although "architectural design" emphasizes enacting "standards" to achieve sustainability goals and principles of "green architecture" are used as regulations for sustainable design in developed countries, the "outcomes" and "standards" are not considered in our country, Iran, and the City of Mashhad. No criterion is restrictive in “locating” high-rise buildings (Pourjafar and Adabkhah 2012, 11).

When Mashhad Municipality signed a contract with Part Plan Consultant for urban studies, this consultant announced the priority of some areas in districts 1, 9, and 11 for construction of high-rise buildings because these were relatively newly built, and the high price of land that made construction const-effective but also the urban infrastructures were new in these areas. However, this guideline was not executed unfortunately, meaning that this guideline was done not only in the mentioned areas but also in forbidden areas of the mentioned districts and even in the districts where high-rise building was not allowed. The reason is that this project has not provided a solution for social issues after its implementation, and has not completely investigated the coordination between functions (job, residence, leisure time, and meeting needs) because suitable coordination and access to this kind of function must be solved in each district based on the “density increase” and subsequent population growth. Moreover, another issue of this project is the "evaluated scale" of municipality districts, so that each district is divided into "homogenous and heterogenous" areas based on its various specifications and it is not possible to consider a district with or without absolute priority (Management of urban development plans, vice-president of urban planning and architecture 2014).

There are high-rise buildings constructed in narrow alleys, and only criteria of "Part" plan are considered in the construction of "high-rise buildings" while it can be stated that a general view such as part plant is required but not sufficient for prioritizing all districts of the city regarding the construction of high-rise buildings. Therefore, some studies are needed at smaller dimensions in the internal level of areas by assessing the details and factors affecting the selection of proper locations for constructing such buildings (Hossein Alipour 2001, 15).

The specific location of Mashhad as the capital of Khorasan Razavi Province and the second religious metropolis in the world with annual statistics of more than 20 million tourists and pilgrims, lack of energy resources, and severe environmental crises such as water crisis have led to more serious attention of urban management especially municipality to monitor, direct, and control urban plans and programs to achieve sustainable urban development. Also, the sustainable design of high-rise buildings that are growing as a new wave in construction over recent years requires observing ecological principles to provide sustainable buildings with an age older than 100 years (Omidvar 2009, 52). Heavy costs of tower construction, from design to implementation and operation, have drawn the attention of tower constructors to economic savings and huge projects of fast-return investment, the “sustainability” that has late-return economic efficiency has been ignored in practice. On the other hand, the horizontal growth pattern in urbanism policies has turned to smart growth that leads to the idea of a compact city. Urban managers and investors have considered "high-rise construction" as one of the techniques used for the construction of a "compact city" for maximum use of limited space and resources (Bemanian 1997, 147). However, negligence of the essential criteria and regulations for the "accurate location" of these buildings and lack of attention to ecological basics in the construction of each building may cause numerous problems in urban areas and the future of cities. Therefore, this study aims to examine the effect of ecologic criteria in different seasons, extract the shortcomings in the ecologic design of high-rise residential buildings, and answer the following question:

How much do the criteria of ecological architecture affect the high-rise residential buildings in Mashhad City during different seasons?

2. THEORETICAL FOUNDATIONS

A human development ecosystem refers to a network of diverse stakeholders that create a dynamic network of human abilities in an appropriate ecosystem and constantly improve the quality of life of people. The level of the mentioned abilities and their impacts on each other play an underlying role in the efficacy and sustainability of the human development ecosystem. Individual abilities and employability are two substantial groups of elements in the human abilities network, and their levels and effects play a key role in human development, while their situations remain unknown in Iran's architecture, and the knowledge gap is severely obvious.

2.1. Ecological City or Eco-City

Most ecological and environmental views in the sustainable development literature have introduced the concept of "ecological city" or "eco-city" into some topics, such as economic development, urban planning, and social justice considering these notions as the theoretical foundation of all previously mentioned concepts. With more than 20 years of history, “urban ecology” explains its goal regarding the creation of ecological cities by obeying the following principles (Roseland 1997, 197):

Although the ecological city or eco-city is a relatively new concept but is rooted in the concepts with a long history. According to the definition presented by the non-governmental organization of "urban ecology," an "ecological city is a human residence with high quality of life and minimal use of natural resources" that is the most durable settlement people can construct, and is a city that provides acceptable living standards without destroying ecosystem and natural life cycles (Mofidi Shemirani, 2013). In such a city, ecological requirements are integrated with social-economic conditions. In natural ecosystems such as "rainforests," wastes of one process are used as resources for another process (Gorgi Mehlbani 2010). For instance, waste withered plants or animals provide nutrients for other trees and plants, while the irregular process of urban metabolism has a linear form; it means that a high rate of consumers exists that use goods, foods, and energy while they are producing many environmental pollutants such as organic and inorganic wastes and toxic gases or noxious emissions (Karimi 2013, 157).

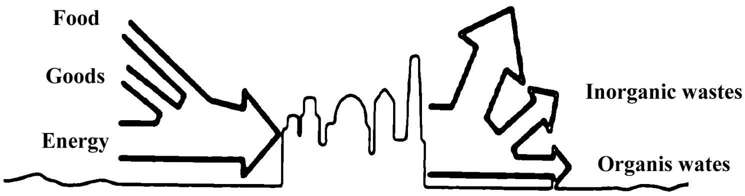


Fig. 1. Linear Metabolism of the City
(Motin and Shirley 2007, 55)

It is suggested to convert this linear system to a metabolism cycle through the design and management of a "cyclic metabolism" like a system that occurs in nature where waste is integrated into a larger ecosystem. It means that new energy inputs and waste outputs are minimized through the "recycling" process (Cooper and Symes 2008, 189). In this case, the ecological footprint remains in the environment based on the ecological occupation area not leading to the decompression of the fragile natural environment (Armstrong and Mir 2008). An ecological city is a sustainable city that can provide a meaningful life for residents without destroying its ecological foundation (Hassan et al. 2005).

Eco-city increases the well-being level of society and citizens through integrated urban planning and management, fully controls the benefits of ecological systems, and keeps the natural capital and resources for the next generation (Haughton and Counsell 2004). The more holistic concept of "ecological city" comprises all cultural, natural, regional, social, and economic aspects drawing the attention of a wide range of social groups, including administrative officials, urban planners, entrepreneurs, and biologists worldwide (Jahad Daneshgahi of Mashhad 2010, 52).

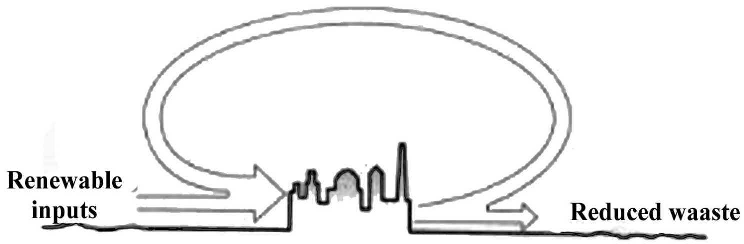


Fig. 2. Circular Metabolism of the City
(Motin and Shirley 2007, 55)

2.2. Ecological Architecture in Building Construction

Sustainable construction has been defined based on the modern architecture styles: "a healthy and clean environmental management based on the effective operation of "natural resources" and "ecological principles"." Hence, the design of sustainable buildings aims to reduce damage to nature, the environment, and energy resources (Hassan et al. 2005).

A sustainable building is defined as "a building with minimum incompatibility and inconsistency with its surrounding environment in a wider area of the region and world." Building construction techniques attempt in a wide area to provide integrated economic, social, and environmental quality (Bahraini 2010, 19). Therefore, rational use of natural resources and proper construction management contribute to less energy consumption, preservation of scarce natural resources, and improvement of environmental quality (Hosseinzadeh Dalir 1999).

"Sustainable housing" is an issue in sustainable urban renewal and renovation. Although many houses have been built with uncertain quality and many urban lands have remained useless, sustainability essentially refers to residential areas not the design of the new neighborhood. The community we are trying to formulate a definition of sustainable housing for it allows us only to renew and renovate the sustainable urban life (Malin 2006).

Table 1. Features of Eco-City and Ecological Architecture in the Building

	Features of Eco-City	Feature of Ecological Architecture in Building		
Ecological Integration	Meeting basic needs of humans (healthy (not polluted and contaminated) air, water, and food), preserving and improving biological, local, and regional ecosystems, protecting land, water, energy resources, and non-renewables such as maximum possible recovery, reuse of wastes, suitable use of renewable resources based on their renewability and using restrictive approaches and proper technology for minimum emission	Using shared gas and electricity counters, quality against thermal loss, using thermal insulation shell, dividing the purified and unpurified waters, recycling rainwater, separating wastes such as chemical waste, building flexibility for technical changes and evolution, building flexibility against possible use change, resistance against earthquake	Energy management, water management, handling the wastes remaining from activities, managing the building maintenance	Ecological Management
Ecological Integration	The strong and diverse economic-financial base, a maximum local tax of jobs, and reinvestment of resources in the local economy, important economic opportunities for all citizens, and providing public education and occupation training to help labore force of next generation	The moisture control system, smart leakage-detection system, thermal thermostat system, the proportionality of location of private spaces and other spaces in terms of sound, using sound insulation system, providing proper view and outlook for occupants, privacy, number of spaces full of natural light, considering some measures to prevent adore, and appropriate ventilation for health spaces	Comfort in terms of temperature and humidity, sound comfort. Visual comfort, smell comfort	Comfort
Economic Security	Rich food storage based on the local production plan, safe, healthy, and qualified housing for all community members, sufficient health services, keeping the place free of violence and crime, providing a healthy workplace, promoting social spirit (sense of place, sense of belonging, and self-value sense), and consistency with changed conditions.			
Quality of Life	Sufficient access to public information of private and public sectors, equal opportunities for participation and decision-making for all people, respect space and tolerance of various beliefs, views, and values, not violating sustainability of other communities, encouraging individuals of all age ranges, genders, religions, races, and physical ability to take responsibility based on a joint view	Access to suitable places for landfills, proper access for waste collection machines, quality of thermal installations, quality of cooling installations, the use rate of harmful chemicals in buildings, appropriate ventilation systemizing pollutants and inexhaustible materials in the watering network, healthy waste disposal network.	Health quality of spaces, health quality of air, health quality of water	Health
Capability	Integrated management of closed water cycle and water resource, reducing waste production and integrated solid waste management, energy management and reducing greenhouse gases, different approach to sewage, predicting climate changes, integrated transportation strategy, suitable policy made on house construction, increasing equality in distribution of interests and justice, accurate policy-making in field of pollution issues			

(USGBC 2020)

2.3. Definition of High-Rise Buildings

The tall buildings are called high-rise buildings. The term "high-rise" is usually used with another word such as residential or administrative.

2.3.1. Definition of High-Rise Buildings in Iran

Height of building is a relative case, so many definitions have been presented for "high-rise buildings" based on various aspects: "urban designers" and "planners" consider the 10-story and higher buildings as high-rise buildings (Rahnama and Razzaghian 2015, 47). According to “national rules of Iran,” minimum floors of high-rise buildings equal 8 floors considering the executive guideline for protection of buildings against fire (Tehran Study and Planning Center 2012). These buildings refer to buildings taller than 6-story buildings based on the rules and regulations enacted by the Iran Supreme Council of Architecture and Urban Planning (approved in 1998); however, this definition refers to buildings with more than 12 floors based on the Tehran Comprehensive Plan (approved in 2007) (Management of Urban Development Plans Vice-president of Urban Planning and Architecture 2014).

Each building that is taller than 23m is defined as a high-rise building (Tehran Study and Planning Center 2012). A "High-rise building" is a multistory and tall building with commercial, residential, administrative-residential, or multi-uses, and its difference from a skyscraper is seen in the height. No standard and unique definition exists for minimum height of a high-rise building but a building with at least a height of 23m is agreed as a high-rise building. According to Nateghi Elahi, a tall residential building is a single high-rise building whose height is higher than the diameter of the plan's inscribed circle (Remouk 2002, 17). However, Bemanian defines a high-rise residential building as a building with a height taller than 10 floors and around 23m (Adeli and Sardeh 2010, 41).

2.3.2. Definition of High-Rise Buildings in the World

High-rise buildings are distinguished from super-high buildings and skyscrapers. An exclusive definition in the USA considers buildings with a height taller than 150m as skyscrapers and buildings taller than 300m as super-high buildings. It is even possible that the buildings that are shorter than the surrounding buildings are defined as skyscrapers. "Germany Emporis" Standard Committee defines a high-rise building as a multistory structure with 35-100m height or a 12-39-story building with unknown height (Remouk 2002, 17). Moreover, this committee defines skyscrapers as multi-story buildings with a minimum of 100m height. One of the world standards about the definition of the term "high-rise building" has been presented herein (Azizi 1999, 18-21). According to the Heidar Baba Code in India, a 4-story or taller building or a 15m building in height are taller than a high-rise building (Adeli and Sardeh 2010, 41).

3. HISTORICAL TREND OF HIGH-RISE BUILDINGS

The tall buildings were limited to temples, pyramids, castles, amphitheaters, mosques, and churches that were signs of power and faith. Other high-rise buildings included 3-story to 4-story buildings with commercial use on their first floors.

3.1. Background of High-Rise Buildings in the World

“High-rise construction” in the world is a phenomenon that occurred from ate 19th century to the early 20th century the first steps were taken in constructing skyscrapers from 1880 to 1900 in Chicago and high-rise construction occurred along with the general ascending rise of buildings in the West during last decades of 19th century (Consultant`s Final Study Document 2010). In summary, four periods can be named in the construction of high-rise buildings, which starts with inventions done by Chicago engineers (Chicago School); in this period, the importance of developments in the structure and use of metal frames and elevator invention (1853) led to an evolution in architecture. In the next period, the popularity of Beaus Arts School and France Academy led to some aesthetical strategies for using historical patterns in creating high-rise buildings (Kunstler and Salingaros 2001). This style became popular from 1890 until World War I in Europe. The tallest building of the city called the World Building was constructed in New York between 1894 and 1899 but was destroyed in 1963-1964. In the third period of European School modernism that became popular by “Gropius and Le Corbusier," an international standard was designed for tall buildings. Historical references and decorations were removed from the design of tall buildings in this period, and a direct expression of structure and materials was created using simple shapes (thin and light shells made of glass, plaster, or similar materials) (Hok Architects Corporation 2006). However, this period is related to the years after 1914 until 1970.

The 40 Wall Street building with 70 floors and 283m height is located in the Manhattan Neighborhood of New York City in the USA. This building is indeed known as the "Bank of Manhattan Trust” building and the “Manhattan Company” building, which is now known as the "Trump Building". This building- from April 1930 to 27 May 1930- has been the tallest in the world and now is the 20th tall building in the USA and the 53rd wall building in the world. The fourth period which is the postmodern and late-modern stage began in the 1970s. Unlike previous steps, the situation of high-rise buildings was considered in relaticoncerningn context, and in addition to returning to neoclassic design principles, special glasses were used for solar photoactive measures, and thinner stone-made coatings were used. Various studies on the negative effects of high-rise buildings in some aspects have made the current designs in most "developed" and some "developing" countries have a tendency towards functional operation, using the principles influenced by ideology and culture, and considering environmental requirements (Armstrong and Mir 2008; Kunstler and Salingaros 2001).

3.2. Background of High-Rise Construction in Iran

Population growth and higher housing needs led to the construction of residential high-rise buildings. Construction of high-rise buildings based on modern techniques began in megacities in the USA and Europe and became popular in "developing countries" after several decades. Around the past half-century, construction of high-rise buildings began in Iran, and the first high-rise buildings in Tehran were constructed from 1951 to 1961 (Remouk 2002). “High-rise building” construction with residential use has been considered over recent decades to solve housing problems. On the other hand, the increased price of land in some populated areas in megacities and the necessity of constructing wide and centralized buildings with commercial, administrative, and business uses to provide the field for the construction of more tall buildings before enacting required rules and regulations (Sadeghieh 2001).

Table 2. Background of High-Rise Buildings in Iran

Decade	High-Rise Construction Process in Iran
1950s	Construction of such buildings began in Tehran, Iran’s capital. The first high-rise building was constructed by Houshang Khasheghani
1960s	Construction of these buildings began with building 16-story building of Plasco (1962) and a 13-story building of Aluminum with "commercial" use then continued with constructing buildings for "Iran National Oil Company" and "Work Bank."
1970s	In the early 1970s, the revenues obtained from the increasing world price of oil and the entrance of oil dollars to the economy of the country led to a high economic boom. This case led to higher income of city dwellers and subsequent rise in immigration to cities and higher demand for housing. In this decade, the construction and sale of apartments became a popular nonprofessional job among governors.
The 1980s and Early 1970s	The process of high-rise construction stopped until the late 1980s but at the end of the 1980s and early years of the 1990s, new tall buildings were constructed after the excessive expansion of cities in the last years of the 1980s. The main factor of this event may be the density license sold by Tehran Municipality to finance the civil urban budget and increased price of land.
Late 1990s	The ascending trend of urbanism rate in large cities of Iran, including Tehran was intensified in recent decades. However, the tallest buildings in Tehran had a maximum of 30 floors and 100m height until 1991.
Continuing High-Rise Construction in 2000s	Since the 2000s, high-rise construction has been considerably higher than in previous decades in terms of number and implementation velocity. One of the reasons may be the public willingness of investors and higher financial interests injected into this sector.

4. EXAMINING HIGH-RISE CONSTRUCTION IN MASHHAD EMPHASIZING THE ECO-CITY THEORY

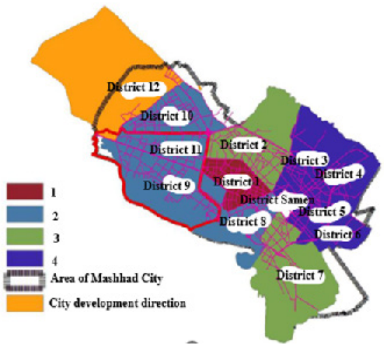
The master plan of high-rise construction in Mashhad was formulated by Part Consultant Engineers in 2001, which studied the urban districts of Mashhad in terms of density. This plan also considered District 1 of Mashhad, which is the case study of this paper as an area with high potential for the construction of high-rise buildings. In this plan, the urban districts of Mashhad have been studied considering economic, social-cultural, physical-spatial, and environmental dimensions (Performance Report of Government Board Approvals 2013). Accordingly, the studies on urban districts of Mashhad have been prioritized based on their high-rise construction potentials. After these districts were prioritized in terms of their relevant criteria and sub-groups (based on the studies on the current status of these criteria in Mashhad), all criteria were considered the same and ranked based on the table (2003) (Iran Urban Planning and Architecture Studies and Research Center 2002).

According to district prioritization, district 1 has suitable potential, districts 9 and 11 have moderate potential, districts 2, 7, 8, and 10 have low potential, and districts 3, 4, 5, and 6 are districts that are not recommended. However, the considerable point is that this plan has not provided a “solution” for social issues after implementing it (Management of Urban Development Plans, vice-president of Urban Planning and Architecture 2014).

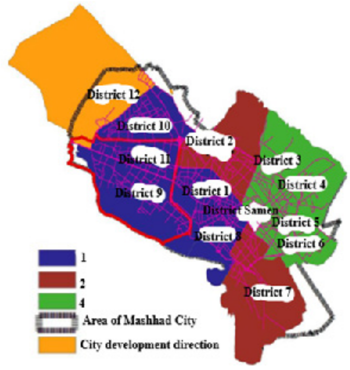
Also, this plan has not fully investigated the functions for providing needs, jobs, settlement, and leisure time, because the desired harmony and access to this function must be solved in each district based on the "density rise" and "population rise." Moreover, other problems of this plan include the evaluated scale that is based on municipality districts, so that each district is divided into "homogenous and heterogenous" areas based on their different specifications, and it is not possible to consider a district with or without "priority" (Farnhad Consulting Engineers 2007). The following maps depict the priority of potentials in urban districts of Mashhad based on the social, economic, environmental, and physical-spatial criteria (Shahrsaz Consulting Engineers and Part Architect 2001).

Table 3. Prioritization of High-Rise Construction Potentials in Mashhad City in Terms of Various Dimensions

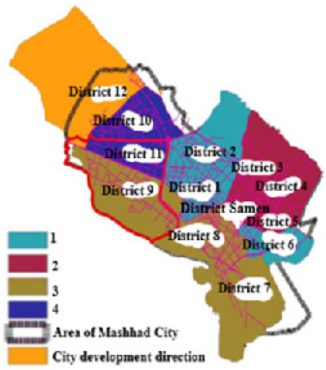
Economic



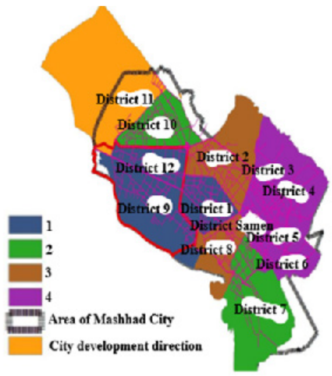
Social



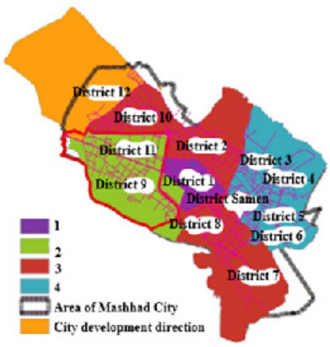
Environmental



Physical



Summarization



(Management of urban development plans, vice-president of urban planning and architecture 2014)

5. BACKGROUND

Mottaeval et al. (2019) carried out a study titled "Ecological Aspects of modern city-planning" to examine the issues and problems in the modern city of Belarus and the shortage of ecological urban components depending on architectural design. It was found that environmental parameters are considerably controlled under the influence of technology, and the use of vernacular materials and simple traditional techniques can be used as promising strategies in this case.

Madiha and Eduardo (2018) conducted a study titled "A reference architecture for ecosystem applications for container modeling" through UML software to control ecosystems with heterogeneities and complexities. It was concluded that the application of containers in the buildings can considerably control various environmental indicators, and this occurs through the Internet of Things (IoT) and instant monitoring of buildings.

Egercioglu et al. (2016) carried out a study titled “Check the location according to the environmental index” to reveal the ecological features of a new residential building in Talas Kayseri in Turkey. Therefore, it was found that a new structure has been considered in the concept of ecology, which is different with some criteria such as ecology, energy, economy, quality of the internal environment, health and wellbeing, innovation, land use management, transportation, water renewable technologies, environment pollution, and CO2 emission.

Ibrahim (2015) analyzes some data about three districts in Duha City in a paper titled "Regeneration of Sustainability in Contemporary Architecture: Approach Based on native function and Activities to Strengthen Identity." The results show what has been learned from the contemporary architecture of Qatar and what has been gained on how "cultural practice" can be integrated with contemporary architecture to support the identity of this country.

Yilmaz and Bakis (2015) carried out a study titled "Sustainability in the construction sector" and concluded that states and institutions, world and non-governmental business organizations, and other stakeholders must act in this way in international communities to adaptation of energy and environmental policies supporting economic development not threatening the natural life. Smart and eco-friendly buildings are the results of sustainable environmental policies made in the construction sector that are responsible for the consumption of natural resources and environmental pollution.

Javadi Nodeh et al. (2019) carried out a study titled “Ecological Architecture Affected by the Interaction of the man-made environment with Nature in Cold Regions: Case Study: Two Historical Houses in Ardabil” to identify ecological Criteria in Historical Houses with Possible Operation in the contemporary era. The results showed that the assessment of ecological criteria indicates compatibility with the environment. The effects of cold climate have been agreed upon by using natural resources so that some rooms with seasonal functions, such as Shah neshin (a kind of living room) and sardab (cold warehouse to store foods) have had an optimal performance against temperature fluctuations.

Razzagian and Rahnama (2019) conducted a study titled "Analysis of ecological city indicators in high-rise buildings of Mashhad metropolis" by comparing ecological design criteria in the studied area trying to reveal the outlook of ecological thought in existing situations. Research findings show that principles of "ecological design" have not been considered in none of the towers and few options for HQE standards have been implemented in these towers.

Mehzoun (2018) carried out a thesis titled "Designing a four-story Residential Apartment System with an Ecological Architecture Approach in District 11 of Tehran" to examine the living organisms' identification, communications, and environment. Findings indicate that although various factors such as cultural, environmental, social, and economic features are effective in the design of a four-story residential apartment based on the "ecological architecture" approach, observance of the principles and criteria derived from fundamental and practical studies on architectural design, site design, and suitable structure fields can make the residential apartment a proper, desired and realistic strategy, particularly in metropolises.

Zohri (2017) conducted a study titled "A comparative comparison of native architectural components with the principles and criteria of ecological design" to find ecological strategies of vernacular or native architecture. The results showed features of "vernacular architecture" are consistent with considered principles in ecological design within four main scopes of architecture, including establishment technique, making relationships with the ecosystem, design technique, and materials.

Arin and Farajpour (2016) carried out a theoretical study titled "The Effect of Green Roofs and Green facade on improving environmental quality and reducing energy consumption in Tehran" to examine the features of green roofs, green façades, and their environmental performances in Tehran. The results of this study indicated a significant reduction in dust particles suspended in the air (around 20000 tones) with 20% production (100km2 equivalent) in the roof and façade of residential buildings in the green space of this metropolis resulting in the conversion of 37000 tones CO2 to O2.

Khoshro and Javadi (2016) carried out a study titled “Ecosystem Thinking in Architecture" to know how ecosystems and nature affect the surrounding environment of humans and improve the quality of architectural designs in the new step for human life within the framework of ecosystem preservation. The results show that ecological concepts provide a better understanding of place design consistent with the ecosystem after passing through ecosystem filters. In addition, this study tries to identify the natural environment and examine the ecosystem to design a superior plan by examining its advantages and disadvantages.

Haji Ghanbari et al. (2015) conducted a study titled “The Combination of ecological architecture and new technologies in reducing energy consumption in mountainous areas, case study: Tabriz Metropolis" to imitate the prominent vernacular architectural elements of "cold and mountainous" climate of Tabriz city and integrating it with new technologies. Therefore, it is recommended to use "double walls" instead of thick walls and "PVC windows" instead of ordinary windows and other elements incorporated in the paper to control energy consumption by reducing the building's heaviness.

Kolivand et al. (2014) carried out a study titled “The Thermal Performance of Vegetation in Open Urban Space, case example: Imam Khomeini Port" in an urban district in the hot and humid climate of Imam Khomeini Port. They simulated the district using Envi-met software and examined 12 effective factors, including height change, building density, vegetation type, and so on. Finally, the results of the study showed the higher the density and height of buildings, the higher the temperature, and the higher the thermal discomfort will be.

6. STUDIED AREA

According to the data and information obtained from theoretical foundations, districts 9 and 11 achieved the first rank in terms of high-rise buildings. The statistical society of this study comprises seven popular and important high-rise residential buildings among 32 high-rise buildings located in the southwest that are selected in this study due to their popularity, end of construction operations, and use as the pattern for construction by other constructors. It is worth noting that the selected towers have been operated and have more than ten floors. Since the research topic is about residential towers, it has been tried to select the case studies among residential towers. Table 4 reports the profile of these towers.

Table 4. Profile of Studied Towers

Name of Tower	Access	Number of Floors	Specifications	Number of Occupant Population	Number of Apartments	Dimension of Apartments	Year of Construction	Total area of Foundation	Land area	Height above the Land	Municipality District
Mania	Margin of Saremi Blvd.	17	Lack of use of suitable and indigenous materials and products; no terrace up to floor 13. It has a terrace with an area of 135m2 after floor 13.	192	30	105, 107 and 125m	1392	7650	980	65	9
Bahman	End of Danesh Amooz Blvd. and margin of Amoozegar Blvd.	16	Lack of terrace for residential apartments, it has been tried in these towers to consider multipurpose conference halls and other service spaces required for occupants.	341	86	96 and 190m	1391	12865	2538	45	11
Niyayesh Complex	Zakarya Lands	6-10	Lack of terrace or open space; the land of this residential complex has a relatively sharp slope, and its rate varies between 15% in the north direction and 39% in the central part of the land.	1280	300	96-190m	1392	56580	22181	25-35	9
Baran 1	Hashemi Street	18	With open space; concrete structure; and welfare and service amenities inside the complex	153	38	180, 240, 270, 350, 55, and 650	1390	16000	1500	60	9
Baran 2	Margin of Golshan Haft-e-Tir street	30	Common and shared spaces that provide welfare services for occupants.	236	59	230, 390, 650, 900m	1393	300000	2200	110	9
Rose Armitage	Saremi Blvd.	16	Apartments with 3 and 4 bedrooms, with welfare, recreational, and service facilities for occupants	127	31	245 and 276m	1392	11119	1615	60	9

(Management of urban development plans, vice-president of urban planning and architecture 2014)

7. METHOD

The research method is applied-developmental in terms of nature with a mixed qualitative in quantitative technique. First, systematic studies are done to understand the concept based on the titles and questions from first-hand resources. After extracting the variables from the theoretical step, variable scrutinizing about the case study is done in the next step. In this step, the Delphi board is shaped based on the four 8-member groups.

The inclusion and selection criteria of experts are based on the Table 5:

Table 5. Criteria for Selecting Experts

Selection based on Snowball	With at Least an MA Degree
Being faculty member	In the discipline of architecture, urban development, and planning
Having a paper on ecological architecture and its associated topics	Familiarity with methodology, participatory observation, and its principles
In the discipline of architecture, urban development, and planning	Being able to visit selected multipurpose buildings
Having a background in the design of residential buildings	Having sufficient information about ecosystem architecture and ecological design
Having enough information about the architecture of residential buildings in Mashhad	Having at least one paper

In the next phase, brainstorming begins and the professional board is asked to confirm variables, and results of each group is sent to another group then in the next phase, which includes limitation the respondents are asked to score variables (1-10) based on their existence or absence based on the preference system. In the selection step, variable screening is done based on Kendall's coefficient of concordance, and variables less than 0.5 are excluded from the assessment procedure.

The quantitative step begins after this part a questionnaire is designed based on the Likert scale and variables, and then is distributed among spatial users of selected high-rise residential buildings. The validity of the instrument is examined based on the formula CVR=0.76 and the reliability of the instrument is measured based on the formula of Cronbach's alpha (0.78). The questionnaires were distributed randomly within four seasons in 2021 and were done for 384 members, which is the upper limit of the Morgan Table. The results are analyzed based on the inferential statistics in all seasons through JMP software, and then the graphical correlation between variables' dimensions is examined through SIGMAPLOT software.

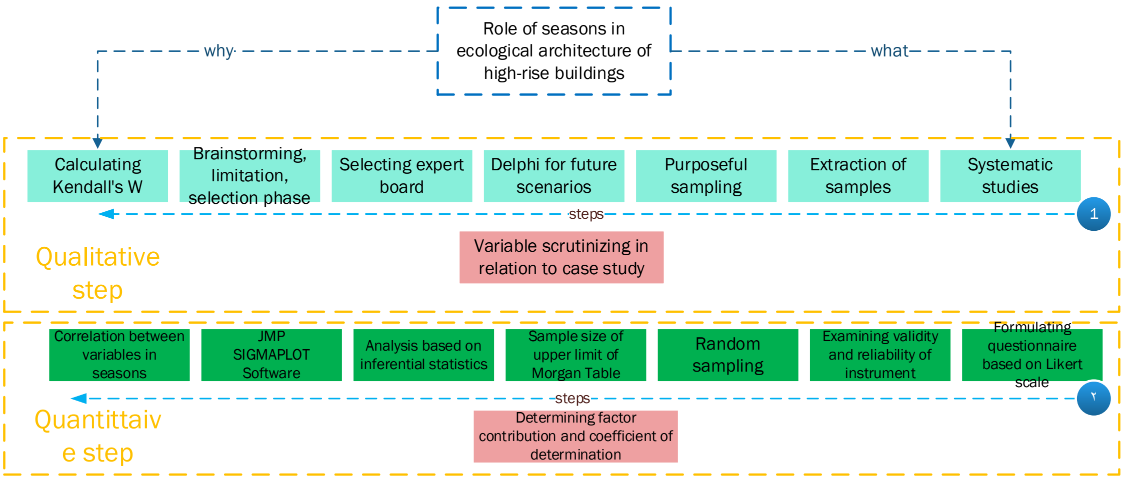


Fig. 3. Research Process

8. FINDINGS

The obtained data and information are used to answer the problem, and questions of the research, confirm the judgment, confirm or reject the hypotheses, and realize the goals. These data are sorted and analyzed.

8.1. Qualitative Findings

In this step, the expert board is asked to review the variables extracted from theoretical foundations and confirm if they represent the ecological architecture, and then the case studies in Mashhad city are introduced to them then they are asked to give a score (0-10) to variables based on their presence or absence in the studied area. In the next step, the experts were interviewed on separate boards asking them to rank the indicators selected by each board then each expert was asked to select 10 indicators; therefore, the indicators selected by 50% of experts were selected for each board. Moreover, the experts were asked to rank the factors available in the edit lists of their board, and which average rank was considered for each case. Evaluation was done in each list using Kendall's W, and this process continued until reaching the consensus and some variables were eliminated from the first round. In Table 6, Kendall's coefficient has been measured for each variable and the deleted variables of the first round have been shown.

Table 6. Kendall's Coefficient obtained from Ecological Architecture Variables Attributed to the Case Study

	Category	Ecological Variables	Kendall's W
Variables of Ecological Architecture	Sustainable Sites	Construction activities preventing pollution	0.635
		Employing LEED experts to use ecological materials and technology	0.761
		Site evaluation	0.321
		Building maintenance management	0.573
		Open space	0.577
		Rainwater management	0.822
		Reducing the heating effect on the environment	0.695
		Providing suitable light	0.423
		Waste recycling using local elements	0.792
	Efficiency of Water Systems	Consumed water amount	0.355
		Water management	0.624
		Reducing the use of internal water resources	0.578
		Cooling towers	0.696
		Water consumption saving	0.730
	Energy and Atmosphere	Running the main energy audit system	0.396
		Minimum energy consumption	0.886
		Energy consumption rate	0.593
		Handling coolers	0.431
		Improving the quality of energy launcher systems	0.769
		Optimization of energy consumption	0.582
		Advanced energy measurement	0.781
		Using renewable energies	0.530
		Using green energies and reducing carbon consumption	0.873
	Materials and Resources	Green space rate in the area	0.506
		Planning and management of waste from destruction	0.617
		Reducing the effect of a building's lifecycle	0.726
		Promoting the use of environmental products	0.492
		Optimization of materials use	0.856
		Using indigenous materials	
		Optimizing transportation of raw materials from the mine	0.901

	Category	Ecological Variables	Kendall's W
Variables of Ecological Architecture	Quality of Indoor Space	Minimum use of ventilation systems	0.569
		Systems for controlling lack of tobacco use in the building	0.483
		Strategies for improving the quality of indoor air	0.496
		Materials with low levels of volatility	0.507
		Plan for indoor air quality management	0.688
		Evaluating the quality of indoor air	0.568
		Thermal comfort	0.576
		Indoor lighting	0.907
		Daylight	0.862
		Perspective	0.617
		Reducing noise (sound pollution)	0.526
		Innovation in air quality monitoring in indoor and outdoor spaces (transparent balconies, etc.)	0.514
	Location and Transportation	Developing neighborhood location based on the LEED index	0.588
		Special building maintenance	0.673
		Suitable parking for mixed uses	0.769
		Access to public transportation	0.595
		Access to the bicycle network	0.671
		Reducing effects of parking lots (decreasing space for parking lot)	0.712
		Providing suitable space	0.307

8.2. QUANTITATIVE FINDINGS, INFERENTIAL STATISTICS, AND CORRELATION

The results of the questionnaire are numbered and then imported to Sigmaplot software, and “correlation” equations are used to analyze the predictor relationships (regression). The Two-Sample Kolmogorov-Smirnov Test has been used to examine the "parametric or nonparametric" type of data.

Table 7. Kolmogorov-Smirnov Test to test Normality of Ecological Architecture Variables during Different Seasons

Variable	Mean	SD	Kolmogorov-Smirnov Z	P
Variables of Ecological Architecture during Different Seasons	34.81	2.54	0.675	0.318

As seen in Table 7, the Kolmogorov-Smirnov test is significant for the scores of ecological architecture variables during different seasons (p=0.318); hence, they do not have normal distribution so the "nonparametric" analyses must be used for it. The "internal correlation matrix" chart of variables is used for using linear or multivariate regression types. After this diagram was plotted, it was found that these factors do not have a "linear" relationship; hence, "multivariate" regression must be used.

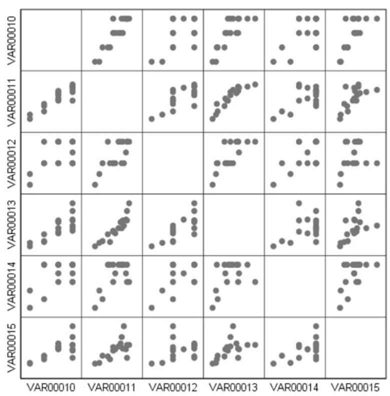


Fig. 4. Factors’ Correlation Matrix

According to the table obtained from the coefficients of determination for variables of ecological architecture during different seasons, variables of ecological architecture in different seasons have different effects. In spring, the variable of using renewable energies (with a value of 0.246) has the lowest effect, while the highest effect is related to thermal comfort and perspective (1.000). In summer, the variable of recycling collection and storage (0.254) has the lowest effect, while the highest impact is related to thermal comfort, reducing the use of internal water resources, and decreasing noise. In the fall, the variable of recycling collection and storage (0.244) has the lowest impact, while the highest impact is related to building maintenance management, thermal comfort, perspective, and reducing noise pollution (1.000). In winter, the variable of the indoor air quality management plan (0.246) has the highest effect while the highest impact is related to the use of the surrounding environment, mixed uses, and reducing effects of parking (1.000).

The reasons for the higher impact of some variables compared to other ones during different seasons indicated that “sunlight” must be used in the coldest days of the year (from November to late March). Moreover, extra “heating” equipment also must be used. Comfort can be achieved in four months of the year (April, May, September, and October) using stored heat in construction materials and heating equipment in the mornings. In the hottest days of the year (August, July, June), thermal comfort is provided at night. It is hot in the days of these months, so evaporative cooling of water must be used in addition to the thermal capacity of the construction materials and wind flow. Also, no use of cooling towers is a reason for dissatisfying occupants. In hot seasons, the indoor air of the building moves upwards after being heated the exists throughout the upper pores in "ceiling adjacency." In this case, air movement is the base for cooling using chimney ventilation and replacing it with cooler air. The "cooling" towers would enter the cool and humid air through the valves at the upper side, their opening is covered with a moist layer. The function base of towers is the use of "evaporative cooling" and cooling through "ventilation" leading to thermal comfort.

The number of tourists is increasing in hot seasons due to many "school and job" holidays during summer. Hence, the higher number of Iranian and Foreign tourists in summer rather than in other seasons leads to heavier traffic and noise.

Regarding the increased rate of water consumption in summer, the occupants think that water systems in residential complexes must be efficient emphasizing the water protection in indoor equipment of buildings and optimal water consumption. In the opinion of occupants, improper installations lead to the waste of water resources in these complexes.

Furthermore, districts 9 and 11 are central districts of Mashhad. The schools and educational centers such as Ferdowsi University, Teacher Training Center of Shaheed Beheshti, and several educational centers would increase traffic rates in streets and subsequent noise pollution. Because fall is the season when educational courses are started, the variable "reducing noise pollution" is more asked by residents in this season.

Also, the green space has not been considered in the design of these residential complexes, while the mass of trees not only creates a good view and smooths the space but also is acoustic and can prevent the disturbing noise of the urban environment. Some trees with wide green leaves 10m in depth can reduce noise pollution up to 50decibel. Moreover, the mass of trees is "sunlight adsorbent" preventing direct irradiation to the indoor and body of the building. Hence, both sun heat and glare are reduced in this case. Trees are the most effective natural tools for solar control. Planting trees inside and around the parking lots creates a shaded grove in the urban heat island, which moderates the temperature of summer or winter in parking lots. During fall when wind flow is higher in the opinion of occupants, trees can serve as windwards in the path of disturbing winds. Therefore, occupants believe that "perspective and reducing noise pollution" is one of the variables that must be more considered in fall.

Since most households have more than one car and lack parking space, their cars may face some changes, such as frosted windows, switch-on dysfunction, or inability to switch the car on in winter due to cold weather. Also, parking lots of studied residential buildings have been designed and built with unpleasant appearance using improper materials without considering environmental issues, so they may cause harmful and devastating effects on their surrounding environment. The floor of these parking lots is dark and made of some impermeable materials such as asphalt and normal concrete; hence, runoffs are not absorbed in parking lots, so their floors remain wet during winter. If these floor coatings were made of porous asphalts, smooth stone, or recycled materials, the water could penetrate the land easily, or some other outcomes such as less light absorption and temperature reduction would occur in hot seasons if the floors with bright colors were used.

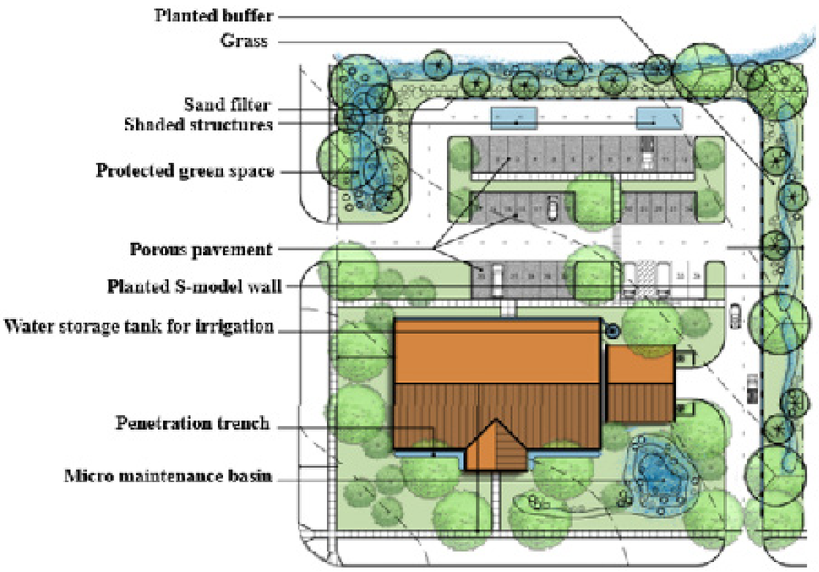


Fig. 5. How to Create Green and Ecological Parking

Table 8. Determination Coefficient (R2) of Multivariate Regression on Ecological Architecture Variables in High-Rise Residential Building

	Spring				Summer				Fall				Winter			
Scale	R2	F	β	T	R2	F	β	T	R2	F	β	T	R2	F	β	T
Construction activities preventing pollution	0.867	314.217	0.762	39.451	0.752	527.222	0.781	46.522	0.710	411.342	0.741	44.571	0.645	411.342	0.741	44.571
Site evaluation	0.895	523.147	0.372	44.328	0.920	405.122	0.732	42.152	1.000	444.446	0.429	31.365	0.788	444.446	0.429	31.365
Building maintenance management	0.825	852.381	0.872	36.823	0.803	217.343	0.662	40.223	0.714	985.752	0.623	31.255	0.913	985.752	0.623	31.255
Open space	0.625	298.921	0.685	39.362	0.746	199.943	0.648	38.239	0.883	211.223	0.685	58.479	0.514	211.223	0.685	58.479
Rainwater management	0.612	247.257	0.597	18.958	0.681	201.612	0.664	8.958	0.619	225.773	0.621	21.982	0.749	225.773	0.621	21.982
Reducing the heating effect on the environment	0.656	644.321	0.436	16.644	0.816	643.623	0.662	11.134	0.836	653.681	0.652	11.134	0.656	653.681	0.652	11.134
Providing suitable light	0.645	845.523	0.852	21.422	1.000	849.683	0.652	18.441	0.920	724.654	0.612	24.425	0.813	724.654	0.612	24.425
Waste recycling using local elements	0.751	689.789	0.799	20.354	0.947	789.745	0.751	19.025	0.875	711.647	0.705	22.657	0.781	719.426	0.718	23.342
Consumed water amount	0.645	754.254	0.665	19.144	0.846	349.603	0.665	19.144	0.654	741.621	0.381	23.132	0.625	741.621	0.381	23.132
Water management	0.715	124.541	0.213	39.231	0.814	184.945	0.483	49.173	0.625	512.325	0.484	48.121	0.715	512.325	0.484	48.121
Reducing the use of internal water resources	0.514	232.241	0.425	29.914	0.546	276.748	0.464	47.963	0.546	276.748	0.464	47.963	0..806	276.748	0.464	47.963
Employing LEED experts to use ecological materials and technology	0.795	201.321	0.414	24.221	0.795	199.943	0.452	46.226	0.881	302.125	0.421	43.564	0.315	985.752	0.372	33.348

	Spring				Summer				Fall				Winter			
Scale	R2	F	β	T	R2	F	β	T	R2	F	β	T	R2	F	β	T
Colling towers	0.323	443.124	0.421	48.248	0.243	499.034	0.463	47.228	0.265	519.034	0.631	49.448	0.756	211.223	0.872	44.524
Water consumption saving	0.958	522.134	0.421	25.288	0.895	523.034	0.472	25.288	0.745	521.125	0.124	15.214	0.792	225.773	0.685	29.325
Running the main energy audit system	0.921	229.265	0.615	65.254	0.978	147.258	0.661	45.256	0.540	149.258	0.311	22.216	0.755	653.681	0.597	22.421
Minimum energy consumption	0.421	323.412	0.424	49.517	0.462	321.564	0.452	41.552	0.368	315.214	0.325	22.552	0.842	724.654	0.436	13.342
Energy consumption rate	0.246	441.211	0.423	25.326	0.331	492.371	0.401	21.356	0.275	458.371	0.425	18.354	0.518	741.621	0.852	44.571
Handling coolers	0.821	321.541	0.454	58.351	0.745	471.658	0.411	58.321	0.882	325.695	0.223	32.341	0.345	512.325	0.665	31.365
Improving the quality of energy launcher systems	0.285	621.991	0.341	29.324	0.254	650.987	0.421	19.694	0.244	621.937	0.529	23.324	0.583	431.175	0.213	31.255
Optimization of energy consumption	0.675	581.920	0.578	21.825	0.455	542.960	0.589	24.879	0.452	521.210	0.679	28.839	0.919	154.425	0.425	58.479
Advanced energy measurement	0.754	218.654	0.514	31.586	0.781	214.362	0.521	44.587	0.654	520.312	0.628	48.581	0.752	131.421	0.414	21.982
Using renewable energies	0.756	752.382	0.542	48.566	0.756	752.382	0.542	48.566	0.756	752.382	0.542	48.566	0.584	461.222	0.421	11.134
Using green energies and reducing carbon consumption	0.661	514.321	0.541	25.618	0.645	699.301	0.545	23.658	0.745	645.317	0.574	29.698	0.958	475.214	0.421	24.425
Green space rate in the area	0.874	428.167	0.654	22.131	0.831	421.115	0.411	12.231	0.418	456.235	0.456	32.214	0.921	215.309	0.615	47.452
Planning and management of waste from destruction	0.265	431.175	0.221	287.861	0.315	411.325	0.309	16.897	0.325	423.125	0.202	16.807	0.421	216.667	0.424	54.218
Reducing the effect of a building's lifecycle	0.727	154.425	0.521	43.418	0.811	161.415	0.517	36.458	0.701	121.405	0.301	13.458	0.246	511.219	0.423	91.398
Promoting the use of environmental products	0.331	131.421	0.522	33.348	0.311	161.415	0.517	36.458	0.311	161.415	0.517	36.458	0.821	369.256	0.454	18.219
Optimization of materials use	1.000	461.222	0.524	44.524	1.000	568.211	0.607	24.564	1.000	523.219	0.603	20.542	0.285	431.175	0.521	11.256
Using indigenous materials	0.275	475.214	0.619	29.325	0.285	475.214	0.619	29.325	0.365	305.211	0.518	39.310	0.675	154.425	0.542	12.321
Optimizing transportation of raw materials from the mine	0.963	215.309	0.162	22.421	0.825	245.475	0.562	25.728	0.635	245.415	0.361	28.725	0.754	865.420	0.545	77.741
Minimum use of ventilation systems	1.000	216.667	0.902	13.342	0.984	114.112	0.823	21.852	1.000	204.104	0.919	26.811	0.756	411.159	0.411	402.735
Systems for controlling lack of tobacco use in the building	0.624	511.219	0.532	45.525	1.000	582.243	0.451	35.555	1.000	324.221	0.765	23.231	0.661	572.633	0.309	36.458
Strategies for improving the quality of indoor air	0.646	369.256	0.852	28.163	0.590	714.284	0.628	28.126	0.658	520.213	0.338	21.128	0.874	152.485	0.517	20.542
Materials with low levels of volatility	0.262	219.544	0.725	30.811	0.369	215.542	0.745	34.878	0.266	122.272	0.716	65.821	0.265	525.117	0.517	39.310

	Spring				Summer				Fall				Winter			
Scale	R2	F	β	T	R2	F	β	T	R2	F	β	T	R2	F	β	T
Plan for indoor air quality management	0.735	865.420	0.911	31.011	0.662	825.411	0.923	81.211	0.726	839.420	0.985	55.316	0.727	731.252	0.607	28.725
Evaluating the quality of indoor air	0.881	411.159	0.147	47.452	0.860	411.159	0.147	47.452	0.852	241.121	0.326	43.411	0.331	37.781	0.619	26.811
Thermal comfort	0.843	572.633	0.436	54.218	0.793	414.653	0.235	24.111	0.681	542.612	0.218	44.321	1.000	652.312	0.562	23.231
Indoor lighting	0.982	152.485	0.274	91.398	0.781	185.444	0.211	63.326	0.921	215.421	0.224	69.331	0.275	746.234	0.823	21.128
Daylight	0.274	525.117	0.688	18.219	0.309	981.136	0.744	26.881	0.425	746.234	0.812	32.181	0.963	731.252	0.451	36.458
Perspective	0.374	731.252	0.821	11.256	0.374	731.252	0.821	11.256	0.374	731.252	0.821	11.256	1.000	124.342	0.628	20.542
Reducing noise (sound pollution)	0.842	37.781	0.835	12.321	0.621	882.781	0.947	42.856	0.316	124.342	0.807	32.214	0.624	372.841	0.793	39.310
Innovation in air quality monitoring in indoor and outdoor spaces (transparent balconies, etc.)	0.675	581.920	0.578	21.825	0.455	542.960	0.589	24.879	0.452	521.210	0.679	28.839	0.919	154.425	0.425	58.479
Developing neighborhood location based on the LEED index	0.274	525.117	0.688	18.219	0.309	981.136	0.744	26.881	0.425	746.234	0.812	32.181	0.963	731.252	0.451	36.458
Special building maintenance	0.982	152.485	0.274	91.398	0.781	185.444	0.211	63.326	0.921	215.421	0.224	69.331	0.275	746.234	0.823	21.128
Suitable parking for mixed uses	0.331	131.421	0.522	33.348	0.311	161.415	0.517	36.458	0.311	161.415	0.517	36.458	0.821	369.256	0.454	18.219
Access to public transportation	0.646	369.256	0.852	28.163	0.590	714.284	0.628	28.126	0.658	520.213	0.338	21.128	0.874	152.485	0.517	20.542
Access to the bicycle network	0.756	752.382	0.542	48.566	0.756	752.382	0.542	48.566	0.756	752.382	0.542	48.566	0.584	461.222	0.421	11.134
Reducing effects of parking lots (decreasing space for parking lot)	0.675	581.920	0.578	21.825	0.455	542.960	0.589	24.879	0.452	521.210	0.679	28.839	0.919	154.425	0.425	58.479
Providing suitable space	0.661	514.321	0.541	25.618	0.645	699.301	0.545	23.658	0.745	645.317	0.574	29.698	0.958	475.214	0.421	24.425

The mean value of determination coefficients in all seasons is measured in the next step and the following diagram indicates that high-rise buildings are designed for two summer and winter seasons, while the average rate of impact factors of variables considerably decline during fall and spring.

8.2.1. Descriptive Statistics

After examining the correlation rate between variables and their effect on ecological architecture, these variables were assessed in the residential towers. According to descriptive statistics for each season, in spring, 253 members (70.7%) of the sample society were men and 131 members (29.3%) were women; 54.4% were in the age range of 20-30, 31.3% were in the age range of 30-40 and 14.3% was older than 40. In the summer, 198 members (51.56%) were men and 186 members (48.44%) were women of which, 48.4% were in the age range of 20-30, 39.1% in the age range of 30-40, and 12.5% was older than 40. In the fall, 216 members (56.25%) and 168 members (43.75%) were men and women, respectively among which, 37.2%, 46.7%, and 16.1% were in age ranges of 20-30, 30-40, and older than 40, respectively. In winter, 195 (50.78%) and 186 (49.22%) members were men and women, respectively of which, 29.6%, 51.1%, and 19.3% were in age ranges of 20-30, 30-40, and older than 40, respectively.

In this research, six popular high-rise residential buildings have been chosen among 32 high-rise buildings located in the southeast area due to their popularity, finished construction operations, and patterns that were imitated by other constructors in the construction process of other buildings. The selected towers are all operated and have more than ten floors. Some evaluation units may have been specified with a "qualitative scale", while all qualitative indicators must be quantified to make indicators "comparable" and value and evaluate them. Therefore, scores 0-4 were considered for indicators with two levels (yes/no) and scores 1-5 were given to indicators with the following five levels: excellent (5-4), good (3-4), somehow (2-3), low (1-2), very low (0-1).

In the research method, the number of questions is matched with the components, and each question or item is scored on a scale of 1-5. The sum score of indicators related to an index represents the score given to considered quality by each person. Therefore, the minimum and maximum scores equal 5 and 25, respectively. The score of considered building is achieved by considering the mean value obtained for each objective.

In the residential tower Armitage, the filled questionnaire indicates that this building has obtained a score in sustainable sites and has a high-quality indoor space, location, and transportation while is weak in terms of energy and atmosphere, materials, and resources for water system efficiency during spring. In summer, this building obtained the highest score in terms of location, transportation, and quality of indoor space, while has shortcomings in sustainable sites, energy and atmosphere, water systems, materials, and resources. In the fall, this building obtained the highest score regarding the efficiency of water systems, quality of indoor space, location, and transportation, while is weak in terms of sustainable sites, energy, atmosphere, materials, and resources. In winter, the highest score belongs to the efficiency of water systems, quality of indoor space, location, and transportation, while is weak in terms of sustainable sites, energy and atmosphere, materials, and resources.

In residential tower Baran 1, the building has obtained the highest score in terms of indoor space quality, location, and transportation, while is weak in terms of water system efficiency, sustainable sites, energy and atmosphere, materials, and resources during spring. In summer, this building obtained the highest score in terms of sustainable sites, location, transportation, and quality of indoor space, while is weak in terms of water system efficiency, energy and atmosphere, materials, and resources, location, and transportation. In the fall, this building obtained the highest score regarding the location, transportation, and quality of indoor space while is weak in terms of efficiency of water systems, sustainable sites, energy and atmosphere, materials, and resources. In winter, the highest score belongs to the quality of indoor space, location, and transportation, while is weak in terms of efficiency of water systems, sustainable sites, energy and atmosphere, materials, and resources.

In residential tower Baran 2, the building has obtained the highest score in terms of indoor space quality, location, and transportation, while is weak in terms of sustainable sites, energy and atmosphere, materials and resources, and water system efficiency during spring. In summer, this building has obtained the highest score in terms of sustainable sites, and quality of indoor space, while is weak in terms of location, transportation, water system efficiency, energy and atmosphere, materials, and resources. In the fall, this building obtained the highest score regarding the quality of indoor space while is weak in terms of efficiency of water systems, sustainable sites, energy and atmosphere, materials and resources, location, and transportation. In winter, the highest score belongs to the efficiency of water systems, and quality of indoor space, while is weak in terms of sustainable sites, energy and atmosphere, materials and resources, location, and transportation.

The residential tower Mania has obtained the highest score in terms of indoor space quality, while is weak in terms of water system efficiency, sustainable sites, energy and atmosphere, materials and resources, location, and transportation during spring. In summer, this building has obtained the highest score in terms of quality of indoor space, while is weak in terms of water system efficiency, sustainable sites, energy and atmosphere, materials and resources, location, and transportation. In the fall, this building obtained the highest score regarding the energy and atmosphere and quality of indoor space, while is weak in terms of efficiency of water systems, location and transportation, sustainable sites, materials, and resources. In winter, the highest score belongs to energy atmosphere, and quality of indoor space, while is weak in terms of efficiency of water systems, location and transportation, sustainable sites, materials, and resources.

The residential tower Bahman has obtained the highest score in terms of indoor space quality, while is weak in terms of water system efficiency, sustainable sites, energy and atmosphere, materials and resources, location, and transportation during spring. In summer, this building has obtained the highest score in terms of quality of indoor space, while is weak in terms of water system efficiency, sustainable sites, energy and atmosphere, materials and resources, location, and transportation. In the fall, this building obtained the highest score regarding the energy and atmosphere and quality of indoor space, while is weak in terms of efficiency of water systems, location and transportation, sustainable sites, materials, and resources. In winter, the highest score belongs to energy atmosphere, and quality of indoor space, while is weak in terms of efficiency of water systems, location and transportation, sustainable sites, materials, and resources.

The residential tower Niyayesh has obtained the highest score in terms of indoor space quality, while is weak in terms of water system efficiency, sustainable sites, energy and atmosphere, materials and resources, location, and transportation during spring. In summer, this building has obtained the highest score in terms of quality of indoor space, while is weak in terms of water system efficiency, sustainable sites, energy and atmosphere, materials and resources, location, and transportation. In the fall, this building obtained the highest score regarding the quality of indoor space, while is weak in terms of efficiency of water systems sustainable sites, energy and atmosphere, materials and resources, location, and transportation. In winter, the highest score belongs to the quality of indoor space, while is weak in terms of efficiency of water systems, sustainable sites, energy and atmosphere, materials and resources, location, and transportation. In the fall, all studied residential complexes had warning situations (score 0-1) in terms of using suitable indigenous materials and products for construction, and the climate was not considered at all.

Table 9. Evaluating Residential Towers in Terms of Ecological Architecture

Seasons	Scale	The score of Armitage Tower	The mean score of Armitage Tower	Score of Baran 1 Tower	The mean score of Baran 1 Tower	Score of Baran 2 Tower	The mean score of Baran 2 Tower	Score of Mania Tower	The mean score of Mania Tower	The score of Bahman Tower	The mean score of Bahman Tower	The score of Niyayesh Tower	The mean score of Niyayesh Tower
Spring	Sustainable sites	3	2.17	2	2.16	1	2.16	2	2	1	1.66	0	1.66
	Efficiency of water systems	2		2		2		2		2		1	
	Energy and atmosphere	1		2		2		2		2		2	
	Materials and resources	1		1		2		0		1		2	
	Quality of indoor space	3		3		4		4		3		3	
	Location and Transportation	3		3		2		2		1		2	
Summer	Sustainable sites	2	2.33	3	2.33	3	2	1	1.5	2	1.66	1	1.33
	Efficiency of water systems	2		2		2		1		1		1	
	Energy and atmosphere	1		2		2		1		1		1	
	Materials and resources	2		1		1		1		1		1	
	Quality of indoor space	4		3		3		3		3		3	
	Location and Transportation	3		3		1		2		2		1	
Fall	Sustainable sites	1	2	1	2.5	2	2.33	1	2.33	2	2	0	1.16
	Efficiency of water systems	3		2		2		2		2		1	
	Energy and atmosphere	1		2		2		3		3		1	
	Materials and resources	1		2		2		2		1		1	
	Quality of indoor space	3		5		4		5		3		3	
	Location and Transportation	3		3		2		2		1		1	
Winter	Sustainable sites	1	2	1	1.5	1	2.16	1	1.66	1	1.66	1	1.66
	Efficiency of water systems	3		1		3		1		1		2	
	Energy and atmosphere	1		0		2		3		3		2	
	Materials and resources	1		1		2		1		1		1	
	Quality of indoor space	3		3		4		3		3		3	
	Location and Transportation	3		3		1		1		1		1	

Finally, the graphical correlation between seasons is depicted. It is found in this step that ecological architecture variables in the two summer and winter seasons have a correlation rate of 0.73. The highest correlation is seen between summer and winter, while the lowest rate (0.0004) exists between spring and summer.

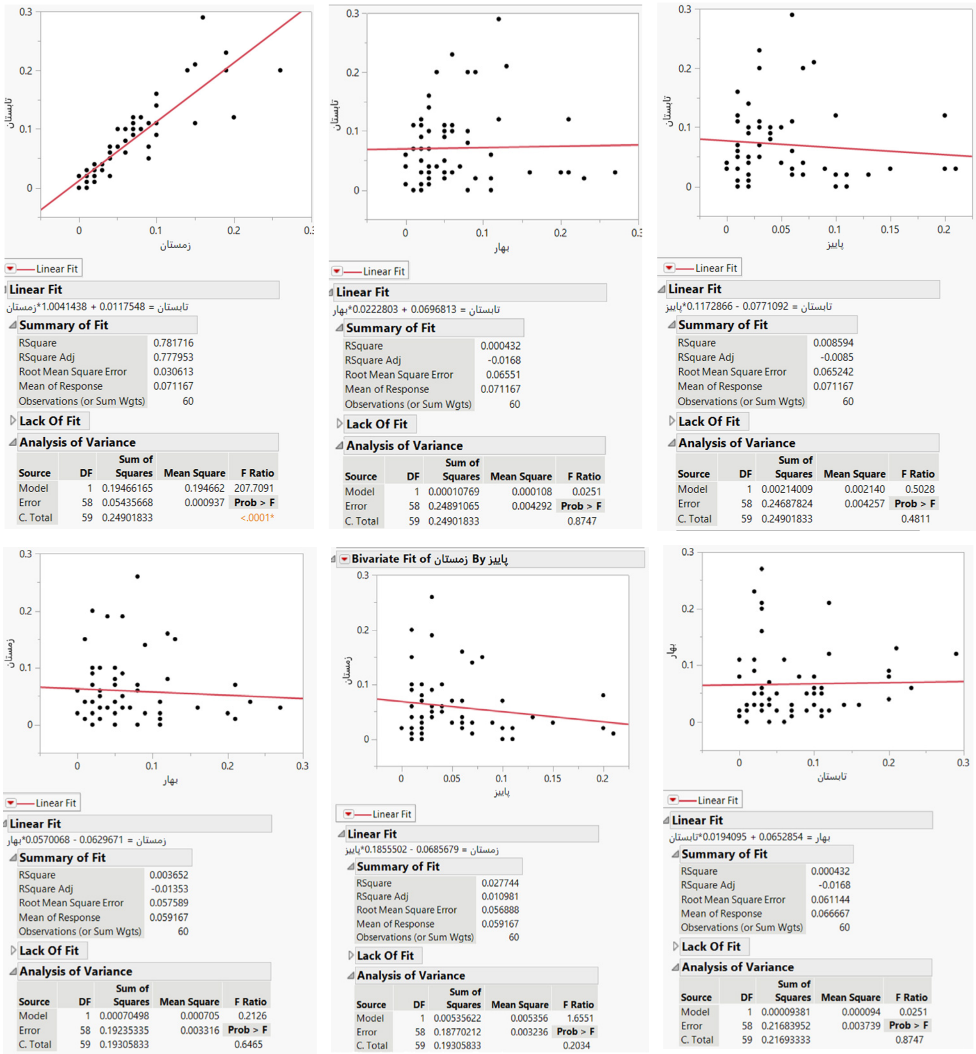


Fig. 6. Graphical Correlation between Ecological Architecture Variables during Different Seasons

9. DISCUSSION

According to the results obtained in the findings, "selection of materials and resources" has a worrying status in all six residential towers indicating unrecyclable and non-indigenous materials used in these buildings. According to occupants living in these towers, on average, 30% of materials used in these towers are “indigenous” or native while other materials are imported from other cities. “Efficiency of water systems” which comprises some indicators such as water consumption amount, water management, reducing use of internal water resources, cooling towers, and water saving rate has the worst situation. This issue requires more attention in Mashhad city where the lack of sufficient water resources is one of the critical "environmental" crises. In terms of energy and atmosphere including lunching main energy audit system, energy consumption rate, minimum energy consumption, handling coolers, optimization of energy consumption, improving quality of energy launcher systems, advanced energy measurement, using "renewable" energies, and using green energies, and reducing carbon use, Manian and Bahman towers have good situation during fall and winter when energy consumption increases. This good situation is associated with using optimal equipment to decrease energy consumption and meet the demand. In terms of sustainable sites, Armitage Residential Tower in Spring and Residential Towers Baran 1 and Baran 2 have the desired situation due to the higher use of open space because of green spaces and improved thermal environment reducing heating impact of space, and providing suitable light.
Residential Armitage and Baran 1 Towers have great status in terms of location and transportation due to available transportation facilities around the site, "management of traveling techniques," public transportation, and a parking lot, creating suitable space for cycling inside the space. Also, Armitage Tower has a walking path of 10 minutes to reach the subway.

All of the studied residential towers have obtained the highest score in terms of indoor space quality indicating the perfect interior design of towers distinguishing their design from other apartments and considering shared spaces, such as coffee shops, lobbies, child rooms, aquatic complexes, etc. to increase the price of each squared meter of the area and provide economic feasibility for constructors. "High-rise construction" is indeed one of the techniques highly considered by urban investors and managers to construct "compact cities" and maximize the use of "space" and limited resources. However, a lack of attention to regulations and criteria required for the accurate location of these buildings and inattention to ecological principles in the construction of each building may cause the advent of many problems in "urban districts" and the future of cities. In this regard, some urban districts such as districts 9 and 11 located in the "southwest area" of Mashhad city are pioneers in such constructions and evidence shows the dispersal of "high-rise buildings" in different districts of the city, which is beyond the ecocity. The increasing number of high-rise buildings causes many issues, such as lack of proper infrastructure, congestion, traffic, and pollution. The current towers are not constructed based on specific plans or rules but are built based on some restrictive regulations, which are almost implementable in all districts. The idea of "ecological" design and "green architecture" has been neglected in these buildings and constructors are only willing to use luxurious and expensive materials without saving energy consumption to build luxury residential apartments and sell them at high prices. Therefore, it is necessary to conduct a study on the growing rate of construction based on the principles of "ecological city" theory to select the best location for tower construction at a general (macro) level that emphasizes the idea of compact city also based on the principles of "green architecture" in design of interior spaces of building at individual (micro) level that aims to reduce energy consumption and keep it for future generations regarding the "sustainable development" and improvement of quality of life.

10. CONCLUSION

Ecological architecture in different buildings is manifested in a specific way by designers and constructors. The conditions for using ecological components relative to spatial dispersion and spatial diversity are complicated in residential buildings. The application of these components in various buildings indicates their consistency and coordination with their surrounding environments regarding the realization of sustainable development goals. In this research, the area of "southwest of Mashhad Metropolis" that includes municipality districts 9 and 11 has been selected as the studied area due to its high contribution in licenses issued for 5-story and taller buildings (30%). Among 32 high-rise buildings located in the southeast area of Mashhad, only six buildings with "residential" use have been finished and operated. This case indicates that none of the studied towers obtains the minimum score for acquiring a LEED certificate and "ecological architecture." It seems that decision-makers and management authorities in Mashhad City must perceive the importance of an ecological city, ecological building, and green architecture before the tower constructors encourage them to follow the approved rules and regulations on ecological design by applying incentives, such as tax exemptions and discounts on construction violations and implementing Ecological Design Act. The "Ecological Design" Act can be formulated as Topic 23 in the Council of "Designing National Construction Rules" and used only for tower construction. In general, the following strategies are recommended for designing, planning, and constructing high-rise residential buildings:

- The shaded structures can be used in hot seasons to park cars outside the area of residential complexes. The shaded structures can reduce the air temperature up to 20° while allowing to use of 96% of the ultraviolet power of the sun. The inside space of cars parked beneath the shaded structure in hot seasons can be 100° cooler than those parked in open spaces or parking lots with closed spaces.

Fig. 7. Sample of Shaded Structures

- Selecting suitable and indigenous or vernacular construction materials and products.
- Access to public transportation when constructing or locating residential towers.
- Comfort in terms of temperature and humidity and thermal comfort.
- Using rainwater recycling and collection systems.
- Environmental studies to collect and recycle the wastes remained in place with minimum environmental harm.
- Paying attention to the type of materials used in the construction while keeping required standards, and protecting the nature and environment.
- Localization of LEED and BREEM acts and other rules based on the environmental and cultural dimensions with feasibility studies.
- Using spatial hierarchy for thermal control over less important spaces rather than more important ones.
- Formulating the rules on the application of empty and negative spaces (central courtyard) based on the climate.
- Using natural elements to improve administrative-environmental conditions in open and semi-open spaces, also using more continuity in the built and natural environment.
- Using indoor green space for internal and external spatial continuity and mental integrity of spatial audiences in natural spaces.

ACKNOWLEDGMENTS

This article wasn't supported by any financial or spiritual sponsors.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

REFERENCES

- Adeli, Zeinab, and AliAkbar Sardeh. 2010. "Locating tall residential buildings in Qazvin using the hierarchical process." In *the third urban planning and management conference*. [In Persian]
- Arin, Somayeh, and Maryam Farajpour. 2016. "The effect of green roof and green facade on improving environmental quality and reducing energy consumption in Tehran." In *the third international conference on civil architecture and urban planning at the beginning of the third millennium*, 1-12. [In Persian]
- Armstrong, Paul, and Ali Mir. 2008. "Overview of sustainable design factors in high-rise buildings." In *Proc. of the CTBUH 8th World Congress*, 3-5. Chicago, IL, USA: CTBUH. https://global.ctbuh.org/resources/papers/download/1308-overview-of-sustainable-design-factors-in-high-rise-buildings.pdf
- Azizi, MohammadMahdi. 1999. The physical and spatial effects of tower construction in Tehran. *Journal of Fine Arts, University of Tehran Publications* 4(5). [In Persian]
- Bahraini, Hossien. 2010. Comparison of development and sustainable development: a theoretical analysis. Behnaz A., Articles on sustainable urban development, Tehran University Press. [In Persian]
- Bemanian, Mohammad Reza. 1997. Factors affecting the formation of tall buildings in Iran. Faculty of Fine Arts, University of Tehran, PhD thesis in the field of architecture. [In Persian]
- Cooper, Ian, and Martin Symes, eds. 2008. *Sustainable urban development volume 4: Changing professional practice*. Routledge.
- Egercioglu, Yakup, and Nur Sinem Ozcan. 2016. Check the location according to the environmental index. *Environment-Behaviour Proceedings Journal* 1(2): 171-177. https://ebpj.e-iph.co.uk/index.php/EBProceedings/article/view/266
- Farnhad Consulting Engineers. 2007. Development and construction plan (comprehensive) of Mashhad metropolis, Ministry of Housing and Urban Development, basic studies of natural environment. [In Persian]
- Foster, Narie, Samuel Luff, and Danielle Visco. 2008. "Green Skyscrapers: What is being built and why." A report for CRF 3840.
- Gorgi Mehlbani, Yousef. 2010. Sustainable architecture and its critique in the field of environment. *Journal of the Scientific Association of Architecture and Urban Planning of Iran* 1(1). https://doi.org/10.30475/isau.2010.61928
- Haji Ghanbari, Ali, Farzad Samai, and Mohammad Karamnia. 2015. The combination of ecological architecture and new technologies in reducing energy consumption in mountainous areas, case study: Tabriz metropolis. *Shabak Monthly* 2(2): 13-21. [In Persian]
- Hassan, Rashid, Robert J. Scholes, and Neville Ash. 2005. *Ecosystem and Human Well-being: Current State and Trends*. Vol I, Island Press, Washington DC. https://www.researchgate.net/publication/266373793
- Haughton, Graham, and Dave Counsell. 2004. *Regions, spatial strategies, and sustainable development*. Psychology Press.
- Hok Architects Corporation. 2006. Design Criteria for Review of Tall Building Proposals, City of Toronto.
- Hossein Alipour, Mojtaba. 2001. "Recognizing, evaluating and classifying the problems of high rise buildings in Iran." *the second international conference on tall buildings, Tehran, University of Science and Technology*. [In Persian] https://jurbangeo.ut.ac.ir/article_65841_835fc909919abc81ab32721ac82b656b.pdf
- Hosseinzadeh Dalir, Karim. 1999. The process of urban development and dense city theory. *the first conference on sustainable development management in urban areas*. Tabriz: Tabriz Municipality. [In Persian]
- Ibrahim, Hatem Galal A. 2015. Regeneration of sustainability in contemporary architecture: approach based on native function and activities to strengthen identity. *Procedia-Social and Behavioral Sciences* 216: 800-809.
- Iran Urban Planning and Architecture Studies and Research Center. 2002. Principles for locating high-rise buildings and completing design and implementation criteria according to the priority of the second section, Secretariat of the Supreme Council of Urban Planning and Architecture of Iran, Tehran. [In Persian] https://shahr.journals.umz.ac.ir/article_3997.html?lang=en
- Jahad Daneshgahi of Mashhad. 2010.
- Javadi Nodeh, Mahsa, Azadeh Shahcheraghi, and Alireza Andalib. 2019. Ecological architecture affected by the interaction of the man-made environment with nature in cold regions: case study: two historical houses in Ardabil. *Naqsh-e-Jahan* 10(4): 1-16. [In Persian]
- Karimi, Elaheh. 2013. Modeling the optimal management of green space in the city of Mashhad using systematic way with an emphasis on ecological city theory, Master's thesis, Faculty of Literature and Human Sciences, Ferdowsi University. [In Persian]
- Khoshro, Sara, and Negar Javadi. 2015. Ecosystem Thinking in Architecture, International Conference on New Approaches in Science. *Technology and Engineering* 1-11. [In Persian]
- Kolivand, Pouria, and Tahereh Kolivand. 2014. "The thermal performance of vegetation in open urban space, case example: Imam Khomeini Port." *International Conference on Civil Engineering, Architecture and Urban Infrastructure*, 1-8. [In Persian]
- Kunstler, James, and Nikos A. Salingaros. 2001. *The end of tall buildings*. Planetizen. com 17.
- Madiha H. S., and B.F. Eduardo. 2018. "A reference architecture for ecosystem applic1ations for Container modeling." *the 13th International Conference*, 1-7.

- Malin, N. 2006. A Green Effort in Green Source. *Cities* 46-51.
- Management of urban development plans, vice-president of urban planning and architecture. 2014. Rules and regulations of urban development. [In Persian]
- Mehzoun, Fatemeh. 2018. Designing a four-story residential apartment system with an ecological architecture approach in District 11 of Tehran, Ishraq Institute of Higher Education, Faculty of Law. [In Persian]
- Mofidi Shemirani, Majid. 2013. Sustainable urban design and natural resources. *Abadi Journal* 42(special for urban architecture and sustainable development). [In Persian]
- Motin, Clif, and Piter Shirley. 2007. Designing urban spaces with a focus on sustainable development. translated by Narsis Mollah Youssef, Saman Al-Hajj Publications. [in Persian]
- Mottaeva, Angela, Natalya Kalinina, Anna Kuzmina, Olga Olenina, and Aznaur Glashev. 2019. "Ecological aspects of modern city-planning." In *E3S Web of Conferences*, vol. 91, 08072. EDP Sciences.
- Omidvar, Mohammad Hassan. 2009. The role of high-rise construction of residential complexes in sustainable development: case study of Firouze high-rise complex of National Bank of Mashhad, Master's thesis, Ferdowsi University of Mashhad.
- Performance report of government board approvals. 2013. Resolution No. 8795 / 34871. [In Persian]
- Pourjafar, MohammadReza, and Mostafa Adabkhah. 2012. The effect of increasing building density on the road network. *Urban Management Quarterly* (11-12): 46-53. [In Persian]
- Rahnama, Mohammad Rahim, and Farzaneh Razzaghian. 2015. Analysis of high rise residential buildings with an emphasis on ecological city theory in the southwest area of Mashhad metropolis, Faculty of Literature and Human Sciences, Ferdowsi University of Mashhad. [In Persian]
- Rahnama, Mohammad Rahim, and Farzaneh Razzaghian. 2012. Locating high rise buildings with an emphasis on the theory of smart urban growth in District 9 of Mashhad Municipality. *Golestan University scientific research quarterly* 3(9): 45- 63. [In Persian]
- Razzagian, Farzaneh, and Moahhamd Rahim Rahnam. 2019. Analysis of ecological city indicators in high rise buildings of Mashhad metropolis. *Quarterly Journal of Geographical Studies of Dry Areas* 10(40): 88-103. [In Persian]
- Remouk, Mitra. 2002. Toll measurement and locating of tall buildings in Tehran. *Urban Management Quarterly* (11-12): 86-93. [in Persian]
- Roseland, Mark. 1997. Dimansions of the Eco-City. *Cities* 14(4): 197-202. https://doi.org/10.1016/S0264-2751(97)00003-6
- Sadeghieh, Leila. 2001. High rise construction, especially in housing, why, how and where?. Master of Architecture thesis, Azad University of Mashhad. [In Persian]
- Shahrsaz consulting engineers and Part architect. 2001. Zoning and determination of areas with potential for high-rise construction in Mashhad city, Mashhad municipality. [In Persian]
- Tehran Study and Planning Center. 2012. Development plan and regulations for the construction of high rise buildings, analysis studies and presentation of proposed criterias, consulting engineers of Part.
- USGBC. 2020. LEED v4 for BD+C: New Construction and Major Renovation. Washington, DC. [In Persian]
- Yılmaz, Mustafa, and Adem Bakış. 2015. Sustainability in construction sector. *Procedia-Social and Behavioral Sciences* 195: 2253-2262.
- Zohri, Sara. 2017. "A comparative comparison of native architectural components with the principles and criteria of ecological design." *National Conference on New Knowledge and Technology in Engineering Sciences*, 1-12. [In Persian]

HOW TO CITE THIS ARTICLE

Hamed Sardar, Hamed, Saeed Tisghalam Zonouzi, and Shooka Khoshbakht Bahremani. 2023. The Role of Various Ecological Criteria in Different Seasons of Residential Buildings located in Mashhad City. *Armanshahr Architecture & Urban Development Journal* 16(43): 281-303.

DOI: 10.22034/AAUD.2023.334522.2645
URL: https://www.armanshahrjournal.com/article_178605.html

COPYRIGHTS

Copyright for this article is retained by the author(s), with publication rights granted to the Armanshahr Architecture & Urban Development Journal. This is an open- access article distributed under the terms and conditions of the Creative Commons Attribution License.

http://creativecommons.org/licenses/by/4.0/