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Researchers in Mashhad, Iran, are investigating how green roofs can enhance the quality of life in cities with arid climates

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ABSTRACT

Mashhad, the second-most populous city in Iran, is situated in a hot and dry climate, and climate change has led to the temperature in this city climbing in recent years. This study's objective is to design a green roof per the region's hot and arid climate to maximize plant growth. The thermal comfort of citizens is explored in this study. A questionnaire was developed and distributed to 406 individuals for this experiment. The frequency measurement test was utilized to do statistical computations in order to quantify the sample's frequency, while the chi-square test (chi-square) was utilized to assess the relationship between class and rank variables. Residents from thirteen distinct neighborhoods are selected at random and proportionally. The findings of this study indicate that the positive effects of green roofs extend beyond the city of Mashhad and have a global impact. When green roof development is performed on a large scale in a city or region, many of the negative consequences of environmental change over the past several decades will be offset. By putting green roofs on buildings and all over cities, the effects of climate change are being fought off better.

However, a scientific and preferred approach for installing and cultivating green roofs in Mashhad is of greater importance. Using the data analysis of the questionnaire, the desires, interests, and concerns of Mashhad's population were identified. The following development plan shows how the green roof field can grow desirably and acceptably.

Introduction

Mashhad is a holy pilgrimage city in northeast Iran. According to the Koppen climate classification, the climate of this city is warm and dry [1]. Mashhad has hot summers and cold winters. Since 2005, the temperature in this city has risen dramatically [2]. The city receives approximately 250 millimeters (9.8 inches) of precipitation annually, some of which falls as snow occasionally [3].

Additionally, there are wetter and drier times in Mashhad, with most yearly precipitation falling between December and May. Summers are often hot and dry, with highs topping out at 33°C (91°F). Winters are often cool to cold and somewhat wetter, with nighttime temperatures routinely falling below freezing. On average, Mashhad receives a little over 2900 h of sunlight annually [4].

It is claimed that contemporary environmental issues threaten the lives of humans and other organisms [5]. Climate change, ozone depletion, deforestation, and the food crisis are some dangers [6]. Population growth, technological advancements, excessive use of natural resources [7], irresponsible human behavior, and numerous other instances that lead to urban pollution, disease, destruction of natural resources, water pollution, soil (due to landfilling), construction debris, and air pollution increase the need to protect the environment [8]. Also, it's essential to realize that proper human development can't happen without outside influences [9,10].

Roofs have the ability to improve the environmental performance of buildings in metropolitan settings due to their vast surface area [11]. The environmental effects of green roofs include lowering the effects of heat islands [12], increasing the life of the roof membrane, managing

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rainfall and preventing floods, reducing noise and air pollution, conserving energy, and boosting the city's biodiversity [13].

Over the last ten years, pollution of suspended particles in the air [14] and climatic heat in Mashhad [4]have increased alarmingly. Consequently, a green roof can help reduce the building's temperature and make it more comfortable [15]. As well as reducing pollution.

This study aims to demonstrate the significance of green roofs. Then, a questionnaire was developed in which residents of Mashhad were asked about their familiarity with green roofs and the amount of green roof space in their homes. A check is written. The questionnaire results are compared with those of residents living in neighborhoods with and without green roofs. It is necessary to investigate the behavioral effects of green roofs on inhabitants.

Literature review

According to research, the concept of a green roof has its origins in the Hanging Gardens of Babylon (modern-day Iraq). Furthermore, this system exists in various civilizations. The Romans cantered their use of green roofing on the monuments of Augustus and Hadrian. Additionally, the Vikings insulated their roofs with algae. On the rooftops of the Iranian ziggurats were gardens, and on the balconies of the upper floors of the stores in Pompei were climbing plants [16].

During the early modern era, the notion of the green roof was widely adopted across numerous regions and civilizations on numerous continents. Unique technology pioneered the concept of a living roof on concrete roofs. The earliest version of this roof debuted during the 1867 Paris Universal Exposition. The model depicts a green roof with waterproofing and drainage systems and is considered the first idea for a large-scale green roof [17].

At the beginning of the 1960s, green roof technologies were expanding fast throughout the world, particularly in Switzerland and Germany. Switzerland utilized this sort of roof to minimize surface drainage. In 1970, a significant specialized study was conducted on the many components of green roofing technology [18].

Technology has become so prevalent that they report: that Germany has a substantial area (13.5 km and, according to some sources, tens of millions of square meters) of green roofs, which is equivalent to 14 percent of the country's flat roofs. According to the report, Germany accounted for the most considerable use of green roof technology in 2008, costing $77 million. According to the website Living roofs censuses, 0.93 square kilometers of Greater London are already covered in vegetation [19].

In a study conducted in 2016 by Navid Vahdati Mashhadyani on the ecological benefits of a green roof with an area of 20 square meters with native vegetation in Mashhad city, it was found that the presence of a green roof did not make a significant difference in reducing air pollution. Despite the fact that only one sample was used to infer results [20].

Younger people tend to create green roofs and feel more relaxed in them than older people, according to a study conducted by Seyed Majid Zargarian in 2018. Green roof gardens are more popular with people with higher education. In general, men prefer green roofs and pets, and they also believe they create a sense of relaxation and connection with nature [21].

Types of green roofs

Green roofs (broad, concentrated, and semi-concentrated) typically include five layers: the roof structure; the roof membrane (roofing materials such as asphalt, ceramic, or isogum; etc.); moisture insulation; drainage; aeration; and protection, respectively: root, cultivation medium (soil and compost combination), and plant species. The lower four tiers are applicable anywhere. However, the fifth layer, which consists of plant species, is an integral design component [22].

There are three types of green roofs: focused, modular, and wide. This is even though only two categories of green roof types exist. The module or box of the plant is located on the roof and hence cannot be considered part of the roof. Alternatively, this style of roof can be divided into two broad and specific groups [23].

Others have proposed three types of green roofs: centralized, semi-centralized, and extensive. The differences between the three categories include the roof's height, the roof's intended function (usable or not), and the maintenance costs. As a result, concentrated ceilings are thick; as a result, they are heavy and are typically utilized as roofs; their maintenance is labor-intensive. On these types of roofs, plant species are abundant. Expansive ceilings are typically lightweight and thin, requiring little to no upkeep and creating helpful little areas. A maximum of two types of plants are used on this type of roof. In between these two groups are semi-compact roofs [24].

According to Fioretti et al. (2010), these classifications are fundamentally incorrect because a roof in a high-maintenance area may require a great deal of upkeep and be highly expensive, yet in other climates and areas, this may not be the case. Consequently, a roof can be installed on either handle type [25]. The research of Mohammad Javad Mirzababaie & Mohsen Karrabi. (2019) validates this viewpoint, such that the implementation of green roofs with an unstable approach and its failure in the city of Mashhad has had detrimental impacts on the

Table 1
Distribution of respondents based on demographic information.

		Abundance	Percentage (%)
Gender	Man	182	44.8
	Female	224	55.2
	Total	406	100
marital status	Single	285	70.2
	Married	115	28.3
	Other	6	1.5
Age classification by year	Young (ages 18 to 34)	344	84.7
	Middle-aged (ages 35 to 49)	53	13.1
	Elderly (age 50 and over)	9	2.2
Classification of housing in Mashhad by year	From 1 to 5 years	41	10.1
	From 6 to 10 years	20	4.9
	From 11 to 16 years	23	5.7
	From 16 to 20 years	68	16.7
	From 21 years and up	254	62.6
Ratio of life spent in Mashhad	One Fourth	45	11.1
	Half	24	5.9
	Three Fourth	34	8.4
	More From Three Fourth	303	74.6
Educational status of individuals	University student Or Knowledge Learn	214	52.7
	Graduate Education	192	47.3
Status of people in terms of type of residence	the apartment	300	73.9
	Villa	86	21.2
	Dorm	20	4.9
Type of ownership	Tenant	120	29.6
	the owner	267	65.8
	Common	19	4.7
Number of people living by regions	Area 1	71	17.5
	Area 2	36	8.9
	Area 3	19	4.7
	Area 4	13	3.2
	Area 5	1	.2
	Area 6	6	1.5
	Area 7	7	1.7
	Area 8	12	3.0
	Area 9	125	30.8
	Area 10	49	12.1
	Area 11	41	10.1
	Area 12	12	3.0
	Region 13 (Samen)	14	3.4
	Total	406	100

Table 2
Combining type of residence and type of ownership by number.

		Type Ownership		Total
		Tenant	the owner	
Type Location	the apartment	99	200	299
	Villa	19	67	86
Total	118	267	385	

community and officials attempting to expand the green roof in Mashhad. This appears to be due to European fashion (without Mashhad canvas) [26]. Williams et al. (2010) also point this out, concluding from their research in Australia that additional research is required on the type of substrate and plant species because some plants can live in hot, dry areas with little water [27].

The majority of reports fall under this category. For instance, research indicates that expansive green ceilings are desirable because the roof structures' load-bearing capacity should not be expanded. In other words, it does not significantly alter the building's load. In addition, 80 percent of Germany's green roofs utilize extensive systems, which are less expensive than centralized systems. In the European climate, expansive green ceilings offer affordable maintenance expenses and grow quickly [28].

Research methods

A questionnaire was created and distributed to 406 people for this investigation. The frequency measurement test was used to do statistical computations in order to quantify the frequency of the sample, and the chi-square test (chi-square) was used to analyze the relationship between class and rank variables. Residents from thirteen distinct neighborhoods are chosen at random but equally in each neighborhood.

In this article, the results of a random sample of the people of Mashhad, taken from thirteen of the city's districts, are shown.

The results of the questionnaire of the residents in these thirteen areas have been compared on two main branches: first, whether a green roof exists in their residence; and second, what is the significant relationship between this green roof, age group, residence rate, gender, marital status, educational status, field of study, type of residence, type of property, area of residence, and level of familiarity with the green roof.

Result

Demographic information

Table 1 reveals that, in terms of gender, male respondents with a frequency of 182 people (the lowest rate) and female respondents with a frequency of 224 people (the highest rate) were the most prevalent (highest rate). In terms of marital status, there were 285 single respondents (the highest rate), 115 married respondents (the average rate), and six other respondents (the lowest rate) (the lowest rate). In terms of age group, 344 young respondents (the highest frequency) and nine elderly respondents (the lowest frequency) were polled. Respondents who have lived for 6 to 10 years with a minimum of 20 individuals and those who have lived for 21 years or more with a minimum of 254 people (maximum). In terms of life expectancy classification, there are a minimum of 24 people who have lived up to half their lives and a maximum of 303 persons who have lived their entire lives (maximum). In terms of educational status, 214 individuals (the highest rate) of respondents said that they are students, compared to 192 people (the second-highest rate) of respondents who reported that they have graduated (the highest rate).

Regarding the type of dwelling, 300 individuals resided in the apartment, 86 in the villa, and 20 in the hostel. One hundred twenty individuals owned rental property, 267 held real property, and 19 owned rental property. Regarding the number of maples living in each region, region 5 has the lowest frequency at one individual, while region 9 has the highest frequency at 125 individuals (maximum).

How many renters and owners reside in apartments, villas, and dorms?

The results of Table 2 indicate that 99 people live in the apartment, 19 people live in the villa, and 200 people own the apartment. There are 67 individuals residing in the mansion. Their villas are rented, and their number is the smallest.

Table 3 indicates that the number of individuals by gender, marital status, age group, type of housing, and type of ownership varies among the thirteen areas, with region five having the smallest population and

Table 3
Survey of the number of sample people among the thirteen regions based on composition (gender, marital status, age category, type of residence, type of ownership) in Mashhad.

		Residential Areas 13												
		Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	Area 10	Area 11	Area 12	Area 13
Gender	Man	30	13	12	3	1	3	3	8	54	23	19	6	7
	Female	41	23	7	10	0	3	4	4	71	26	22	6	7
Condition Marital status	Single	54	24	15	12	1	5	4	8	79	34	29	9	11
	Married	16	12	4	1	0	1	3	4	45	13	11	3	2
	Other	1	0	0	0	0	0	0	0	1	2	1	0	1
Category Persons	Young (ages 18 to 34))	58	30	17	13	1	6	4	11	106	42	35	10	11
	Middle-aged (ages 35 to 49)	10	6	1	0	0	0	3	1	17	5	6	2	2
	Elderly (age 50 and over)	3	0	1	0	0	0	0	0	2	2	0	0	1
Condition Persons at Now Study	University student Or Knowledge Learn	37	18	9	11	0	4	1	6	64	23	25	7	9
	Graduate Education	34	18	10	2	1	2	6	6	61	26	16	5	5
	Other	0	0	0	0	0	0	0	0	0	0	0	0	0
Type Location	the apartment	58	27	10	4	0	3	2	6	98	38	31	11	12
	Villa	13	9	9	9	1	3	5	6	10	10	9	0	2
	Dorm	0	0	0	0	0	0	0	0	17	1	1	1	0
Type Ownership Home	Tenant	12	10	6	3	0	4	4	4	41	15	10	5	6
	the owner	59	26	13	10	1	2	3	8	68	33	30	6	8
	Common	0	0	0	0	0	0	0	0	16	1	1	1	0
total	426	216	114	78	6	36	42	72	750	294	246	72	84	

Table 4
Results of the survey number and percentage of sample people who are familiar with green roofs.

Variable	Indicators	Abundance	Percentage
Familiarity with the green roof	A range of names Or None	145	35.7
	The same flower pot	16	3.9
	Without flower pot	55	13.5
	Tree Both it is possible	190	46.8
	Total	406	100

region 9 having the most significant population across all parameters. In this respect (in region 5: number of men and women 0, number of single and married 0 and others 0, young age one and middle-aged and elderly 0, pupil and student 0 and graduated one and others 0; type of residence 1 apartment, villa, or dormitory 0, type of tenant property 0 and actual owner one and standard 0; and a total of 6 people living in this area). Also (in region 9: 54 males and 71 females, 79 single and married at 45, and others 1; young at age 106 and middle-aged at 17; old at 64 and graduate 61; and others 0; young at age 106 and middle-aged at 17; and elderly at 64 and graduate 61; and others 0). The number of apartment dwellers is 98, the number of villa dwellers is 10, and the number of dormitory dwellers is 17.

How acquainted were the sample population members with the green roof

Table 4 reveals, as expected, the results of the indicators (145 people by name or none, 16 people by the same pot, 55 people without pots, 190 people by the tree, always familiarity) announcing a green roof.

Exists a correlation between the acquaintance with green roofs and (age, gender, level of education, and field of study)?

At the 0.05 significance level, Table 5 reveals a significant relationship between gender options, level of education, the field of study, and level of familiarity with the green roof. Because of their experience with green roofs, it appears that these individuals can promote healthy plant growth.

Questionnaire results

On the green roof, there are a variety of possible uses

One benefit of green roof space to buildings is the ability to conduct an increasing variety of semi-public and semi-private activities on the roof [12]. People were asked what they thought about these plans to find out what they wanted and what they thought was important.

Fig. 1 effectively depicts the demand of citizens for potential green roof activities. Graph analysis reveals that people have altered expectations regarding the activities that will take place on the green roof. According to the research, the two activities with the highest approval and desire to be performed on the green roof are playing and having an assembly. This demonstrates that individuals anticipate the green roof to provide a leisure zone. It is the exact opposite of what roofs are currently and only permits one set of essential and cross-sectional activities.

On the other hand, individuals are reluctant to engage in activities

Table 5
Examining the significant link between the level of green roof familiarity and (age group, gender, level of education, and field of study).

	The amount of xi two	Degrees of freedom	Significant amount	The significance level	Result
Ages	10.785	6	0.095	p< 0.005	It does not matter
Gender	12.648	3	0.005	p< 0.005	It has to do with
Level of Education	45.319	9	0.001	p< 0.005	It has to do with
Major	204.402	108	0.001	p< 0.005	It has to do with
Living area	58.426	36	0.010	p< 0.005	It has to do with

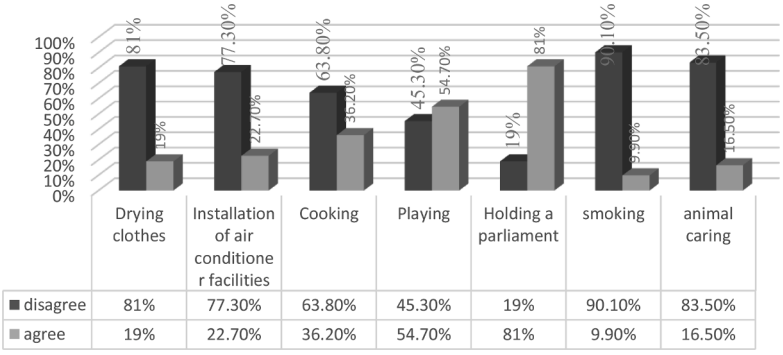

Fig. 1. Percentage of people who want to do something on the green roof.

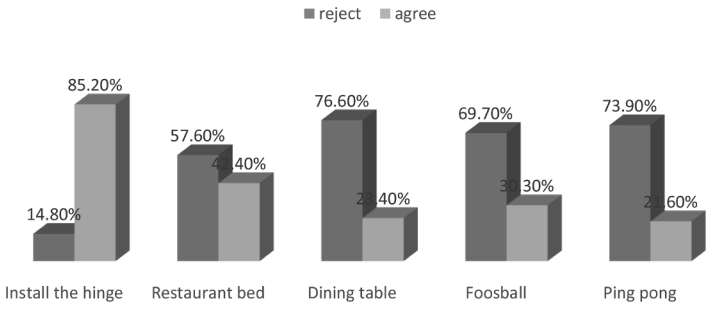

Fig. 2. inclination to utilize diverse furniture on the green roof.

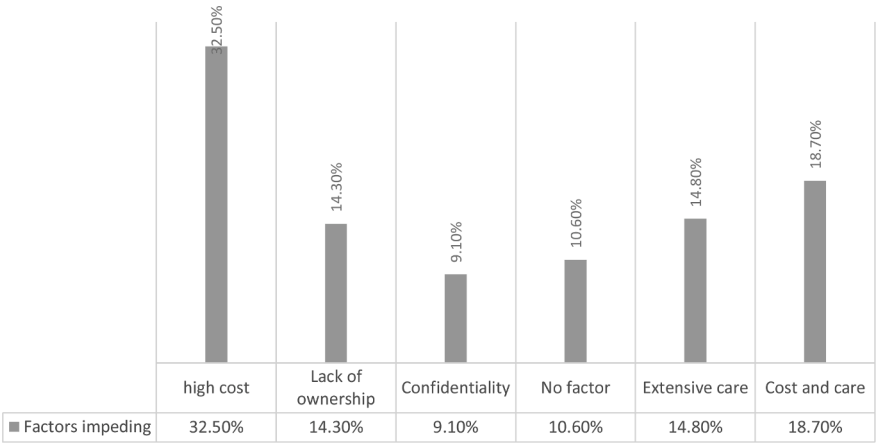

Fig. 3. The scope of obstacles to the development of green roofs.

such as smoking, clothes drying, and raising animals on green roofs. From the viewpoint of most people, backyard activities that were formerly commonplace are no longer a priority. In this regard, further examination of the questionnaire results revealed that, on average, smoking and animal ownership should not be practiced on green roofs. However, the results indicate that the prohibited behaviors differ depending on factors such as gender, marital status, and the subject of study.

Utilization of furnishings on the green roof

The relationship between any size and scale green space and the furnishings and tourist facilities utilized by inhabitants is close. Green Roof has the potential to provide a variety of services to users by utilizing a variety of furnishings and amenities.

Fig. 2 demonstrates how the questionnaire regarding respondents' opinions on placing usable furniture on the green roof was administered through an examination of the data analysis.

Analyses indicate that with the distinction, the usage and construction of pavilions on the green roof is at the forefront of citizens' desires, followed by the use of restaurant beds anchored in traditional style. The ping-pong table is of little significance.

Factors impeding the proliferation of green roofs

So far, only the positive responses of respondents to the creation and development of green roofs have been discussed. However, in this study's questionnaire, negative comments were also evaluated.

Fig. 3 depicts why individuals do not want to construct green roofs. High cost is the most effective deterrent. In fact, the cost of constructing, maintaining, and caring for a green roof is the primary worry of those who choose not to install one. Lack of ownership and privacy are among the least important factors.

The examination of the questionnaire's data reveals that criteria such as gender, marital status, type of residence, type of ownership, and organ engagement have played a role in deciding why individuals are reluctant to install a green roof.

Discussion

Green roof advantages for the environment of Mashhad

The most significant environmental problems in Mashhad province are [29]: air pollution (caused by both stationary and moving sources, like commercial and residential buildings and vehicles), noise pollution (caused mainly by construction and traffic), and water pollution (caused by sewage and waste).

Moreover, soil pollution (has three causes) [30]:

1 Improper application of chemical fertilizers, as well as the use of pesticides and insecticides to repel plant pests
2 Transmission of smoke and air pollution to the soil via rain and snow
3 Municipal wastewater and household waste).

Heat conditions are an additional environmental hazard in Mashhad. To demonstrate this, they compare the temperature of Mashhad from 1950 to 1984 with that of 1985 to 2002 and find that the city's temperature has increased. Then, they compare the rise in temperature from 1985 to 2002 with the data from the Golmakan station and conclude that the city's temperature rise is more extensive than that of its suburbs [31].

Effective implementation techniques can

The choice of plant species for the green roof is an essential issue in design and implementation. Climate is one of the most important factors in determining the appropriate plant species. Based on the average temperature of Mashhad in 1987–2007 and the ranges of heat sensation (Table 6), Mashhad has three seasons: very cold; two months cold; two months cool; two months slightly cold; two months slightly warm; and one month hot. Isn't it? Therefore, 75% need heating and 25% need cooling. Also, based on the average humidity of the same years (Table 6), Mashhad has three wet months (February, March, and April), two semi-dry months (May and June), and seven dry months (July, August, September, October, November, and December).

Based on the research of Vahdati Mashhadian et al. (2016), willow, dew, and scorpion are the most resilient plants among those studied [32]. Seasonal variations in Mashhad have resulted in various

Table 6
Average Mashhad temperature from 1987 to 2007 (Mashhad Meteorological Department).

Month	January	February	March	April	May	June	July	August	September	October	November	December
temperature	2.46	4.18	9.21	15.43	20.94	25.98	26.48	21.81	15.28	9.09	4.56	2.46
relative humidity	66.18	65.69	62.43	54.92	45.521	28.75	23.70	21.93	26.55	36.31	55.31	66.92

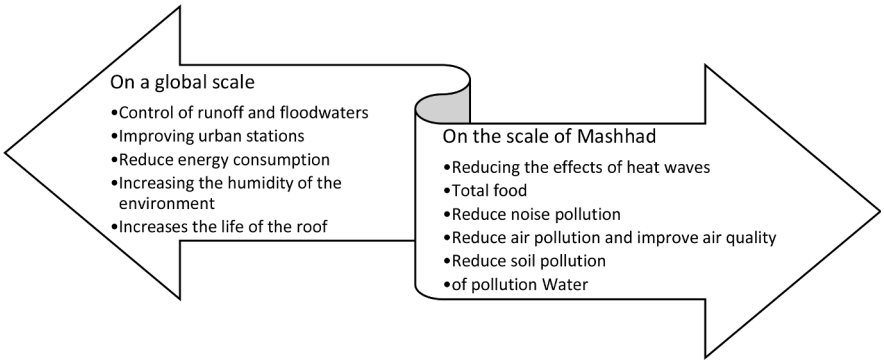

Fig. 4. The environmental impact of green roofs on a global and urban scale in Mashhad.

Fig. 5. The process of green roof development takes place inside the Mashhad spatial framework.

circumstances on the roof's surface, and the utilized plants have exhibited many responses. Spring and fall are the most suitable seasons for green roofs in Mashhad, but from early June to mid-September, when there is a significant amount of drought, these roofs face the most stress. In both the hot and cold seasons of the year, the scorpion plant was the best option for use in Mashhad, followed by dew and leaf clover. These species are appropriate for expansive ceilings. According to a study and comparison conducted by Shooshtarian et al. (2011) between 10 species of plants, the closest scorpion scored an average of nine points in the visual scoring part, which was significantly higher than other species in this regard. This demonstrates the elegance of this plant [33].

Due to their increased leaf area, trees and shrubs are more effective at eliminating toxins than perennial grasses, making concentrated roofs more ideal for air pollution. Due to the current drought, they are not advised in large quantities unless used for urban agriculture on green roofs.

Conclusion

As a result, many of the detrimental effects of environmental change during the past few decades will be mitigated when green roof development is implemented widely in a city or area. By installing green roofs on buildings and cities, cities are becoming more resistant to climate change's consequences. Table 7 demonstrates that the good impacts of green roofs transcend beyond the city of Mashhad and have a worldwide impact.

However, a scientific and desired method to install and cultivate a green roof in Mashhad is of higher significance. With the use of the

questionnaire's data analysis, the desires, interests, and concerns of the residents of Mashhad were uncovered. Therefore, the following development process is provided so the green roof field can expand desirably and acceptably.

On the basis of the information gathered through the field methodology and the questionnaire, a methodical process for the incorporation of green roofs into the architectural framework of Mashhad has been devised as a result. Fig. 4 illustrates a process consisting of seven steps that can be used to develop green roofs in Mashhad. When done thus, the implementation step of this strategy is the one that proves to be the most successful. During this phase of the process, the preferences of the employee, the requirements of the employer, and the input of the authorized authority are taken into consideration in order to arrive at the most effective solution to the problem.The building of the green roof is controlled by executive and theoretical bodies, as well as by local requests and economic considerations. This is similar to the process that is used in many other creative architectural projects in Iran. These indicators must to be taken into consideration whenever there is construction of green roofs in Iran or in Mashhad.It is recommended that additional research be done on the impact of green roofs suitable for hot, dry conditions and lowering energy consumption in various Middle Eastern cities that are battling the issue of heat and air pollution. Specifically, it is recommended that this research be done in an effort to help the cities combat the issue of heat and air pollution.

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