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RESEARCH PAPER

Green Roof Valuation: Economic and Environmental Benefits Analysis

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Abstract

In the city of Tehran, factors such as the high value of land and rising prices have prevented the expansion of urban green spaces and kept green space per capita at a low level in comparison to international standards, leading to an increase in the need for citizens to have a place to rest and relax. Accordingly, creating vertical green spaces, such as walls and green roofs, plays a significant role. Therefore, introducing the functions and explaining the value of the economic and environmental benefits of developing such spaces is a necessity that can pave the way for the expansion of investment in this area. In this regard, the present study aims to assess the economic justification of green roofing in Tehran. Considering the two criteria of air pollution and green space per capita, district 2 of the municipality was selected, which is a host to a variety of social and economic classes. The discrete choice experiment (DCE) method was used to determine the economic value of green roof environmental services. In addition, the net present value (NPV), internal rate of return (IRR), and benefit–cost ratio (BCR) indices were utilized for cost–benefit analysis (CBA) of green roofing. Based on the results, citizens were willing to pay an average of 182.1 $\$/m^2$ to enjoy the aesthetic and environmental benefits of green roofs. Moreover, green roofing in the study area was economically justifiable, so that the average IRR was 44% and NPV was $187 during 2020. However, the IRR increased by 175% to an average of 121% considering the environmental benefits of this technology, and the NPV grew by approximately 388% to $914.

Keywords: Cost–Benefit Analysis, Discrete Choice Experiment Method, Environmental Services, Green Roof.

JEL Classification: D1, Q51, P25, P28, Q57.

1. Introduction

The environment can reduce some of the pollution produced by urban and industrial communities, including air pollution, according to its ecological capacity. However, sometimes discharging harmful substances into the environment is such that the rate and speed of cleaning is less than the amount of pollutants and these substances, which creates dangers in densely populated or active industrial centers, leading to crises and disruption of daily life in some cases (Zhiming et al., 2018; Vang et al., 2017; Angeler et al., 2019). Thus, dealing with the pollution created and preventing the creation of new sources of pollution is among the necessities for the continuation of human life. In recent years, various solutions have been proposed, including the green economy. According to the definition of the United Nations, the green economy is among the methods to improve the equality of human well-being and social justice, along with a significant reduction in environmental risks and ecological scarcity. The green economy includes all economic sectors of a country and provides frameworks for human activities. Meanwhile, the need to achieve green economy objectives in the field of human capital development, the attraction of sustainable living standards, and concerns about the planet has led to urban planners' tendency toward sustainable cities that pursue objectives such as developing human capital, improving energy conservation and efficiency, water security, construction standards, food waste management, and economic and social justice (Sodiq et al., 2019). Construction is among the most important dimensions of a sustainable city, which is called green building. Green buildings help reduce environmental pollution, especially air pollution, with various components, the most important of which is the green roof or using unused spaces in urban buildings to create a green landscape, which improves and softens the air, reduces air pollution, decreases energy consumption, prevents ultraviolet radiation to buildings, reduces the temperature and the heat island phenomenon, and so on, resulting in improving the environment of city residents (Shafique et al., 2018; Williams et al., 2019). Green roofs usually include several layers, are planted with design and purpose, do not interfere with other urban uses of the roof, and are implemented easily in current and new buildings (Vanstockem et al., 2018).

Based on some studies, 67.9% of the area in Tehran (730 km^2) includes roofed lands with different uses, and the rest is related to passages and open spaces. Based on the statistics of Tehran Municipality, the green space area of Tehran is approximately 480,000 hectares, and the average per capita green space, including private gardens, is approximately 15 m^2 (Taghavi, 2013), which is significantly far from the standard announced by the United Nations (UNEP), which is equal to 20 to 25 m^2 per person. Using green roof technology in Tehran seems to be a good option due to the improvement and stability of urban environments, along with the high added value of the land and the low area of green space (Khosravi and Ghobadi, 2014). Some studies indicate that at least approximately one-fifth of the area in Tehran can be turned into green space, and air pollution can be significantly reduced by encouraging citizens to implement the "green roof" project (Taghavi, 2014).

Many studies have been conducted around the world on the economic and environmental dimensions of green roofs (e.g., Ruan, 2006; Nurmi et al., 2013; Zeng et al., 2017; Teotónio et al., 2021; Calheiros and Stefanakis, 2021; Manso et al., 2021; Mihalakakou et al., 2023; Mohamad Hamzah et al., 2023). Mohammadi et al. (2019) reported that using green roof technology is justifiable only by considering its benefits, such as reducing air pollution, decreasing energy consumption, and alleviating harmful effects on the environment, so that an initial cost of 29,76 $\$/m^2$ generates a profit of 33,33 $\$/m^2$. In addition, Peng and Jim (2015) emphasized the usage of green roofs in aspects of climate change, including thermal insulation and carbon dioxide decomposition, by utilizing the cost–benefit analysis (CBA) method in scenarios of extensive and centralized construction methods, indicating that extensive and centralized green roofs have values equal to 10,77 and 18,33 $\$/m^2$, respectively. Furthermore, Zhang et al. (2019) calculated the willingness to pay in Beijing, China, using a conditional valuation method and found that each family is willing to pay an average of 148,582 yuan (US$22,446) per year for applying for a green roof to reduce the urban heat island (UHI). Abedi and Kheiri (2020) investigated the economic justification of the construction of a green roof in District 9 of Tehran Municipality. For this purpose, the Discrete Choice experiment and indicators of profitability indexes have been used. The results show that the construction of a green roof is not justifiable from an economic point of view in the study area. Importing the value of environmental benefits in the assessment leads to a net present value of 11.349 million rials and an internal rate of return of 53 percent. The results also show that the value of the environment that the citizens of this region are willing to pay for the construction of each square meter is equal to an average of 5.44 million rials. In this case, the benefit-to-cost ratio will be 1.92. Bus and Szelągowska (2021) calculated the ecological (EE) and economic effect (EcE) of water harvesting via Green roofs, by using the Net Present Value (NPV) method for both intensive and extensive GRs in 11 of the largest municipalities in Poland. Results showed that the economic and ecological effects of GRs equal 507,000 m3/yr and 621,000 USD/yr. The NPV results show that the average equals 60.77 and 4.47 USD/yr for intensive and extensive GRs, respectively. Hekrle et al. (2023) aim to provide comparable information on the economic value of three Green roof projects using two alternative CBA approaches in Czechia and Portugal. The results showed that the monetary GR benefits are four to six times greater than the costs, depending on the case study.

Green roof technology has not been widely used due to a lack of sufficient information on cost–benefit issues, although some studies have confirmed the environmental value of this technology (Mahdiyar et al., 2016). Furthermore, a large number of researchers have aimed to translate the environmental benefits of green roofs into monetary values (Peng and Jim, 2015). However, Williams et al. (2019) argued that the number of studies in this field is limited, despite proving the psychological effects of green roofs, including beauty, recreation, and health, probably because the studies related to this technology are in the early stages of development.

In this study, the information function of the green roof, including beauty, recreation, and health, is evaluated through the choice experiment method, and its economic value is calculated as the added value of the building. Finally, a cost–benefit analysis is used in scenarios with and without considering environmental benefits to investigate the justifiability of using this technology in Tehran. It should be noted that the paper could interest readers in urban environmental planning, urban economy, and natural resource economics. Regarding the valuable functions of green roofs, there is a significant gap in assessing this technology, especially in developing countries such as Iran. However, very few studies in Iran have descriptively examined the benefits of green roofs. Moreover, no studies have evaluated the specific functions of green roofs, such as "beauty, recreation, and health," especially by the contingent choice experiment method. Therefore, the present study is considered innovative in terms of considering economic and environmental value, as well as comparing the two scenarios, and its results can be used in economic and environmental policies.

2. Methodology and Data

Economic evaluation is regarded as a necessary process to calculate the potential or initial costs and benefits of a strategy and evaluate its feasibility, which is done by assessing the costs and benefits of each project over time. This technique makes it possible to compare the alternatives and provides a systematic system for decision-making and bargaining (Mahmoud et al., 2017). In this context, CBA is among the methods of economic evaluation implemented in public and private projects and is considered the practical application of modern welfare economics in public policy-making. CBA seeks to account for the positive and negative consequences (advantages and disadvantages) of economic activities by converting them into financial flows and choosing the best possible option. The benefit–cost ratio (BCR), net present value (NPV), and internal rate of return (IRR) are utilized to accept or reject the investment plan in the framework of CBA (Boardman et al., 2018; Choy, 2018).

Benefit–Cost Ratio (BCR): This method is obtained by dividing the present value of the benefits by that of the costs as follows.

$$\mathrm{BCR} = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+r)^t}} \quad (1)$$

where r represents the discount rate (reflecting the opportunity cost of resources), and B_t and C_t indicate the benefits and costs of the project in year t, respectively. Deciding on the investment plan is conducted as follows. The plan is economically justified and accepted if the BCR > 1. In addition, the plan is at a breaking point if BCR = 1, in which it is not possible to comment on its acceptance or rejection. Finally, the plan has no economic justification and is not accepted if the BCR <1.

Net Present Value (NPV): This index is regarded as the difference between expected discounted cash flows and initial investment. The discounted present value of the project is shown in Equation (2), if I represent the amount of zero-year capital, B_1 to B_n indicate project revenues in years 1 to n, and C_1 to C_n are considered project costs in different years. According to the decision criterion based on NPV, the plan is economically justified and accepted if NPV > 0, and it has no economic justification and is not accepted if NPV < 0.

$$\mathrm{NPV} = -\mathrm{I} + \frac{(\mathrm{B_1} - \mathrm{C_1})}{(1+\mathrm{r})} + \frac{(\mathrm{B_2} - \mathrm{C_2})}{(1+\mathrm{r})^2} + \cdots + \frac{(\mathrm{B_n} - \mathrm{C_n})}{(1+\mathrm{r})^{\mathrm{n}}} \quad (2)$$

Internal Rate of Return (IRR): This rate is equivalent to the rate of return that an investor can earn by investing in a project. The IRR is regarded as the discount rate at which the present value of benefits equals that of costs. The IRR can be calculated as Equation (3) by setting the NPV equal to zero and considering r unknown. In this equation, r represents the discount rate, which is considered a reflection of the lost costs of resources in the plan. The IRR is greater than the discount rate (market interest rate + risk savings) in an acceptable scheme. In general, two scenarios can be regarded for IRR as follows. The plan is economically justified and accepted if IRR > MARR, and the plan has no economic justification and is not accepted if IRR < MARR. It is worth noting that MARR is equal to the minimum acceptable rate of return and is regarded as the same as the discount rate.

$$\sum_{t=1}^{n}\frac{(B_t - C_t)}{(1+r)^t} - I = 0 \qquad (3)$$

From an economic point of view, values can be due to the consumption of goods and services that are bought and sold in the markets. In addition, they are dependent on services received from the environment without payment (Pak et al., 2010). In the present study, the information function of green roofs in the fields of beauty, recreation, and health is among these values. For this aim, the choice experiment method was used for valuation as one of the subsets of modeling and an indirect method of expressing preferences, which has been used to evaluate nonmarket goods in the fields of environmental and health economics in recent years. The choice experiment method seeks to evaluate the mental structure of consumers with an emphasis on the relative importance of features. To this aim, individuals are asked to choose the alternative option with the most appropriate among the options gathered on a selection card (Champ et al., 2003). Based on the choice experiment method, the product is described according to a number of its features, which can be used to examine consumers' reactions to changes in the properties of goods. The suggested alternatives in each selection card are different levels of each feature. Variation among alternatives is created by considering different levels for each feature, which is based on a systematic process called experimental testing (Kjaer, 2004; Shanahan et al., 2019). According to this method, the indirect utility function for each respondent i (U) is divided into a definite section (V), usually regarded as a linear index of the feature of the various options j in the choice experiment set, and a random section (ε), which indicates the invisible effects on individuals' selection. The following equation displays the indirect utility function (Shin and Lyu, 2018).

$$\mathrm{U_{ij}} = \mathrm{V_{ij}}(\mathrm{X_{ij}}) + \varepsilon_{\mathrm{ij}} = \beta \mathrm{X_{ij}} + \varepsilon_{\mathrm{ij}} \qquad (4)$$

The implicit prices can be calculated for the corresponding features and levels after assessing the model. The partial prices can be calculated as follows using the marginal rate of substitution (MRS) once the cost of selecting each option is entered as one of the features (Hogberg et al., 2007).

$$\mathrm{WTP_j} = -1 \times \left(\frac{\beta_{\mathrm{i}}}{\beta_{\mathrm{price}}}\right) \qquad (5)$$

2.1 Steps for Designing and Executing the Choice Experiment Method

a) Selecting the features and level allocation: The features or traits selected should be meaningful and understandable to the respondents. To determine the traits and identify the levels of each, previous studies in this field (e.g., Mohammadi et al., 2019; Vanstockem et al., 2018), as well as the experts' opinions in green roof design and construction companies such as "Chekad Bam" and "Iran Roof Garden", were used, and criteria such as operationally, separability, and having minimum size were considered. It is noteworthy that price is among the studied traits, which makes it possible to evaluate the willingness to pay (Champ et al., 2003). Finally, four features with three levels were selected (see Table 1).

b) Selecting a statistical plan: To combine the features with different levels, a statistical plan should be used to create some scenarios or profiles for presenting to the respondents from these combinations (Vanstockem et al., 2018). A fractional factorial design was applied because it is widely used to reduce the number of options (Street et al., 2008; Shin and Lyu, 2018).

Table 1. Selected Features and Levels for Designing a Choice Experiment

Features	Levels	1	2	3	4
1	Procedure	Extensive (Requires less infrastructure)	Centralized (Requires more) infrastructure	Boxlike (Preprepared box with plants)	
2	Vegetation	Grass and a variety of herbaceous plants	Combining a variety of grass, decorative plants, and fancy décor	Shrubs, decorative plants, and fancy decor	I do not want to pay extra to use this technology, or prefer the current condition of the roof
3	Percentage of greenery	Less than 30% of the roof surface	30-60% of the roof surface	More than 60% of the roof surface	
4	Price (value added per square meter of property)	$83.5	$137	$190.5	

Source: Research finding.

Table 2. An Example of the Designed Selection Card

Which option do you prefer?			
	Option 1	**Option 2**	**Option 3**
Procedure	Boxlike (preprepared boxes with plants)	Centralized (Requires more) infrastructure	
Dominant vegetation	Combining a variety of grass, decorative plants, and fancy décor	Grass and a variety of herbaceous plants	I do not want to pay extra to use this technology, or prefer the current condition of the roof
Amount of vegetation	30-60% of the roof surface	Less than 30% of the roof surface	
Extra payment per square meter of property (Which leads to an increase in the price of the property at the time of sale)	$190,5	$83,5	

Source: Research finding.

c) Constructing selection and blocking sets: The scenarios are grouped into the selection sets after determining the composition by the statistical plan, so that each has two or more alternatives with an option called "current situation", in which the person is not willing to change and does not choose any of the proposed options. In addition, the current situation option helps make the questionnaire more realistic (Lancsar et al., 2017). In the present study, 12 optimal options with the highest statistical efficiency were formed through orthogonal design using SPSS software. Then, the sets were selected considering conditions such as balance of levels (equal repetition of each level) and minimum overlap (existence of different levels in each selection set) (Hazlewood, 2018). Table 2 shows an example of the designed selection card.

d) Designing questionnaire, selecting statistical population, sample size, and sampling method: The questionnaire was designed in three parts. Some explanations about green roof technology and its procedures were given at the beginning of the questionnaire to acquaint the audience. Then, several questions were asked about individual features and socioeconomic status in the first part. The questions in the second part were related to the respondent’s personal attitude toward the environment and its general acceptance among individuals. Finally, three sets of choices with three scenarios in each were presented in the third part as the most important part of the questionnaire, among which the respondents chose the most appropriate one. It is worth noting that the population included the residents in District 2 of Tehran municipality. Based on the air pollution data during the last three years extracted from the reports of Tehran Air Quality Control Company, as well as the statistical yearbooks of Tehran municipality, district 2 is among the regions with the highest per capita green space and the lowest air pollution. Therefore, studies can determine the importance of green roofs among the population without any need for this technology and facilitate policy-making for their expansion. Highly large and small samples (fewer than 30 people) lead to a waste of time and resources with no good results, since the sample size depends heavily on the researcher's budget and time (WHO 2012). Sampling was conducted in the clusters due to the selection of a specific area of the city. Then, 200 questionnaires were distributed considering the Morgan table, among which 60 completed and provable questionnaires were collected in 2020. Finally, 540 observations were obtained.

e) Level coding: In the present study, virtual coding was used (Hensher et al., 2005). To perform coding, the variables related to each feature should be determined, the number of which can be obtained as follows.

$$\text{Number of variables} = L-1 \tag{6}$$

where L represents the number of levels of each feature.

f) Economic model: The conditional logit model was selected according to the existing theoretical literature (Strauss et al., 2018; Clark et al., 2014; Cleland et al., 2016; Costa et al., 2018). However, selecting from the selection sets should have the feature of independence of irrelevant alternatives in explaining this model (IIA hypothesis), which indicates that the ratio of the probability of choosing between the two alternatives does not depend on the presence or absence of the third one. Assessing the conditional logit pattern without considering this hypothesis provides biased results. There are various tests for examining this hypothesis, among which the Hausman-McFadden test is widely used. The conditional logit model is not considered reliable, and more complex models should be applied in case of violating the aforementioned hypothesis (Mogas et al., 2006).

2.2 Introducing the Experimental Regression Model

The experimental model utilized in the present study is expressed as follows, considering the studies conducted in the field of choice experiments (Ruokamo, 2016; Costa et al., 2018).

$$Choice_i = \mathrm{ASC} + \beta_1 X_{1i} + \cdots + \beta_s X_{1i} + \delta_1 Z_{1i} + \cdots + \delta_j Z_{ji} + \varepsilon_i \quad (7)$$

where choice is regarded as a dependent variable indicating the individuals' selection. Choice represents the individual's selection among the three alternatives (options) in each selection set. ASC indicates Alternative-Specific Constant, which accepts 1 when individuals are willing to pay (options 1 and 2) and zero when they are reluctant to pay or maintain the status quo (option 3). X_s are considered the specific features of the alternatives (three green roof features with price), and βs represent their coefficients. Individuals' personal-economic features should enter the model as a product of a particular feature, such as ASC or price, since they are considered constant during the alternatives of a selection set (Palmquist 2005). The abovementioned product was used in the present study because multiplying these features by the price led to more consistent results. In the above model, Z represents the individuals' personal-economic features, which are multiplied by P (price), and δ are regarded as their coefficients.

2.3 Hypothesis Used in the Economic Evaluation

The hypothesis used in the CBA is shown in Table 3. The base year of 2018 is considered because the extracted costs used in the analysis were collected in the winter of 2018. The period under consideration is 30 years, which was selected according to the useful life of green roofs (30-40 years in Iran). The discount rate is 25%, which is regarded as attractive for investment and represents the opportunity cost of capital. The discount rate was obtained based on bank and stock market interest rates and previous studies (e.g., Feng and Hewage, 2018; Nurmi et al., 2013), in which a single discount rate is used to discount all the benefits studied. The initial cost of green roofing, including the infrastructure of required layers and tree planting, as well as the cost of maintenance and irrigation, was obtained through field research and consultation with experts and green roofing companies in Tehran, such as "Iran Roof Garden" and "Negin Azin Part", which is equal to 238 $/m^2$ for initial implementation and 85 $/m^2$ per year for maintenance activities such as irrigation and gardening. The cost of replacing conventional roof insulation was obtained through field research and consultation with experts, which is equal to 119 $/m^2$. Replacing conventional roof insulation is among the advantages of green roofing since it eliminates the need for individuals to pay this cost. The added value of the property is among the economic benefits of green roofing, which is created by adding a welfare option to the building. According to some studies (e.g., Feng and Hewage, 2018; Bianchini and Hewage, 2012), as well as field studies, the added value created by green roofing for a building is equal to 5% of the price per square meter of the building. This amount was equal to $190.5 and $83.5/m2 for district 2 of Tehran municipality, with a price of $1667-3810/m2 during 2020. The value of beauty, fun, and health, which are among the benefits of green roofs, was obtained through the choice experiment and calculated in maximum, average, and minimum modes.

Table 3. Hypotheses Used in the CBA

Title		Description	Unit
Base year		2020	Year
Review period		30	Year
Discount rate		25	Percentage
Initial cost of green roofing		238	$/m^2$
Maintenance and irrigation costs (monthly cost × 12)		85	Yearly $/m^2$
Cost of replacing conventional roof insulation		119	$/m^2$
Value added of the property in District 2 of Tehran municipality		190,5	Yearly $/m^2$
Value of beauty, fun, and health in District2 of Tehran municipality	Considering the maximum willingness to pay	307,1	Yearly $/m^2$
	Considering the average willingness to pay	182,1	Yearly $/m^2$
	Considering the minimum willingness to pay	147,4	Yearly $/m^2$

Source: Research finding.

3. Result

3.1 Choice Experiment Method

Table 4 shows the respondents’ economic and social features, in which the majority of respondents in this region (55%) are men with an average age of 37.5 years. In addition, the highest and lowest relative frequencies belong to the category of individuals under 30 years (55.8%) and over 50 years of age (3.5%). In terms of marital status, most of the respondents (76%) are married; it is noteworthy that the respondents who are single and live in their father's house or with their family were excluded from the sample to increase the accuracy of the questionnaire. Accordingly, all respondents have a relatively correct understanding of the cost of living and housing in their place of residence. Regarding the number of family members or housemates, the maximum and minimum numbers are equal to 5 and 1 persons, respectively, with an average of 3. The highest frequency of education is among bachelor respondents (40%), and the individuals' average level of education is equal to 16.4 years, indicating a high level of general education among the respondents. Regarding the respondents' economic features, 88.3% are employed (it is worth noting that the students and housewives are among the unemployed). In terms of monthly expenses, the highest frequency is in the category of 714, 3-1190, and 5 (48.1%), and the lowest, highest, and average monthly expenses are 476.2, 1904.8, and $1061.9, respectively. Regarding the ownership status of residential housing, the majority of people (65.9%) are landlords, among whom 78.4% live in apartments and 21.6% live in villas. Most respondents live on the first floor, with a relative frequency of 40%.

Table 4. Respondents' Economic and Social Features

Variable	Relative frequency (%)		Mean	Variable	Relative frequency (%)		Mean
Employment status	Employed	88.3	-	Gender	Man	55	-
	Unemployed	11.7			Woman	45	
	238.1-$714.3	34.0			Under 30	55.8	
Monthly family income ($)	714.3-$1190.5	48.1	$1061.90	Age (year)	30-40	30.7	37.53 years
	1190.5-$1666.7	15.5			40-50	9.9	
	1666.7-$2142.8	2.3			50 and above	3.5	
Ownership status of residential housing	Landlord	66.0	-	Marital status	Married	76	-
	Tenant	34.0			Single	24	
Type of housing location	Apartment	78.4	-	Number of housemates	2 and less	35.8	3
	Villa	21.6			3	32.8	
	1	33.9			4	25.5	
Residential floor	2	24	2.35	Level of education	More than 5	5.8	16.43 years
	3	21.9			Diploma	1.2	
	4 and above	20.2			High school	13.8	

Source: Research finding.

Table 5. Respondents' Environmental and Personal-Economic Attitudes

Question code	Item	Percentage of responses					
Respondents' environmental attitudes							
		Strongly agreeing	Agreeing	Indifferent	Disagreeing	Strongly disagreeing	SD
Q1	A green roof can help improve my family's and my mood	63.7	21.8	1.9	0.7	0	0.6
Q2	A green roof helps increase the green space around my place of residence	62.4	28.4	7.1	1.4	0.7	0.8
Q3	Extensive use of green roofs reduces air pollution	53.5	26.4	12.3	7.0	0.7	0.1
Q4	A green roof plays a significant role in the beauty of individuals' living environment, freshness, and health.	75.5	21.6	2.2	0	0.7	0.7
Respondents' personal-economic attitudes							
Q5	A green roof has several benefits, and I am willing to pay extra for the property	30.9	29.2	24.2	13.0	2.7	1.2
Q6	A green roof is regarded as a luxury technology, which can only be used by the upper deciles of society	9.1	39.8	23.7	26.8	0.5	1.1
Q7	Using a green roof is considered expensive, and its implementation requires the support of government organizations and incentives such as tax breaks, overcrowding, construction loans, and the like	24.1	48.4	11.6	11.3	3.8	1.2
Q8	There is no culture for the common use of green roofs in Tehran, and implementing its technology is only appropriate for private property	26.5	43.6	18.2	9.3	2.2	1.1

Source: Research finding.

Table 6. Results of Assessing the Hybrid Conditional Logit Model

Symbol	Variable	Coefficient	Standard error	Z-statistic	Significance level
ASC	Alternative-specific constant	- 0.1246	0.4315	- 0.29	0.773
Motemarkez	Centralized construction method	** 1.2280	0.6070	2.02	0.043
Jabei	Boxlike construction model	*** 1.8093	0.6093	2.97	0.003
Chaman	A cover of grass and herbaceous plants	*** 5.6458	1.6099	3.51	0.000
Tarkibi	A combined cover of herbaceous and fancy plants	*** 6.8206	2.0112	3.39	0.001
Fantezi	A cover of fancy plants	*** 8.3008	2.6966	3.08	0.002
Less_than_30	greenery percentage of less than 30%	*** - 4.2065	1.5107	- 2.78	0.005
Mid	greenery percentage of 30-60%	*** -2.3150	0.8868	-2.61	0.009
Pr	Price	*** - 0.0110	0.0020	- 5.35	0.000
prHhExpmtoman	Price × Income	*** 0.0004	0.0001	3.46	0.001
PrEdu	Price × Education	*** 0.0003	0.0000	4.51	0.000
Prgnr	Price × Gender	* 0.0006	0.0003	1.86	0.063
prMarstatus	Price × Marital status	* 0.0006	0.0003	1.72	0.085
prHousestatus	Price × Home ownership status	* 0.0007	0.0003	1.91	0.056
Prob > chi^2 = 0.000 Peseudo R^2 =0.1426			N = 540 LR chi^2 = 75.80 Log likelihood = -227.94928		

Source: Research Finding.

Note: * Significance at the level of 10%, ** Significance at the level of 5% , *** Significance at the level of 1%.

Table 5 indicates the respondents' environmental and personal-economic attitudes. In the environmental attitude questions, the majority of respondents selected the options of agreeing and strongly agreeing. As shown, 85.5, 90.8, 79.9, and 97.1% of the respondents chose the options of agreeing or strongly agreeing in the questions with Q1, Q2, Q3, and Q4 codes, respectively.

Additionally, Table 5 represents the respondents' personal-economic attitudes in District 2 of Tehran municipality. As illustrated, the option of strongly agreeing has the most answers in questions with Q5 (30.9%), Q6 (39.8%), Q7 (48.4%), and Q8 (43.6%) codes.

3.2 Results of Assessing the Conditional Logit Model

In selecting the variables according to the study of Vanstockem et al. (2018), all of the features and levels were entered into the model, and the software used (STATA 14.2) eliminated two levels of "extensive" (from the construction method) and "more than 60%" (from the roof greenery) due to alignment. Therefore, the variables were excluded during the assessment, and the final model was evaluated with 14 variables, the results of which are shown in Table 6.

The heterogeneity of preferences created due to differences in people's tastes is among the issues in demand for environmental and tourism goods. Incorporating socioeconomic variables is regarded as the solution for addressing this issue. However, the individuals' personal-economic features should be entered into the model by multiplying by a specific feature, such as ASC or the price, because these features are considered constant during the alternatives of a choice experiment (Palmquist, 2005). In the present study, price interactions with individuals' socioeconomic variables were used. In the evaluated model, gender, income, education, marital status, and home ownership status had more consistent results among the individuals' socioeconomic variables, which were entered into the model as a product of the price variable. The IIA hypothesis should be examined before interpreting the results of the evaluated model, since there is a possibility of bias in the results, and another model should be applied when the hypothesis is not accepted. As represented in Table 7, the IIA hypothesis is not rejected, and the conditional logit model is considered appropriate for evaluation. In addition, the null hypothesis is not rejected, and the results of the evaluated model can be cited.

Table 7. Results of the Hausman-McFadden Test for the Conditional Logit Model

Eliminated option	Statistic	Significance level
First option	19.3	0.0134
Second option	14.4	0.0722

Source: Research finding.

As indicated in Table 6, the value of Pseudo R^2 in this model is equal to 0.1426, which is regarded as acceptable when its value is more than 0.1 (Louviere et al., 2000). The value of the statistic χ^2, which is considered the ratio of likelihood and represents the overall significance of the coefficients, is equal to 75.8, and its probability is zero, meaning the overall significance and appropriateness of the model and its variables. Based on the results, ASC has a negative sign, which indicates that the respondents are generally reluctant to pay extra and change the current state of their roof, and their appropriateness does not increase by paying the amount and constructing a green roof in houses (e.g., Hashemibonab et al., 2012; Ruokamo, 2016; Cosmina et al., 2016; Bazzani et al., 2017). The aforementioned result is among the expected states for ASC. All variables have a positive coefficient, except for the greenery percentage of less than 30 and 30-60% and price, meaning that the presence of the feature leads to increased WTP. For example, the negative coefficient for coverage of 30 and 30-60% indicates that people do not prefer these two modes to the current state of the roof. In other words, these levels of roof greenery reduce people's WTP when other features remain constant. However, people prefer centralized and box-like methods to the current situation, which can increase their WTP for green roofs when other features are constant. Regarding the price feature, the negative coefficient indicates that people's willingness to pay extra to use the green roof decreases with an increase in the cost of this technology. Comparing the results of the study regarding price features with other studies confirmed that the coefficient of price features is negative, as in most studies of the choice experiment method (e.g., Isazade et al., 2013; Shin and Lyu, 2018; Cosmina et al., 2016). As observed, individuals' socioeconomic features have positive coefficients. Based on the coding, the positive coefficient of gender indicates that men are more willing to pay. According to the positive coefficient regarding individuals' marital status, married people are more willing to pay than single people. In addition, individuals' willingness to pay the price rises with an increase in income and the years of education. Furthermore, home ownership status is regarded as a positive sign, meaning that landlords are more willing to pay than tenants.

In the choice experiment studies, the marginal rate of substitution between the features and the price variable is calculated according to Equation (2) to make more practical use of the obtained coefficients. The choice experiment eases calculating the value of each feature separately, in addition to evaluating the willingness to pay overall and assessing the total value of an environmental commodity, which is among its advantages. It is noteworthy that in the present study, the willingness to pay the total is considered, and analyses are entered. Table 8 shows the results related to the calculation of the WTP for the environmental features of green roofs. To analyze more accurately and calculate all the cases, the studies were conducted in maximum, average, and minimum scenarios, which represent the highest, average, and lowest willingness to pay for each feature and the sum of the features.

Table 8. Results of the Willingness to Pay for the Features of the Green Roof

Feature	Procedure	Type of covering	Percentage of greenery	Sum ($\$/m^2$)
Maximum willingness to pay ($\$/m^2$)	38,8	178,1	- 90,2	307,1
Average willingness to pay ($\$/m^2$)	32,5	149,6	- 69,9	182,1
Minimum willingness to pay ($\$/m^2$)	26,2	121,2	- 49,5	147,4

Source: Research finding.

As shown in Table 8, the respondents in District 2 of Tehran municipality are willing to pay 307, 1 $\$/m^2$ at best to have a green roof. The lowest WTP in this area is equal to $147.4/m2. In addition, the highest WTP of 178.1 $\$/m^2$ is for the type of green roof covering, which is related to fancy plants. Furthermore, the lowest WTP is related to centralized green roofing, which is equal to 26,2 $\$/m^2$. Regarding the percentage of roof greenery, WTP cannot be interpreted and analyzed due to its negative coefficients.

3.3 Cost-Benefit Analysis (CBA)

The CBA was conducted only in terms of the costs and economic benefits of green roofing. Table 3 shows the hypothesis used in the CBA.

As shown in Table 9, the NPV of green roofing in district 2 of Tehran municipality over a period of 30 years (useful life of green roof) is economically equal to 180.8 $\$/m^2$, meaning that green roofing in this area creates a value of 180.8 $\$/m^{2,}$ considering all the costs and economic benefits. In addition, the IRR of green roofing is only 44% considering the economic benefits and costs, and its BCR is equal to 2 if we regard green roofing as the equivalent of an investment project. These figures improve significantly by increasing the environmental benefits so that the NPV triples to $769.6, considering the minimum willingness to pay. Furthermore, the IRR increases by 62% in this case and reaches 106%. Given the maximum willingness to pay, the NPV increases approximately 6.5 times to $1407.8. In this case, the IRR increases by 129% and reaches 173%.

Table 9. Financial Indices

Value		NPV-($)	IRR	BCR
Economic		180.8	44%	2
Economic-environmental	Considering the maximum willingness to pay	1407.8	173%	4.5
	Considering the average willingness to pay	908.5	121%	3.2
	Considering the minimum willingness to pay	769.6	106%	2.8

Source: Research finding.

4. Conclusion

The prevalence of apartment dwellings, lack of green space per capita, and the high value of land are among the factors that increase the need of urban residents for an environment for relaxation. Due to the importance of this issue for the Tehran metropolis, the present study aimed to assess the economic justifiability of green roofing in District 2 of the Tehran municipality. Based on the results, the NPV is 180.8 $\$/m^2$, the IRR is equal to 44%, and the BCR is equal to 2, considering only the economic benefits and costs. In addition, the residents of district 2 are willing to pay an average of 182.1 $\$/m^2$ for green roofs, which increases the NPV to $908.5 in terms of the environmental benefits. In this case, the IRR grows by 175% and reaches 121%. Furthermore, the BCR improves by approximately 60% to 3.2.

Furthermore, a high percentage of residents chose a strongly agree option, which can justify their high WTP considering four statements related to the environmental attitude of people in District 2 of Tehran municipality. The tendency to pay high can be attributed to the young population responding in district 2 and their willingness to accept new technologies and change their lifestyle, which are consistent with the results of conversations with individuals when completing questionnaires and developing their mental patterns, so that most people who were not familiar with this technology were older and did not want to change their lifestyle.

Based on the theoretical foundations in the field of economic evaluation, a positive NPV and an IRR higher than the individual discount rate, which is usually obtained by adding market interest rates and risk savings and is considered equal to 25% in common studies in Iran, and a BCR greater than one make a project economically justifiable. Green roofing has both economic and economic-environmental justifications, considering only two benefits among others, such as beauty and recreation, along with health and economic added value. Therefore, future studies can be conducted by assessing the overall value of the environmental functions related to green roofs through the results of the present and other studies in this field and implementing incentive policies such as collecting less toll, expediting issuance, licensing, and density through their results since most people believe that using this technology is considered costly and requires the support of government organizations and incentives. In addition, investigating the field of comparative study of metropolises in the world to provide a practical model for implementing this technology can be useful.

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