Green Standard Model Using Machine Learning: Identifying Threats and Opportunities Facing the Implementation of Green Building in Iran

Mohamad Rajabi[1], Javad Majrouhi Sardroud[2], Ali Kheyroddin[3]*

[1]Ph.D. Researcher, Department of Civil & Construction Engineering, Central Tehran Branch, Islamic Azad University, Tehran, Iran

[2]Assistant Professor, Department of Civil & Construction Engineering, Central Tehran Branch, Islamic Azad University, Tehran, Iran

[3]Distinguished Professor, Department of Civil Engineering, Semnan University, Semnan, Iran

[*]Corresponding Author Email: j.majrouhi@gmail.com

Abstract

Residential buildings consume a major portion of energy resources and hence are seriously involved in environmental pollution. In Iran, the consumption of fossil fuels is on the rise, to the extent that it has grown by more than 400% from 1990 to 2018. One of the fundamental solutions for reducing fossil fuel consumption and creating a healthy environment inside and outside buildings is the implementation and development of green buildings. This study seeks to examine the obstacles and opportunities facing green building and proposes a localized green standard befitting the conditions of Iran with the aim of contributing to the development of green buildings. To this end, the requisite parameters were identified using the opinions of experts and Delphi method, and the opinions of 81 building experts including the employer, consultant and contractor were obtained using a three-part questionnaire. Based on the results obtained using the machine learning method, the score of the local green building in a total of five dimensions, namely site, water, energy, materials and quality of indoor environment was calculated to be 77.2, while the energy dimension was determined to be the most important green standard dimension with a significance coefficient of 0.548. In the ranking analysis of all parameters using Friedman test, the parameters of energy consumption management, use of renewable energy and thermal zoning attained the highest scores among other factors.

Furthermore, lack of awareness on green buildings (77%) and high potential for renewable energy production (81%) were respectively identified as the biggest obstacle and opportunity facing the implementation of green buildings in Iran.

Keywords*: Green standard, machine learning, energy consumption, environmental pollution, Iran*

Abbreviations

LEED	Leadership in Energy and Environmental Design
BREEAM	Building Research Establishment Environmental Assessment Method
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
ITACA	In English: Institute for Transparency of Contracts and Environmental Compatibility, Italy
DGNB	In English: German Sustainable Building Council
ASGB	Assessment Standard for Green Buildings
SB Tool	Sustainable Building Tool
GBL	Green Building Label
GM	Green Mark
GS	Green Star

1. Introduction

Climate change and the gradual process of global warming are among the serious threats and challenges facing different societies that is directly related to the consumption of fossil fuels and carbon dioxide production (Mirzaei and Bekri, 2017; Sarwar and Alsaggaf, 2020). The ever-increasing demand for exploration and exploitation of natural resources in different countries has resulted in devastating environmental impacts (Balaban and Oliveira, 2017). The complications of increasing pollution and climate change have long been accounted by scientific evidence and various studies, as approximately 20% of pollution and greenhouse gas emissions are attributed to residential buildings, which are a significant part of carbon emissions in the environment (Zhang et al, 2018; Cordero et al, 2019). Buildings often require special attention given their high energy consumption and their role in creating environmental challenges, as they account for about 20 to 50% of global energy consumption and more than 40% of solid waste production (Dwaikat and Ali, 2016; MacNaughton et al, 2018; Kim et al, 2014). In China, about 60% of carbon dioxide emissions and in the United States and the EU, 35 to 40% of carbon dioxide emissions are attributed to residential buildings (Sinha et al, 2013; Li et al, 2014).

Energy consumption is reportedly excessive in Iran, which has resulted in threatening consequences for various economic, political and environmental aspects (Taghvaee et al, 2017). Iran is a rich country in oil and gas energy resources, holding 11% of world's oil reserves and 15.3% of the natural gas reserves, where energy is mainly produced using fossil fuels. Unfortunately, the pattern of energy consumption in Iran is highly inefficient and many factors such as low energy prices, energy subsidies, high population rates, economic growth and poor resource management have also resulted in a sharp increase in energy consumption, high carbon dioxide production as well as environmental pollution (Moshiri et al, 2012; Hosseini et al, 2013). Energy consumption in Iran has increased by 415% from 1990 to 2018, that is from 53 to 273 TWh, while also the amount of carbon dioxide emissions has increased by 238%, from 171 to about 580 million tons, During the same period (IEA, 2018; EIA, 2018) and is projected to increase with annual growth of 5% to about 985 million tons by 2025 (Mirzaei and Bekri, 2017).

Widespread concerns regarding high energy consumption, global warming, and depletion of non-renewable energy sources have led to development of green building movement (Esa et al, 2011). Green buildings have been proposed as one of the most efficient and ideal solutions for sustainable and healthy buildings, optimal use of resources, increasing the recycling capacities of construction materials, and hence has been proposed as an approach to alleviate environmental challenges (Nguyen et al, 2017; Zuo et al, 2017). Green buildings greatly contribute to mitigation of the harmful effects on the environment, economy and people (Neyestani, 2017), in which increased energy efficiency and renewable energy are employed to significantly reduce the consumption of fossil fuels (Eliasa and Lin, 2015). In recent years, the existence of some incentives or government subsidies in some countries is one of the factors that has led many small contractors to build and develop green buildings (Shan et al, 2020). Studies indicate that the significance of and the ensuing interest in green buildings is rapidly growing in many countries around the globe, and some developed countries such as the United States, the United Kingdom, Singapore, Hong Kong, Australia and Italy have taken major strides in the development of green buildings, while developing countries such as Colombia, Egypt and China have also sought to develop green building research (Darko and Chan, 2016). As the understanding of the concept of green building development grows all around the world, the notion of green construction has been widely expanding, and more attention is now being given to the construction and development of green buildings worldwide (Qifa, 2013).

Huo and Yu (2017) examined the benefits of green buildings from 2007 to 2016 and reported that green buildings are more environmentally-friendly, conserve energy, and provide better performances in terms of thermal comfort, indoor air quality and noise pollution. Green buildings have many positive environmental, social and economic consequences and contribute to national economy and gross domestic product (GDP), effects of which gain more prominence over time (Zuo and Zhao, 2014; Zhao et al, 2019). Although the initial costs of green buildings are higher than those of conventional buildings, they hold a plethora of advantages, such as the use of renewable energy, rainwater recycling, and environmentally friendly material, outweighing the costs (Khot et al, 2019; Lee et al, 2013). MacNaughton et al. (2018) studied the benefits of implementing green buildings in six countries, namely the United States, China, India, Brazil, Germany and Turkey, the results of which revealed that implementing green buildings in the aforementioned countries has saved $7.5 billion in energy consumption and has prevented 33 million tons of carbon dioxide emission into the atmosphere. (Nangare et al, 2015) also revealed the implementation of green buildings has reduced energy consumption by at least 25% in China. In Turkey, green buildings with platinum and gold certification have respectively save 40% and 31% in energy consumption, respectively (Uğur and Leblebici, 2018). Implementation of green buildings in Israel has reduced water and electricity consumption respectively by 24% and 23% compared to those in conventional buildings (Meron and Meir, 2017). Dwaikat and Ali (2018) reported that implementing green buildings in Malaysia has reduced energy consumption by 28.9%, while Ebadati and Ehyaei (2018) been reported that implementing green ceilings in Iran reduces energy consumption by 17%.

Despite the widespread benefits of green buildings, their implementation has been faced with many challenges and obstacles in some countries. Darko and Chan (2017) reviewed the literature on green buildings, and identified lack of information, high cost, lack of motivation, and lack of demand, interest and regulations of green buildings as the most significant threats to the implementation of green buildings. Esa et al. (2011) reported lack of education and lack of awareness regarding the benefits of green buildings, and Samari et al. (2013) identified the lack of credit resources, high investment risk, lack of demand and high costs as the greatest obstacles to the implementation of green buildings. Based on the results Li et al. (2014), three factors of lack of awareness on the stakeholder side, lack of research and non-favorable existing laws have been identified as the most important threats to the development of green buildings in China (Li et al, 2014). In Thailand, lack of motivation from landlords, high initial costs and financial and technical constraints (Shen et al, 2018), in Saudi Arabia, lack of government support and lack of skilled labor (Mosly, 2015), and in Ghana, high costs, lack of government incentives, and lack of financial plans have been identified as the biggest obstacles to implementation of green buildings (Chan et al, 2018).

The implementation of green rating systems for the evaluation of buildings is of paramount importance increase awareness of sustainable development in the construction industry and help thus reduce environmental pollution (Hedaoo and Khese, 2016; Cordero et al, 2019). Environmental evaluation methods are one of the most prevailing and efficient instruments to enhance the performance of buildings and in the last decade, a plethora of assessment standards have been published or are under development around the world (Amos and Chan, 2016). Some of the green building rating systems include LEED (US), BREEAM (UK), CASBEE (Japan), GS (Australia), BEAM PLUS (Hong Kong), GM (Singapore), DGNB (Germany), GBL (China) and SB Tool are multinational organizations established for different types of residential buildings (that is, detached houses and apartments), schools, hospitals, office buildings, and industrial buildings among others (Alyami and Rezgui, 2012; Zuo and Zhao, 2014 Gou and Xie, 2017). The BREEAM standard, launched in 1990, is recognized as the world's first residential building rating assessment, followed by the pilot version of the LEED standard in 1998 (Doan et al, 2017). Mattoni et al. (2018) compared 5 well-known standards of LEED, BREEAM, Green Star, CASBEE and ITACA, the result of which reveal that, except for the CASBEE standard, in which comfort and safety are given the highest importance, the highest ratings in other standards are attributed to energy consumption. Moreover, Cordero et al. (2019) examined the application of different standards among EU countries and reported that 65% of EU housing projects employ the UK BREEAM standard, 6.49% are based on the German DGNB standard, 5.46% are based on the LEED standard, and the rest have employed other standards.

Unfortunately, unlike many developed countries, Iran is yet to develop a green standard, and given that the green standard of each country is developed tailored to the conditions and regulations of that country, employing green standards of other countries is not recommended for Iran, and each country should develop green building standards according to the laws, instructions and climatic conditions, and only after identifying the existing opportunities and threat therein. Hence, based on the aforementioned discussion, the purpose of the current study was to provide an overview on the opportunities and obstacles of implementing green buildings in Iran based on different viewpoints from employers, consultants and contractors, discusses the need to implement green buildings owing to excessive consumption of fossil fuels and the high potential of using renewable energy, provide a localized green standard model tailored to the conditions of the Iran using 6 widely used standards of LEED, BREEAM, CASBEE, GS, BEAM PLUS and ASGB, and ultimately, seeks to predict total score and rank the relevant items. Findings of this study can contribute to knowledge of green building localization in Iran and can have implications for contractors, investors and decision makers in the construction and energy sector with the aim of paving the way for development of green buildings. It can also pose as a useful reference for international organizations seeking to develop solutions to alleviates obstacles to and increase the potential of green buildings.

2. Research method

For the purposes of this study, 14 experts with postgraduate education in the fields of civil engineering, architecture, electricity and mechanics who had the criteria of knowledge and experience, sufficient opportunities and effective communication skills in the field of research formed the Delphi research panel. In the first part of the research, 8 obstacles and 5 opportunities/necessities of implementing green building in Iran were identified by the panel, and in the second part, 6 widely used green standards in the world, namely LEED, BREEAM, CASBEE, GS, ASGB and BEAM PLUS, which had partial similarities with the conditions in Iran, were examined to help identify national items for green building. After reviewing the items within the 6 standards, experts were able to comment, and hence delete, edit or add new items appropriate to the conditions of Iran, and ultimately, 67 green standard parameters were identified in accordance with the conditions of Iran in 5 dimensions of the site, water, energy, materials and the quality of the indoor environment.

2.1. Questionnaire

A 3-part questionnaire with the issues of localized green standard items, obstacles and opportunities/necessities of implementing green building in Iran was developed and the respondents were asked to give their opinions and score the items using a 5-level Likert scale, ranging from zero (insignificant) to 4 (with high importance). The questionnaires were proven to have proper validity and reliability and Cronbach's alpha coefficient for national green standard items was 0.715, for green building obstacles was 0.772, and for opportunities/necessities of implementing green building was 0.778. In this study, 110 questionnaires were distributed among the statistical population of contractors, employers and consultants, from which 81 questionnaires were completed and returned. The characteristics of the respondents are presented in Table 1. The inclusion criteria were having an education level of bachelor's degree to PhD in the fields of civil engineering, mechanics, electricity and architecture, working experience in the field of construction and high familiarity with construction industry projects. descriptive statistical method (central tendency and dispersion) was employed to rank the items of the inventory for obstacles and opportunities of implementing green building, while Friedman test in SPSS was used to rank items of green building standard.

Table 1: Background information of the respondents

Characteristics	Frequency	Percent	Years of Experience						
			construction industry				green buildings		
			1-5	6-10	10-20	More than 20	1-2	3-5	More than 5
Field of education									
Civil	39	48.2	2	9	18	10	23	11	5
mechanical	23	28.4	2	5	11	5	12	6	5
electrical	12	14.8	2	2	5	3	8	3	1
Architectural	7	8.6	3	1	3	0	4	3	0
Subtotal	**81**	**100**	**9**	**17**	**37**	**18**	**47**	**23**	**11**
Job Type									
Employer	26	32.1	6	5	10	5	15	7	4
Consultant	17	20.9	2	3	8	4	8	5	4
Contractor	38	47	1	9	19	9	24	11	3
Subtotal	**81**	**100**	**9**	**17**	**37**	**18**	**47**	**23**	**11**

2.2. Machine Learning

Machine learning (ML) is a type of artificial intelligence (AI) which seeks to develop applications that can learn and progress without being explicitly programmed to do so. Machine learning is in fact consisted of various algorithms and statistical models used by computer systems instead of explicit instructions (Everitt and Hothorn, 2011). One of the most important branches of machine learning is multivariate analysis methods, in which several variables in the data set are reviewed and analyzed simultaneously. Two highly groundbreaking methods among multivariate analysis methods are exploratory factor analysis (EFA) and principal component analysis (PCA). In this research, PCA method and R software were used to predict or estimate the green building score.

3. Results

3.1. Obstacles to the implementation of green buildings

Eight major obstacles to the implementation of green buildings in Iran were identified by the expert panel and thus evaluated by the respondents using a 5-point Likert scale, the results of which are shown separately for employers, consultants and contractors in Table 2.

Table 2: Ranking the obstacles to the implementation of green buildings

Items	Overall			Employer			Consultant			Contractor		
	M.	SD	R.	M.	SD	R.	M.	SD	R.	M.	SD	R.
Lack of awareness	3.1	.889	1	3.23	0.815	1	2.94	0.966	2	3.08	0.912	1
High investment risk	2.89	1.024	2	3.04	0.999	2	3.12	0.693	1	2.68	1.141	3
Lack of economic justification	2,74	.946	3	2.38	0.941	3	2.94	0,899	3	2.89	0.924	2
Lack of national green standard	2.4	1.08	4	2.15	1.19	4	2.59	0.939	5	2.47	1.059	5
Lack of government support	2.38	1.056	5	2.04	1.183	6	2.65	0.931	4	2.5	0.98	4
Lack of skilled labor	2.25	.929	6	2.11	0.952	5	2.29	0.849	8	2.32	0.962	8
High initial cost	2.22	1.084	7	1.92	1.129	7	2.41	0.939	6	2.34	1.097	7
Lack of technology or services	2.2	1.123	8	1.81	1.2	8	2.41	0.939	7	2.37	1.1	6
Average	2.52	-	-	2.34	-	-	2.67	-	-	2.58	-	-

Note: M.= mean; R.= rank; SD= standard deviation; Cronbach's Alpha=0.772

As can be seen from Table 2 and Figure 1, the item with the highest rank according to the respondents was the lack of awareness with a mean 3.1, which is consistent with the findings of many different studies in the world (Darko and Chan, 2017; Esa et al, 2011, Li et al, 2014). Items with the second and third highest ranks according to the respondents were respectively high investment risk and lack of economic justification with respective means of 2.89 and 2.74. The opinion of respondents from the 3 job groups (namely employer, consultant and contractor) slightly diverges in ranking the evaluation indicators. All items on obstacles to green building have relatively high scores with a minimum of 2.2, indicating that the implementation of green buildings in Iran is met with serious challenges and obstacles.

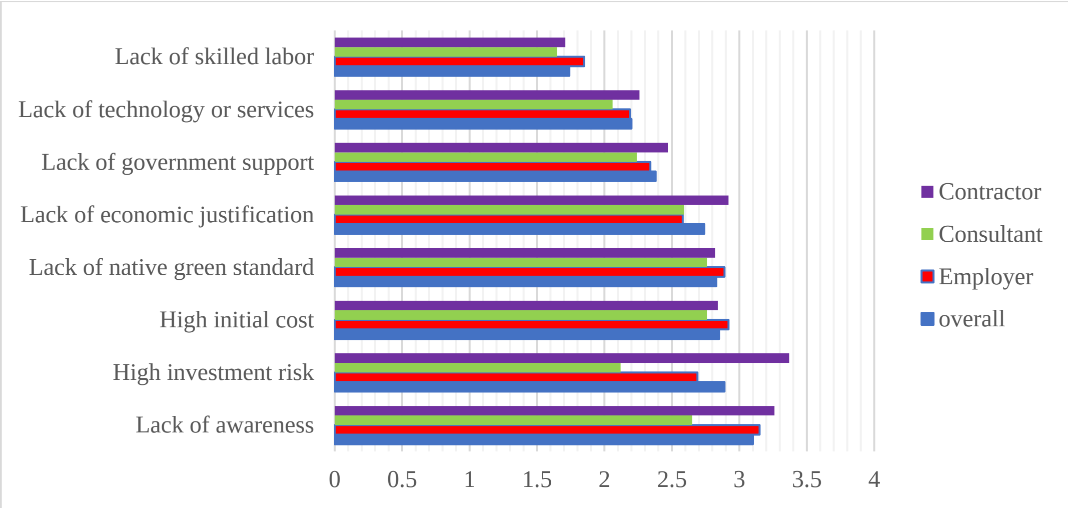

Figure 1: Obstacles to the implementation of green buildings in Iran

3.2. Opportunities or necessities of implementing green buildings in Iran

Respondents were asked about various indices for assessing the opportunities or necessities of implementing green building in Iran, the results of which are shown in Table 3.

Table 3: Ranking opportunities or necessities of green building implementation

Items	Overall			Employer			Consultant			Contractor		
	M.	SD	R.	M.	SD	R.	M.	SD	R.	M.	SD	R.
Renewable energy potential	3.25	0.874	1	3.08	1.055	2	3.35	0.786	1	3.32	0.775	1
High consumption of fossil fuels	3.15	0.95	2	3.12	0.993	1	3.24	0.903	2	3.13	0.963	4
Cheap manpower	3.07	0.946	3	2.92	0.935	3	3.06	1.144	4	3.18	0.865	3
High production of construction waste	3.07	1.093	4	2.85	1.287	4	3.12	1.111	3	3.21	0.935	2
Low annual rainfall	2.88	1.279	5	2.65	1.355	5	3.06	1.088	5	2.95	1.314	5
Average	3.08	-	-	2.92	-	-	3.17	-	-	3.16	-	-

Note: M.= mean; R.= rank; SD= standard deviation; Cronbach's Alpha=0.778

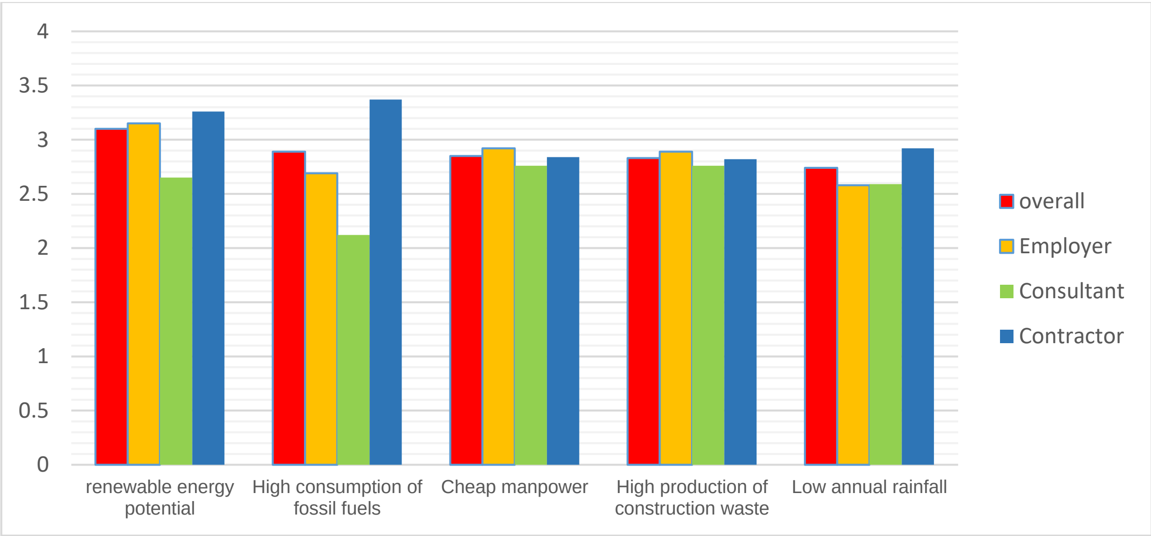

Figure 2: Opportunities or necessities of implementing green buildings in Iran

Based on the results obtained from Table 3 and Figure 2, the potential of renewable energy production in Iran was ranked first with a score of 3.25, followed by the the high consumption of fossil fuels, which was ranked second with a score of 3.15 among other factors. The average score obtained is significant and equal to 3.08, except for one item, the score of other items is higher or approximately equal to the average of the results. Based on the obtained results, evaluation indicators in all 3 occupational groups are of paramount significance, and hence a brief description is provided for each item.

3.2.1. Renewable energies

Iran offers highly favorable conditions for the production of renewable solar and wind energy, as about 60% of the land is desert which can receive maximum solar radiation. There are areas in Iran where sunny hours are significant, that is, 1050 hours in summer, 700 hours in spring, 830 hours in autumn and 500 hours in winter. Also, the presence of various tropical wind currents results in an abundance of windy areas and fortunately Iran's wind sites have attained the highest-ranking classes by the US Department of Energy (Ghorashi and Rahimi, 2011). Although the production of renewable energy and especially solar energy in Iran has increased in size in recent years, that is, more than 8 times from 2016 to 2019, this amount of energy in 2019 still stands at a very small value of about 367 MW, accounting for only 2% of the total energy produced in Iran (IRENA, 2019).

3.2.2. High consumption of energy and fossil fuels

Iran is one of the top ten producers of carbon dioxide in the world, while it has the most natural gas reserves and the fourth most oil reserves in the world (Mousavi et al, 2017). Energy consumption in Iran is increasing rapidly and most of the energy production is supplied by fossil fuels, to the extent that in 2018, about 96% of energy in Iran is supplied from non-renewable sources such as oil and natural gas (IEA, 2018). Energy consumption in Iran is 15 times that of Japan, 10 times that of the European Union and 2.5 times that of other countries of Middle East, and with a growth rate of 3.2%, the construction industry has one highest annual energy growth, only second to the manufacturing industry (EIA, 2018). The implementation of green buildings can provide a significant reduction in fossil fuel consumption and hence carbon dioxide emissions.

3.2.3. Cheap manpower

Manpower is one of the most significant issues in the economic development of any country and the optimal use of physical capital heavily relies on the human resources of that country (Sameei, 2012). Due to the high initial cost of green buildings (Chen et al, 2011; Hwang and Tan, 2012), the cheap manpower of the country offers a good potential for the implementation of green buildings. High unemployment, high youth population, and abundance of foreign immigrants, who work mainly as construction workers, have led to reduced construction wages.

3.2.4. High production of construction waste

Production of construction waste has rapidly increased in many countries with the increased trend of urbanization, and has thus been acknowledged as one of the most serious environmental challenges (Ding et al, 2018). The construction industry in Iran is considered as one of the largest waste production industries of the country (Eghbali et al, 2019), to the extent that only in Tehran from 2013 to 2014, about 23 million tons of construction waste was produced, a small part of which was recycled and the rest to were transferred to landfills (Nikmehr et al, 2015). Implementation of green buildings can lead to the use of renewable materials, recycling of construction waste and reducing the consumption of natural materials, all of which can contribute to the reduction of carbon dioxide emissions and hence environmental pollution.

3.2.5. Low mean annual rainfall

Iran is located in one of the semi-arid regions of the world which has low rainfall as well as unequal distribution of rainfall in different regions (Khozeymehnezhad and Tahroudi, 2019). Intermittent droughts in recent years have led to serious challenges for drinking water supply in some cities, and green buildings can provide ground optimal use of water, rainwater recycling and gray water treatment.

3.3. Ranking of different items of green standard

For the localized green standard in Iran, 67 indicators were identified in a total of 5 dimensions, namely site, water, energy, materials and quality of indoor environment. After obtaining the results from the questionnaires, each dimension was ranked based on Friedman ranking test (Soleymani and Nik Nafs, 2017), the results of which is presented in Table 4.

Table 4: Suggested list of green standard parameters in Iran

code	F.	R.	Activity description
Site			
S2	12.24	1	At least 10 different services such as bank, store, school, university, etc should be provided within a maximum distance of 500 meters from the site
S13	10.48	15	The project is located in areas where residents can walk inside or outside the project
S10	10.13	13	The building is designed in accordance with the rules and preserves the historical landscape of the area
S3	10.04	16	At least 2 different recreational or sports facilities are provided within the site for the use of residents
S5	9.79	14	Provide places for parking bicycles and electric motorcycles
S11	9.67	2	Design green space on the roof that covers at least 50% of the roof area
S9	9	3	Build the building in areas that do not need to occupy new land
S7	8.9	4	The building is designed according to local laws for the physically disabled
S6	8.64	5	In the parking lot, there are places for parking cars for the disabled
S15	8.29	6	Build the building in areas where the risk of flooding is low and there is a possibility of rapid discharge of runoff (mandatory)

S1	7.77	7	The maximum distance of the building from one of the public transport networks is 500 meters
S8	7.1	8	Avoid selecting sites in agricultural areas or areas endangered by animal and plant species
S14	6.81	9	Landscaping and planting of suitable plants in the site has been done
S4	5.85	11	In the house there is a work room with convenient services such as internet, printer, desk, chair, etc.
S12	5.72	10	Protect the ecological features of the land and prevent the destruction of existing trees during construction
S16	5.63	12	In order to reduce the volume of runoff, various plans have been taken to direct or absorb surface water
Water			
W1	7.56	1	Drinking water consumption should be managed so that the average water consumption in a one-year period is at least 25% less than the normal consumption of the city or region under study
W5	6.78	2	There is the necessary equipment to collect and recycle rainwater in the project
W9	6.51	6	Use leak detection systems that are able to detect major water leaks
W7	6.46	3	At least 50% of wastewater is treated and used for non-drinking purposes
W3	6.19	4	All faucets are equipped with water saving facilities
W10	5.99	5	Water consumption monitors have been installed for bathrooms, kitchens, and toilets
W2	5.01	7	In the building, sanitary components and drinking needs are separated from non-drinking needs
W4	4.07	8	Installation of efficient valves and devices in water that have a grade A or B efficiency label design
W6	3.98	9	The quality of drinking water in the building is good and has the necessary standards
W8	2.44	10	Drip irrigation has been used to irrigate the yard and green space
Energy			
E1	7.81	1	The location of the building, the dimensions of the windows, the thermal insulation and in general the energy design of the building should be done in such a way that the estimated energy consumption of the building using simulation is at least 20% lower than the energy consumption of similar non-green buildings
E6	7.31	2	Use green and renewable energy to provide at least 5% of total energy
E2	6.23	3	In order to encourage consumption reduction, the average electricity consumption of a building over a one-year period should be at least 25% less than the normal consumption of the city or area under study
E4	6.19	7	In the building, energy consumption display systems have been used in different parts of the building
E10	6.17	4	In order to encourage consumption reduction, the average gas consumption of the building in the period of one year has been studied and should be at least 25% less than the normal consumption of the city or region under study
E5	5.76	9	If the equipment is not optimally operated, alarm systems have been used to users
E9	5.21	5	The outer shell of the building, including the walls, ceiling and floor, is made of suitable thermal insulation
E8	4.65	6	Intelligent disconnection and connection system has been used in heating and cooling systems of the building
E7	3.51	8	At least 80% of energy devices and equipment must have energy consumption categories A and B.
E3	2.14	10	Insulation of cooling and heating distribution systems such as water pipes and canals has been done.
Materials			
M6	8.75	1	Use at least 50% of construction waste to the production process and reuse them in the building
M12	7.98	2	Use materials that have the least environmental impact (LCA)
M8	7.88	3	At least 5% of non-structural building materials are recycled materials
M4	7.23	4	The building is designed so that at least 30% of the building skeleton can be reused
M7	7.15	5	At least 5% of structural concrete is made from recycled materials or green items, rubber scraps, slag, etc
M5	6.77	6	At least 5% of the total cost of materials from renewable materials such as bamboo, fiber, chipboard, straw cardboard, etc. has been used
M10	6.69	7	At least 20% of the prefabricated elements of the building are produced off-site and in a separate workshop
M1	6.33	8	At least 50% of the building materials are procured at a maximum distance of 800 km
M2	6.15	9	Building materials are prepared based on modeling different parts of the building and have a valid standard
M9	5.1	10	At least 50% of the wood materials used in the building are sustainable and licensed forest products

M3	4.1	11	In the design of the building, a false roof and a duct have been used to pass the installation pipes
M11	3.88	12	Provide plans that allow the development or change of the architectural layout of the building in the futur
Indoor Quality			
I17	14.64	1	Hot and cold thermal zoning is designed and implemented for all parts of the building
I16	13.19	2	There is adequate heating equipment to achieve the desired temperature of residents in summer and winter
I8	12.35	3	Lighting control by different areas as a remote control or automatic control system
I4	12.41	4	All parts of the building have adequate daylight
I15	12.31	6	For proper ventilation, the window open space is designed for at least one-eighth of the room space
I6	11.69	7	At least 60% of the interior of the building has a direct and unmediated view to the outside
I19	11.63	5	Telephone and internet connections and access to fiber optic network are available in each room
I13	11.14	8	Natural or mechanical ventilation design is done for all residential spaces (mandatory)
I14	10.9	9	Selected from the air conditioning system to reduce the vertical distribution of temperature and air velocity in the room
I2	10.48	10	The building is equipped with carbon dioxide warning devices inside the building
I11	10.32	11	Suitable materials have been used to create sound and heat insulation in the walls and floors
I3	10.23	12	The building is located away from noise-sensitive areas and is at least 800 meters away
I10	9.48	13	Air inlets are located away from pollution sources and away from sewage outlets
I18	8.67	14	Appropriate security measures such as installing CCTV cameras are designed for the building
I12	6.86	15	All areas of the building are equipped with fire alarm and extinguishing system (mandatory)
I9	6.75	17	Intelligent or sensor lighting has been used for the common areas of the building
I1	6.62	16	Interior paints, adhesives and sealants comply with the standard for volatile organic compounds
I7	6.03	18	Facade lighting from the top to the bottom of the building is minimized and all external lighting (except safety and security lighting) is automatically turned off between 11pm and 7am
I5	4.33	19	Sunlight is controlled by conventional curtains or in the advanced type by automatic curtains

Note: F.= Friedman test; R.= rank; Cronbach's Alpha=0.715

Based on the results from the Friedman test for each dimension, facility access items (S2) for the site dimension, water consumption management (W1) for the water dimension, energy consumption management (E1) for the energy dimension, construction waste recycling (M6) for the material dimension and thermal zoning (I17) for the indoor quality dimension have obtained the highest scores in their respective dimensions. In the second stage, in order, Friedman test was re-formed based on a total of 67 evaluation indicators to identify and assess the significance of each item in the whole green standard, the results of which determined that the parameters of energy management (E1) with a score of 53.48, renewable energy (E6) with a score of 50.72, thermal zoning (M6) with a score of 48.44 and the proximity of the building to the service centers with a score of 48.25 have achieved the highest overall scores among all the parameters of the local green standard. The results for the top 10 parameters are shown in Figure 3.

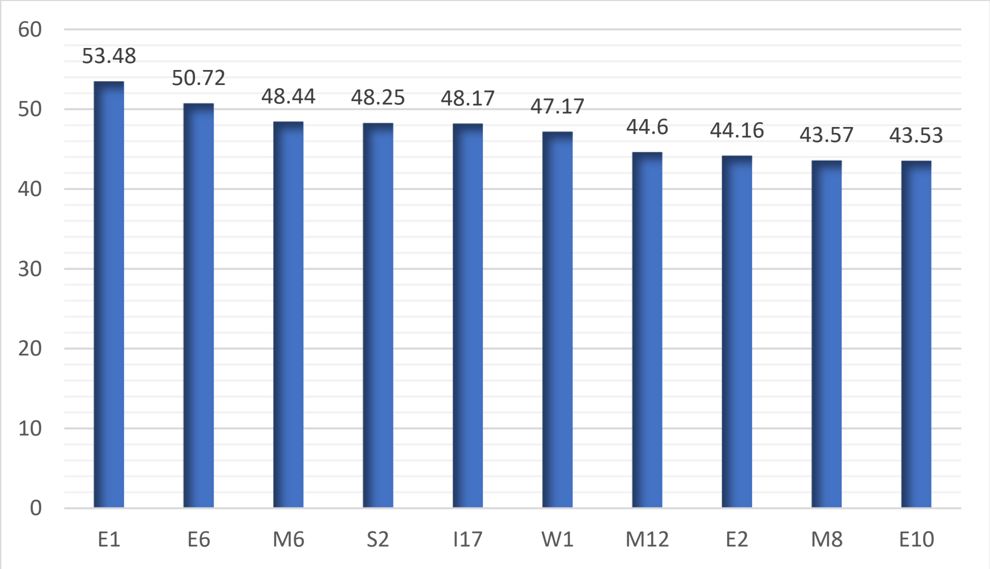

Figure 3: The most important items of national green standard in Iran

4. Numerical results

4.1. Principal Component Analysis

The principal component method is an orthogonal linear transform that transfers data to a new coordinate system, such that the greatest variance of the data is formed on the first coordinate axis and the second variance of the data on the second coordinate axis. Correlation of variables is the prerequisite to this method which has been met in this study, and the numbers in Figure 4 indicate the amount and type of correlation, while plotted histograms illustrates how the variables are distributed. The highest correlation value pertains to the two variables of energy and site with 0.47, followed by energy and indoor quality with 0.45

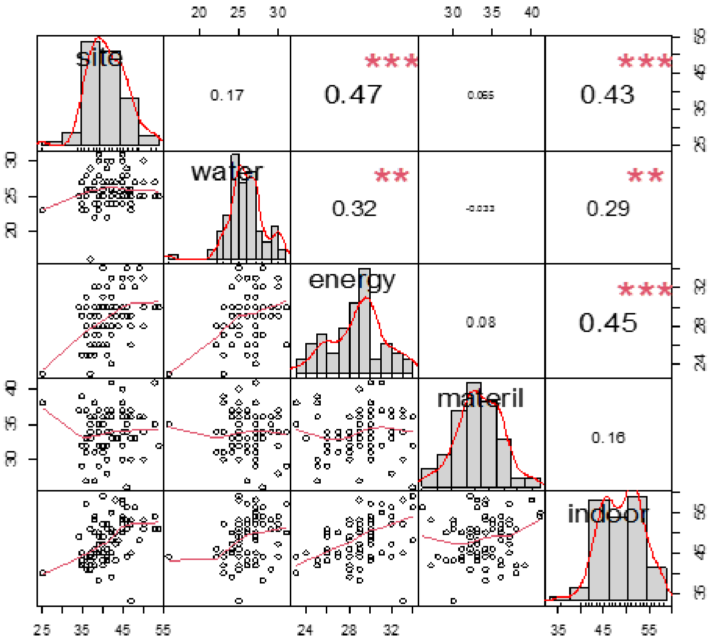

Figure 4: Histogram charts and distribution of variables in 5 standard green chapters

Due to the existence of a latent variable, that is, the projected green building score, only the first component (PC1), which has the highest amount of variance and variability, has been used in the calculations, the equation of which is as follows:

$$pc1 = a_1 Site + a_2 Water + a_3 Energy + a_4 Material + a_5 Indoor\ Quality \quad (1)$$

$$\boldsymbol{a} = (a_1.a_2.a_3.a_4.a_5)^T. \quad s.t. \quad \boldsymbol{a}^T\boldsymbol{a} = 1 \quad (2)$$

Where a_j $(j = 1. \dots .5)$ are the coefficients of each dimension of green standard, and based on the first component, the standard deviation is 1.4535 and the variance ratio is 0.42. In other words, about 42% of the total changes can be explained by the first component. To calculate the values of a_j, first the data correlation matrix is formed and then the eigenvalues, eigenvectors and finally a_i are calculated using R software. The highest and lowest significance coefficients respectively pertain to the energy and materials dimensions, the supplementary results of which are shown in Figure 5.

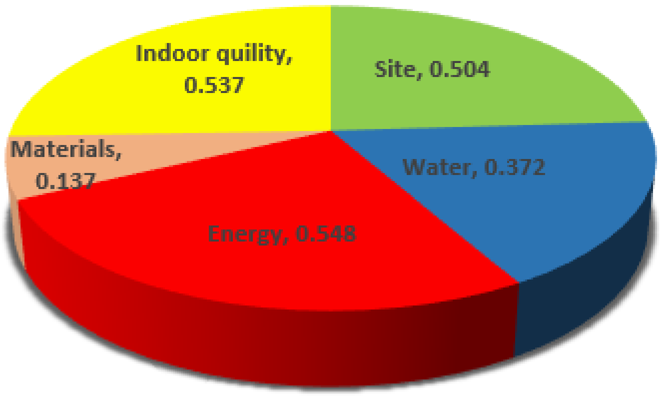

Figure 5: Significance coefficients of 5 Green Standard dimensions

4.2. Biplot graph

Biplot is another tool to examine the significance of each green standard dimension. The numbers on the graph indicate the number of the person responding to the questionnaire, in which the horizontal axis represents the first component (PC1) and the vertical axis represents the second component (PC2). Owing to the existence of only one dummy variable, the first component is the focal point of the study, and variables that are parallel to the first component are hence considered more important. According to Figure 6, the energy dimension has the highest importance, followed by the dimensions of quality of indoor environment, site, water and finally, the least importance dimension, materials.

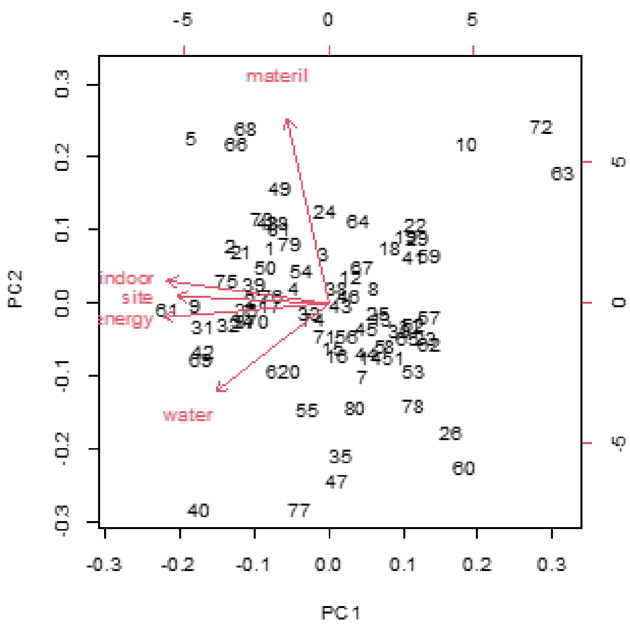

Figure 6: Significance of each of the standard green seasons based on the Biplot graph

4.3. Predict the national green building score

After estimating the $a_j s$, it is necessary to calculate the scores of the first component, which the general equation is as follows:

$$\widehat{pc1} = \boldsymbol{\Lambda}^{-1} A^T \boldsymbol{x}_i \quad (3)$$

Where $\boldsymbol{\Lambda}$ is a matrix with diagonal elements of eigenvalues, A^T is the transposition of the matrix A, $\boldsymbol{\Lambda}^{-1}$ is the inverse of $\boldsymbol{\Lambda}$ and $\widehat{pc1}$ is the projected score of the first component per $\boldsymbol{x}_i$.

Given the existence of a principal component $\mathbf{A}_5 = \boldsymbol{a}$ and also we have:

$$\boldsymbol{x_i} = ((site)_{\boldsymbol{i}}.(water)_i.(energy)_i.(material)_i.(Indoor\ Quality)_i)^T.\ i = 1.\dots.81 \quad (4)$$

To predict the green building score, there are many options for central criteria and scatter, such as median, mode, variance, standard deviation, minimum, etc., but given that the central indicators are numbers that are usually located around the center of many curves, so the most appropriate The option for this is to use the mean (or expected value) of the central index, which is used in this study according to the following formula:

$$\overline{\widehat{pc1}} = \boldsymbol{\Lambda}^{-1} \boldsymbol{\Lambda}^T \overline{\boldsymbol{x}} \quad (5)$$

$\overline{\boldsymbol{x}}$ is calculated using Equation 6, in which $\overline{site}$ is the average for the site variable, $\overline{water}$ is the average for the water variable, $\overline{energy}$ is the average of the energy variable, $\overline{material}$ is the average for the material variable and $\overline{Indoor\ Quality}$ is the average of the indoor quality variable.

$$\overline{\boldsymbol{x}} = \left(\overline{site}.\overline{water}.\overline{energy}.\overline{material}.\overline{Indoor\ Quality}\right)^T \quad (6)$$

Finally, $\overline{\widehat{pc1}}$ is the estimated score for the national green building standard based on the average of the variables, which is calculated to be 77.2088 using R software with an error of 0.2387.

4.4. National Green building ranking

The basis of the rating for the proposed green standard was on the US LEED standard rating pattern, such that in the local standard, a building with a green score of 30 to 38 (40 to 49%) receives a certification, 39 to 45 (50 to 59%) would result in a silver certification, green buildings with scores of 46 to 61 points (60 to 79%) are awarded the gold certificate, while those with scores of 62 to 77 (80 to 100%) are awarded the platinum certificate.

5. Conclusion

The development of green buildings has garnered a high level of global attention in recent years, mainly owing to limited resources and high energy consumption and, as such, various standards have been developed to this end. Nevertheless, Iran is yet to develop a local green standard, and despite high fossil fuel consumption within the country, green buildings are still highly neglected. The current study sough to identify the parameters of the national green standard, as well as the obstacles and opportunities for the implementation of green buildings, with the aim of contributing to the development of green buildings. The study was performed by obtaining comments through questionnaires from 81 construction industry experts, the results of which showed that items with the topics of access to public services for the site dimension, water consumption management for the water dimension, energy consumption management for the energy dimension, construction waste recycling for the materials dimension, and thermal zoning for indoor quality dimension achieved the highest scores in each dimension. Also, lack of awareness on green buildings and renewable energy potential obtained the highest scores respectively among the obstacles and opportunities for green buildings. Using the machine learning method and multivariate analysis, the total score of the local green building standard was predicted and calculated to be 77.2, on which the energy dimension had the most and the materials dimension had the least impact among the five dimensions of the local green standard. A building with a score of at least 40% is considered green in this standard, and, silver, gold and platinum certifications are handed out based on the scores obtained in different categories.

Findings of this study can contribute to knowledge of green building localization in Iran and can have implications for contractors, investors and decision makers in the construction and energy sector with the aim of paving the way for development of green buildings. It can also pose as a useful reference for international organizations seeking to develop solutions to alleviates obstacles to and increase the potential of green buildings.

Although research objectives were mostly achieved, but this study has remarkable limitations and weaknesses. First, although the size of samples was sufficient for statistical analysis, increasing the number of samples for future studies can enhance the quality of findings. Secondly, since in this article, only the parameters and scores of the national green standard have been examined, as future research avenue in Iran and other countries with similar climatic conditions, case studies of green buildings can be conducted using the proposed green standard.

Declarations

Ethics Approval: Not Applicable

Consent to Participate: Not applicable

Consent to Publish: Not applicable

Authors' Contributions: Conceptualization: [Mohamad Rajabi, Javad Majrouhi Sardroud];

Methodology: [Mohamad Rajabi, Javad Majrouhi Sardroud];

Writing -original draft preparation: [Mohamad Rajabi, Ali Kheyroddin];

Writing -review and editing: [Javad Majrouhi Sardroud];

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