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Analysis and Modeling of Green Building Rating Criteria in Iran Using the Hybrid ISM-SEM Approach

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Abstract: As a driver of national development, the construction industry has in recent decades gained substantial environmental importance due to its extent and effects on life, business, and the environment. Due to its economic, social, and environmental impacts, the construction industry has been discussed extensively in the sustainable development literature, contributing to development of Green Building Rating Systems (GBRSs) worldwide. Therefore, the effective criteria were modeled using Interpretive Structural Modeling (ISM) and categorized through the clustered them through Matrice d'Impacts Croisés-Multiplication Appliquée a un Classement (MICMAC) matrix. In addition, to check the consistency of the results, the ISM-MICMAC results were validated through Structural Equation Modeling (SEM). The results indicated that the modeling of the effective criteria for the rating of the Green Building (GB) consisted of 20 general criteria, which were classified into ten general levels. Moreover, the results of the ISM model showed that the Criterion related to the region-specific conditions had the main role to influence the rating of the green building. In addition, the obtained results were confirmed by SEM with a high level of consistency.

Keywords*: Analysis and Modeling, Green Building Rating Systems (GBRSs), Interpretative Structural Modeling (ISM), Structural Equation Modeling (SEM).*

1. Introduction

Iran requires sustainable development due to an energy consumption rate above the global average, the rapid consumption of non-renewable energy assets like oil and gas, and an architectural identity crisis. Enabling sustainable development requires the implementation of certain infrastructures [1]. There is a need for a system to evaluate and control such development. Such standards could handle urban challenges in Iran and help save fuel and non-renewable energy resources, control air pollution, and minimize construction waste [2]. Most building rating systems adopt a comprehensiveapproach to building performance or society; whereas some only consider easily accessible or evaluable aspects [3]. Rating systems help users to make decisions and encourage

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owners to cooperate. Such systems could also offer recommendations on the combination of green elements in the design and construction of buildings with flexible criteria. Numerous Green Building Rating Systems (GBRSs) have been established meanwhile the overview of the Building Research Establishment Environmental Assessment Methodology (BREEM) (1990) and the 1992 Rio Earth Summit [4,5]. Today, environmental aspects influence almost all human activities, particularly in the business and industrial sectors, and represent a focal point for citizens, governments, and even international relations. The United Nations named the 2005-2014 period as the Decade of Education for Sustainable Development [6]. This can be an environmental warning as the United Nations cautioned the international community to further enhance sustainable development [7]. The building trade is a major customer of assets and resources of waste in the world. It involves a set of socioeconomic activities that can negatively impact health through the reduction of natural resources (for construction), greenhouse gas emissions, and construction noise and waste [8,9 and 10]. Buildings in current societies protect humans from intense incidents while imposing environmental and health impacts [11]. Green architecture was an emerging discipline upon the revelation of the environmental impacts of buildings [12,13 and 14]. Green buildings (GBs) or sustainable buildings are constructed, renovated, operated, maintained, and destroyed using healthier models with more efficient resources [15]. Kannan et al. [16] reported that GBs reduce CO2 emissions, energy consumption, water consumption, and construction waste by 34%, 25%, 11%, and over 80 million tons, respectively. Liu et al. [17] argued that many green construction-associated organizations adopted greenness principles upon global greenization. The global GBs movement appeared to create a better environment and alleviate the adverse environmental impacts of humans. GB projects have higher costs than conventional buildings since GB materials are rarely offered in the market and require more expensive electronic, mechanical, and piping equipment. Organizations supporting GBs stated that the higher GB construction costs are repaid by improved environmental performance since the building value is higher, and GB occupants enjoy higher degrees of comfort [18]. Green construction influences building prices [19], reduces carbon emanations [20], saves drive for retrofitting [21], improves health and efficiency [22] and provides higher comfort for occupants [23]. Through a new approach to buildings and their surroundings, GBs seek to minimize the negative consequences of construction to protect air, water, and the earth and are associated with the optimal selection of construction materials and novel environmental practices [22]. Developers, investors, and corporations construct GBs using GBRSs and distinguish their buildings from others in a global approach [20]. Vierra [24] argued that in recent decades, governments and the associated organizations issued GBRSs to rate buildings based on green construction standards and receive original greenness certificates. Today, no GBRS guarantees that all three objectives of sustainability, environmental performance improvement, and economic improvement can be achieved at the same time. However, environmental impacts should be lowered by 80% by 2050. Global reports suggest that built-up buildings account for nearly 40% of global energy ingesting. The design, building,

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utilization, and reconstruction of buildings are essential for reducing energy consumption. These challenges in the energy literature require new and effective technologies, new standards, and reconsideration of building requirements. Such a comprehensive perspective of energy saving in buildings requires high-performance and energy-saving buildings. Green regulations and standards could strongly contribute to the development of green, sustainable buildings. Developed countries with more GB experience have developed efficient criteria and standards for their climates and issued certificates for buildings based on the scores. Such certificates often evaluate all types of buildings and can be implemented in a variety of buildings, involving newly constructed and/or reconstructed buildings, commercial buildings, schools, and interior/exterior components. A review of these standards may help define effective criteria for GB development in Iran. Despite substation GB concerns in developed countries, analysis and modeling of GB rating criteria have rarely been reported. Such evaluations would be useful for GB academics and practitioners [25]. This study analyzed and modeled GB rating criteria in Iran through a hybrid Interpretive Structural Modeling and Structural Equation Modeling (ISM- SEM) approach. The contributions of this study include:

1) Identifying criteria to rate Iranian GBs through a literature review, questionnaires, and expert opinion.

2) Developing a hierarchy of contextual relationships of the criteria for GB rating in Iran using ISM and categorizing such criteria using categorized through clustered them through MICMAC analysis.

3) Validating the ISM results using SEM.

The remainder of this study is prepared as follows: Section 2 reviews the GBRS literature; Section 3 explains the research method; Section 4 provides the GB rating indices in Iran through ISM and MICMAC analyses and the certification of the proposed framework through SEM; Section 5 discusses the conclusions and recommendations and the end highlights the limitations and suggestion for further research.

2. Literature review

Historically, the Club of Rome, a Non-Governmental Organization (NGO) founded in Rome, Italy, in 1968, proposed green construction toward sustainable development. It evaluates the pressing global challenges and requests several researchers at the Massachusetts Institute of Technology to research economic and population growth. The club reported the Limits to Growth in 1972, which predicted for the first time that economic growth would not continue indefinitely due to the finite natural resources, particularly oil. The Club of Rome's Mankind at the Turning Point report published later in 1974 suggested that the international community could control many environmental and economic disasters. The Rio Earth Summit held in 1999 argued that development was destroying the environment and would endanger life on earth; i.e., the world ecosystem would no longer be able to

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regenerate the environment, and animals and biological species could not continue to live the same life [25]. The City of the Century Conference in Berlin, in 2000, expressed sustainable urban growth as "improvement of quality of life in a city, including environmental, cultural, political, institutional, organizational, and socioeconomic improvement, without tensions arising from over-reduction of natural capital and regional debts on the future generations". This aims to establish a trade-off between materials, energy, and finances for it plays a key role in future decisions on urban development. Construction is a large socioeconomic sector in Europe that, combined with the constructed space, significantly influences the natural environment. These two factors have become keys to global sustainable development. Adopting sustainability concepts to reduce energy waste and environmental pollution in architecture led to green construction. This approach emphasizes the site of a building relative to the native and global ecosystems [26]. Improving overall energy efficiency during a building's lifetime is the most important goal of green construction, and it is based on decisions that address the negative environmental and human impacts of buildings. GBRS is a model for assessing building functioning, with environmental influences, based on a set of criteria often covering energy functioning, location choice, water effectiveness, interior air quality, and material use. To develop GBs, several instruments have been designed. For this purpose, a building is scored based on base performance in each index and the total score obtained from the sub-indices [27]. Liu et al. [17] evaluated the impacts of green construction on building waste administration and green building ratings. They argued that buildings significantly impact human life and that construction is not only a business but also an environmental challenge. The impacts of green construction on waste management were examined using semi-structured interviews and a hybrid approach. The results showed that green construction could not reduce construction waste management, which was attributed to the design of GBRSs and a lack of incentive to improve waste management. Varma and Palaniappan [24] compared GBRSs in North America, Europe, and Asia, arguing that GBRSs are a practical instrument for sustainable growth in the building trade. Green building rating meets user demands, preserves natural resources, and reduces environmental degradation. They comprehensively compared ten GBRSs in North America, Europe, and Asia and evaluated sustainable development goals, selecting two Indian green building schemes. Zhang et al. [27] evaluated renewable energy in GBRSs and reported that green buildings could help address environmental degradation, economy, and society. There have been numerous GBRSs developed worldwide for evaluating buildings and issuing green building certificates. Renewable energy is essential for achieving green buildings by reducing fossil fuel consumption and GHG emissions. However, they have a major difference in renewable energy evaluation in GBRSs. There was a deep review of renewable energy evaluation approaches in GBRSs to help investors, users, and policymakers better understand GBRSs and take steps toward developing GBS. Berawi et al. [9] reviewed stakeholder views on GB rating in Indonesia and demonstrated that the Indonesian government and Council of Green Buildings should evaluate GBs to adopt GB and encourage

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practitioners to receive green permissions. Freitas et al. [12] reviewed GBRSs in the Swedish market and reported a comparative analysis of four GBRSs. The GBRSs were evaluated in different aspects, including the certification process, construction cost, educational requirements, and classification/rating practices. They used the SWOT matrix to identify strengths, weaknesses, opportunities, and threats.

3. Methodology

The main objective of the current study was to examine and formulate the key factors for evaluating green buildings in Iran. To achieve this objective, a mix of quantitative and qualitative techniques was utilized to strengthen the justification and validation of the data. The quantitative method involved gathering data through surveys, whereas the qualitative method involved conducting formal interviews with industry experts. Subsequently, the effective criteria for ranking green buildings in Iran were modeled using ISM, MICMAC, and SEM methodologies. The research approach used in the current paper was divided into four stages, detailed in Fig. 1. The initial phase involved conducting a wide review of the literature to identify green building rating criteria in the Iranian construction industry. According to the findings, 20 criteria that adopt the implementation development of green building rating criteria in the construction industry in Iran have been extracted. To validate the selected criteria (validity and reliability), a questionnaire was prepared and distributed among active construction companies in the Tehran metropolitan area. The companies were qualified by the Management and Planning Organization. The total number of active construction companies in Tehran is 214. Due to the impracticality of accessing the entire population, the Cochran formula was employed to determine the example size, finding an example size of 137 members. The questionnaires were distributed among 137 members both in person and non-face-to-face, with 30 experts providing complete responses in the pilot study. Of the respondents, 53% had work experience ranging from 5 to 10 years, while 47% had experience ranging from 10 to 20 years. Approximately half of the professionals held degrees in architecture or urban planning, 27% were civil engineers, and 23% were other types of engineers. Approximately 45% of the respondents held a master's degree, while 32% held a bachelor's degree, and 23% held a doctoral or postdoctoral degree. To ensure the validity of the questionnaires, face validity was employed by presenting the designed questionnaire to experts, and its validity was confirmed. Subsequently, to measure the dependability of the questionnaire, Cronbach's alpha coefficient was utilized, with a generally acceptable value above 0.70. Using the data obtained from the questionnaires and the statistical software Statistical Package of Social Science (SPSS), the reliability coefficient was calculated using Cronbach's alpha method. The Cronbach alpha value for this questionnaire was 0.811, indicating that the questionnaire had acceptable and suitable reliability. The results of the examination and validation of the criteria led to the identification of twenty ranking criteria for green buildings in Iran. Subsequently, through structural-interpretive modeling and MICMAC analysis, the relationships among the criteria were graded, and the research model was illustrated and presented. Using

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Structural Equation Modeling (SEM), the proposed model was validated. As shown in graphical abstract, in the first stage, the proposed criteria for ranking green buildings in Iran were recognized qualitatively through a systematic review of research literature. A specific number of criteria were identified based on the conducted reviews, and for the sake of reliability, their decision-making validity was evaluated and finally confirmed by expert specialists. In the second phase, the implementation of structural-interpretive modeling was addressed. ISM was employed as a proficient approach to establish textual relationships between the proposed criteria for ranking green buildings in Iran. During the third phase, the MICMAC analysis categorizes the criteria into distinct groups according to their impact and interdependence. Subsequently, in the fourth stage, the SEM method was employed to verify the generated ISM model and to include hypothesis testing.

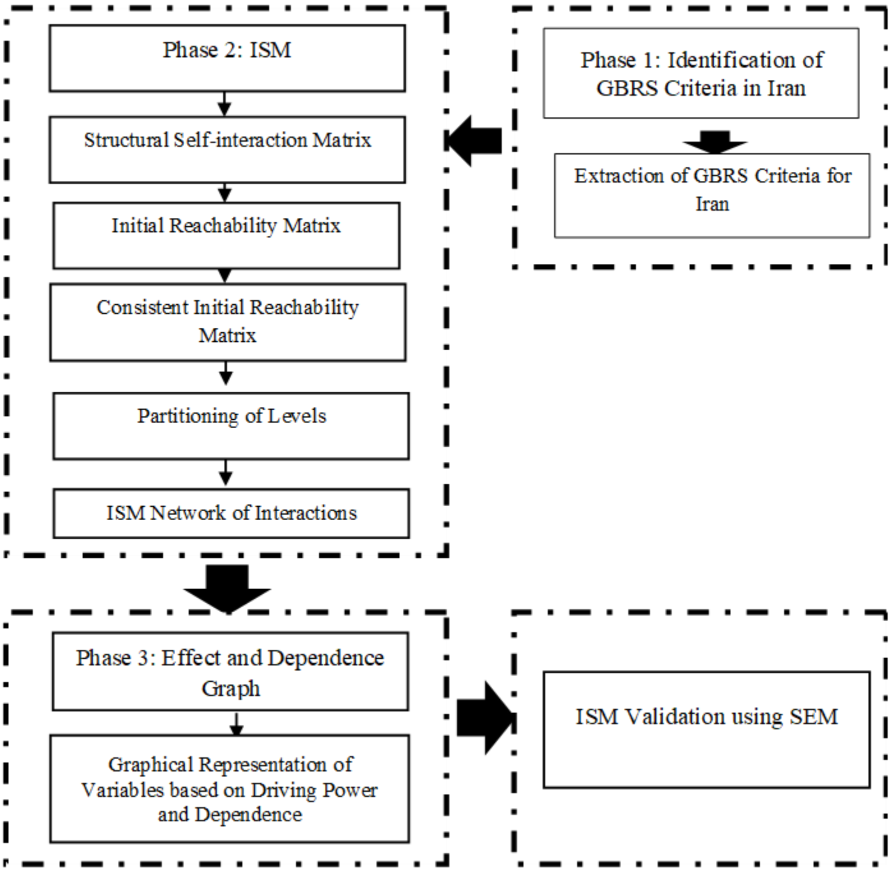

Fig. 1: Schematic of the Methodology.

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3.1. Interpretative structural modeling (ISM)

Harary et al. (1965) and Warfield (1974) mathematically developed ISM. based on graph theory. ISM establishes a hierarchical structure equations model based on complex elements. Once the structure equations model is analyzed by the relevant experts, a guided diagram is plotted to define the contextual relationships between essentials. ISM identifies and analyses relationships between specific variables and graphically and verbally describes a problem, system, or area of research described in a precise model. Following the pairwise comparison of variables, a Structural Self-Interaction Matrix (SSIM) is constructed. The SSIM transforms into a Reachability Matrix (RM) that undergoes SSIM is converted into a Reachability Matrix (RM) which is then assessed for transitivity. The introduction of transitions leads to the creation of a matrix model. The stages of ISM development, as outlined by Iqbal et al. [15] entail the following steps:

- Establishing SSIM and Reachability Matrix (RM): Once the variables have been identified, they are incorporated into the SSIM. This matrix aligns the variables along the dimensions indicated by the first row and column. The relationships between these variables are represented using symbols denoting the "leads to" conceptual relationship. Experts and specialists in the field complete this matrix by comparing the dimensions and criteria using four modes of conceptual relations. This process follows the principles of the interpretive structural modeling method, resulting in the final SSIM containing the identified dimensions and criteria. The conceptual relationships are delineated using specific modes and symbols.
    - ✓ V: row factor i causes column factor j to be understood.
    - ✓ A: The element of column j causes the element of row i to be understood.
    - ✓ X: row and column elements make each other happen (elements i and j have a dual-pathway connection).
    - ✓ O: There is no relation among row and column operator.
- Then the RM is derivative from the structural self-interaction matrix by converting it into a binary matrix consisting of zeros and ones. To generate this matrix, the X and V symbols in each row of the self-interaction matrix are replaced with one, while the A and O symbols are replaced with zero. This resulting matrix is referred to as the initial Reachability Matrix, where all main diagonal elements are set to one. The final RM is then gained by transforming the symbols of the structural self-interaction matrix into zeros and ones according to the primary Reachability submatrix.
    - ✓ If the emblem of cell ij is the communication V, the number 1 is located in that cell and the number 0 is located in the corresponding cell.

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- ✓ If the emblem of cell ij is the communication A, the number zero is located in that cell and the number 1 is located in the corresponding cell.
- ✓ If the emblem of cell ij is the communication X, the number 1 is located in that cell and the number 1 is also located in the corresponding cell.
- ✓ If the emblem of cell ij is the letter O, the number zero is located in that cell and the number zero is also located in the corresponding cell.

- RM Consistency: Ensuring the internal coherence of the initial Reachability Matrix (RM). To illustrate, if factor 1 influences factor 2 and factor 2 influences factor 3, then factor 1 should also influence factor 3 in the RM. If this relationship is not met, adjustments need to be made to the RM. This consistency criterion is incorporated into the initial RM by introducing secondary connections that may not be present originally.
- Variable Hierarchy Analysis: Assessing the variable levels involves first calculating the criteria for input (antecedent) and output (reachability) sets. Subsequently, the shared factors are identified. The criteria that exhibit identical output sets (reachability) and intersection are considered to be at the highest level. Once these variables are pinpointed, their corresponding rows and columns are removed from the matrix. This procedure is then repeated for the remaining criteria. The input and output components are derived from the coherent initial RM, where the count of 1-elements in each row signifies the output, and the count of 1-elements in each column signifies the input.
- Plotting the interaction network: An interaction network is plotted based on the levels of criteria and their relationships. The ISM interaction network is plotted using the levels of criteria. The relationship between variables i and j would be denoted by a directional arrow.
- Creation of the graph: During this phase, the graph is constructed by taking into account the transitive relationships among criteria (for instance, if factor A is linked to factor B and factor B is linked to factor C, then factor A would be directly linked to factor C as well).
- Construction of ISM model: After deriving the digraph, eliminate the transitive connections based on the relationships outlined in the reachability matrix, which is referred to as the ISM model. Within this model, the variable nodes of the digraph are replaced with statements.

3.2. MICMAC analysis

According to the effects and dependencies of variables, MICMAC analysis enables further evaluation of the range of each variable and classifies variables into linkage, autonomous, dependent, and independent [26].

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3.3. ISM validation using SEM

SEM is a method to evaluate relationships between latent variables while also considering observable variables. Latent variables are factors represented in a conceptual model. Observable variables, on the other hand, are questionnaire items that measure the main factors. This framework provides a specific causal structure between a set of latent and observable variables. Drawing on SEM, the relations between latent variables and between the items of each latent variable and the latent variable could be measured. SEM is implemented in SmartPLS to validate a model rather than construct models. The researcher designs an initial model that is then validated using SEM [25].

4. Findings

The criteria were modeled and assessed using ISM and MICMAC analysis. Furthermore, the ISM was confirmed using SEM in SmartPLS. The hybrid ISM-SEM approach is described in the following sub-sections.

4.1. Implementing ISM to model green building rating criteria

- ☐ Phase 1: Identification of indices: Drawing on a qualitative methodology, the indices were extracted from a literature review, as shown in Table 1.

Table 1: Criteria studied in the research.

Code	Index
S1	Climatic details
S2	Land use
S3	Region-specific conditions
S4	Building facade performance
S5	Ecological site development
S6	Material storage and recovery
S7	Sustainable regional development
S8	Recycled materials
S9	Quality management
S10	Building density
S11	Innovation
S12	Construction cost reduction
S13	Initial cost reduction
S14	Thermal performance of buildings
S15	Water consumption control/monitoring
S16	Operation-time cost reduction
S17	Wastewater management
S18	Waste reduction
S19	Pollution reduction
S20	Renewable materials

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- Phase 2: Establishing the SSIM and Initial RM: The SSIM was formulated by incorporating input from experts who provided responses and conducted pairwise comparisons of the criteria. It encompassed twenty dimensions and detailed the guidelines as follows: Identifying whether a row factor i influences the factor in column j (V), if a factor in column j influences a row factor i (A), if there is a bidirectional correlation between factors i and j (X), or if no relationship exists between the factors in the rows and columns (O). The data obtained from the questionnaires were consolidated, and analyzed using ISM, and the SSIM was structured. Table 2 presents the SSIM based on non-parametric methodologies. Initial RM: The initial RM should be constructed by transforming SSIM elements into 0s or 1s according to the below instructions:

  - ✓ If cell ij is V, it becomes 1; the opposite cell becomes 0.
  - ✓ If cell ij is A, it becomes 0; the opposite cell becomes 1.
  - ✓ If cell ij is X, it becomes 1; the opposite cell also becomes 1.
  - ✓ If cell ij is O, it becomes 0; the opposite cell also becomes 0.

- Phase 3: Ensuring initial RM coherence: The initial RM must exhibit internal coherence. A condition for this coherence is that if factor 1 influences factor 2, and factor 2 influences factor 3, then factor 1 should also influence factor 3; if not, adjustments to the initial RM are necessary. This coherence is achieved by incorporating secondary relationships into the initial RM, even if these relationships do not currently exist. The adaptive initial RM, illustrating the relationships that were augmented in the RM, is presented in Table 3.

- Phase 4: Partitioning of levels: The input (antecedent) and output (reachability) criterion sets are calculated. Then, the common features are fixed; the criterion for which the output (reachability) is set is the same as the intersection with the highest level. Once this variable(s) has been identified, the corresponding row(s) and column(s) are excluded from the RM, repeating the process for the other factors. The outputs and inputs are obtained from the consistent preliminary RM. Here, the number of 1-cells in each row signifies the output and the number of 1-cells in each column stands for the input. Table 4 demonstrations the levels of the factors.

- Phase 5: ISM interaction network: The ISM interaction network was plotted based on the factor levels. The relationship between variables i and j would be represented by a steering arrow. The final chart was plotted by excluding the repeated cases and using the partitioned levels, as shown in Fig. 2.

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Table 2: Structural Self-Interaction Matrix (SSIM).

	S20	S19	S18	S17	S16	S15	S14	S13	S12	S11	S10	S9	S8	S7	S6	S5	S4	S3	S2	S1
S1	V	V	V	O	V	X	V	O	V	O	V	V	V	X	X	X	V	V	x	
S2	A	O	O	O	V	O	O	V	V	O	V	V	V	X	O	V	O	V		
S3	V	V	V	V	V	V	V	V	V	V	V	V	V	O	V	V	V			
S4	A	V	O	O	O	O	V	A	O	V	O	V	V	O	O	O				
S5	V	V	V	V	V	V	O	V	V	V	O	V	V	O	O					
S6	V	V	V	V	V	V	V	V	V	V	O	V	V	O						
S7	O	O	O	O	O	O	O	O	O	O	O	O	O							
S8	A	V	V	V	V	V	V	V	V	V	O	V								
S9	X	X	X	V	V	X	V	O	O	V	A									
S10	O	X	O	O	V	A	V	O	O	V										
S11	V	V	V	V	V	V	V	V	V											
S12	A	A	A	A	V	O	O	A												
S13	A	A	A	A	X	A	A													
S14	A	O	O	O	V	O														
S15	A	O	A	X	V															
S16	A	A	A	A																
S17	A	X	O																	
S18	X	X																		
S19	X																			
S20																				

Table 3: Consistent initial RM.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	Power of

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S1	1	1	1	1	1	1	1	1	1	1	*1	1	*1	1	1	1	*1	1	1	1	20
S2	1	1	1	*1	1	*1	1	1	1	1	*1	1	1	*1	*1	1	*1	*1	*1	*1	20
S3	*1	*1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	19
S4	0	0	0	1	0	0	0	1	1	*1	1	*1	*1	1	*1	*1	*1	*1	1	*1	14
S5	1	*1	*1	*1	1	*1	*1	1	1	*1	1	1	1	*1	1	1	1	1	1	1	20
S6	1	*1	*1	*1	*1	1	*1	1	1	*1	1	1	1	1	1	1	1	1	1	1	20
S7	1	1	*1	*1	*1	*1	1	*1	*1	*1	0	*1	*1	*1	*1	*1	0	*1	*1	*1	18
S8	*1	0	0	*1	0	0	0	1	1	*1	1	1	1	1	1	1	1	1	1	*1	15
S9	*1	*1	0	*1	0	0	0	*1	1	*1	1	*1	*1	1	1	1	1	1	1	1	16
S10	0	0	0	0	0	0	0	0	1	1	1	*1	*1	1	*1	1	*1	*1	1	*1	12
S11	*1	*1	0	*1	0	0	0	*1	*1	*1	1	1	1	1	1	1	1	1	1	1	16
S12	0	0	0	0	0	0	0	0	0	0	0	1	*1	0	0	1	0	0	0	0	3
S13	0	0	0	1	0	0	0	*1	*1	0	*1	1	1	*1	0	1	0	0	*1	0	9
S14	0	0	0	*1	0	0	0	0	0	0	0	*1	1	1	0	1	0	0	0	0	5
S15	1	*1	*1	*1	*1	*1	*1	*1	1	1	*1	*1	1	*1	1	1	1	*1	*1	*1	20
S16	0	0	0	*1	0	0	0	0	0	0	0	*1	1	0	0	1	0	0	0	0	4
S17	*1	0	0	*1	0	0	0	0	*1	*1	0	1	1	0	1	1	1	*1	1	*1	12
S18	*1	*1	0	*1	0	0	0	*1	1	*1	*1	1	1	*1	1	1	*1	1	1	1	16
S19	0	*1	0	*1	0	0	0	*1	1	1	*1	1	1	*1	*1	1	1	1	1	1	15
S20	*1	1	*1	1	*1	0	*1	1	1	*1	*1	1	1	1	1	1	1	1	1	1	19

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The degree of dependence	13	12	8	18	8	7	7	15	17	16	15	20	20	17	16	20	15	16	17	16	

Table 4: Factor Levels.

Criterion	Output	Input	Subscription	Level
S1	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S1-S2-S3-S5-S6-S7-S8-S9-S11-S15-S17-S18-S20	S1-S2-S3-S5-S6-S7-S8-S9-S11-S15-S17-S18-S20	5
S2	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S1-S2-S3-S5-S6-S7-S9-S11-S15-S18-S19-S20	S1-S2-S3-S5-S6-S7-S9-S11-S15-S18-S19-S20	5
S3	S1-S2-S3-S4-S5-S6-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S1-S2-S3-S5-S6-S7-S15-S20	S1-S2-S3-S5-S6-S15-S20	5
S4	S4-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S1-S2-S3-S4-S5-S6-S7-S8-S9-S11-S13-S14-S15-S16-S17-S18-S19-S20	S4-S8-S9-S11-S13-S14-S15-S16-S17-S18-S19-S20	4
S5	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S1-S2-S3-S5-S6-S7-S15-S20	S1-S2-S3-S5-S6-S7-S15-S20	5
S6	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S1-S2-S3-S5-S6-S7-S15-	S1-S2-S3-S5-S6-S7-S15-	5
S7	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S12-S13-S14-S15-S16-S18-S19-S20	S1-S2-S5-S6-S7-S15-S20	S1-S2-S5-S6-S7-S15-S20	6
S8	S1-S4-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S1-S2-S3-S4-S5-S6-S7-S8-S9-S11-S13-S15-S18-S19-S20	S1-S4-S8-S9-S11-S13-S15-S18-S19-S20	4
S9	S1-S2-S4-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S13-S15-S17-S18-S19-S20	S1-S2-S4-S8-S9-S10-S11-S13-S15-S17-S18-S19-S20	3

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S10	S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S15-S17-S18-S19-S20	S9-S10-S11-S15-S17-S18-S19-S20	3
S11	S1-S2-S4-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S1-S2-S3-S4-S5-S6-S8-S9-S10-S11-S13-S15-S18-S19-S20	S1-S2-S4-S8-S9-S10-S11-S13-S15-S18-S19-S20	3
S12	S12-S13-S16-	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S12-S13-S16-	1
S13	S4-S8-S9-S11-S12-S13-S14-S16-S19-	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S4-S8-S9-S11-S12-S13-S14-S16-S19-	1
S14	S4-S12-S13-S14-S16-	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S13-S14-S15-S18-S19-S20	S4-S13-S14-	2
S15	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S15-S17-S18-S19-S20	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S15-S17-S18-S19-S20	3
S16	S4-S12-S13-S16-	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S4-S12-S13-S16-	1
S17	S1-S4-S9-S10-S12-S13-S15-S16-S17-S18-S19-S20	S1-S2-S3-S4-S5-S6-S8-S9-S10-S11-S15-S17-S18-S19-S20	S1-S4-S9-S10-S15-S17-S18-S19-S20	2
S18	S1-S2-S4-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S15-S17-S18-S19-S20	S1-S2-S4-S8-S9-S10-S11-S15-S17-S18-S19-S20	3
S19	S2-S4-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S13-S15-S17-S18-S19-S20	S2-S4-S8-S9-S10-S11-S13-S15-S17-S18-S19-S20	3
S20	S1-S2-S3-S4-S5-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16-S17-S18-S19-S20	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S15-S17-S18-S19-S20	S1-S2-S3-S4-S5-S7-S8-S9-S10-S11-S15-S17-S18-S19-S20	3

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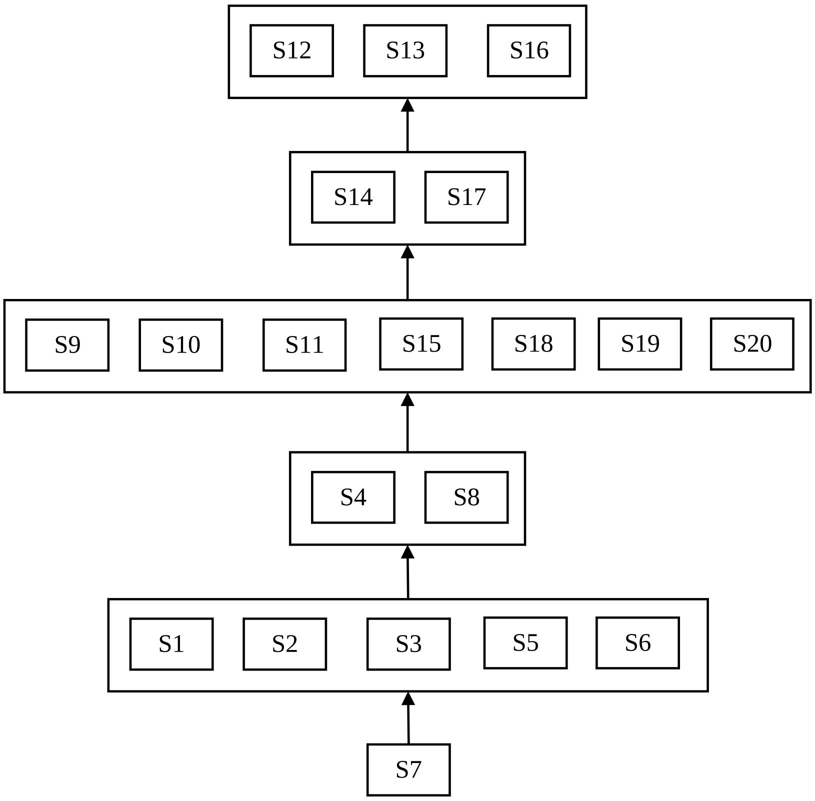

Fig. 2: Schematic of the Methodology.

According to Fig. 2, the research model includes 5 levels, and the index Sustainable regional development (S7) is at level 5 and is the most influential index. This index directly S1, S2, S3, S5, and S6. Construction cost reduction (S12), Initial cost reduction (S13), and Operation-time cost reduction (S16) are at level one, which are the most influential criteria.

4.2. Implementing MICMAC to Analysis green building rating criteria

The current study framework can be represented in terms of power of influence and dependency as depicted in Figure 3. Criteria (S6), (S5), (S3), and (S7) serve as independent variables with characteristics of low dependency and high directivity, meaning they exhibit high influence and low influence. On the other hand, criteria (S14), (S13), (S16), and (S12) function as dependent variables with notable dependency and weak directionality. Essentially, these variables hold significant effect and little effect on the system. The remaining factors act as linkages, displaying high dependency and strong guiding capabilities—where any slight modification to these variables can bring about substantial changes within the system.

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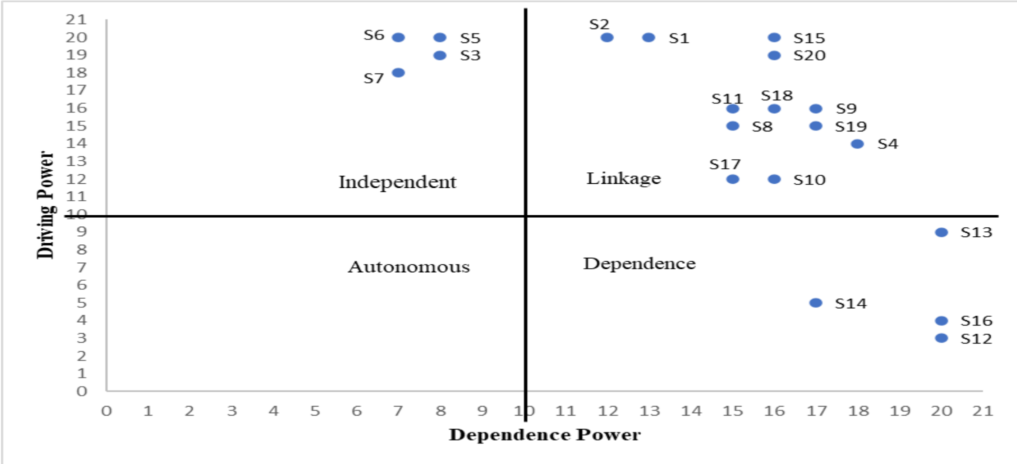

Fig. 3: Clustering of green building rating criteria in Iran.

4.3. ISM validation using SEM

After modeling the effective criteria of green building in Iran, to validate the compiled model, structural equation modeling is used in Smart-PLS software. The results related to the path coefficients are shown in Fig. 4.

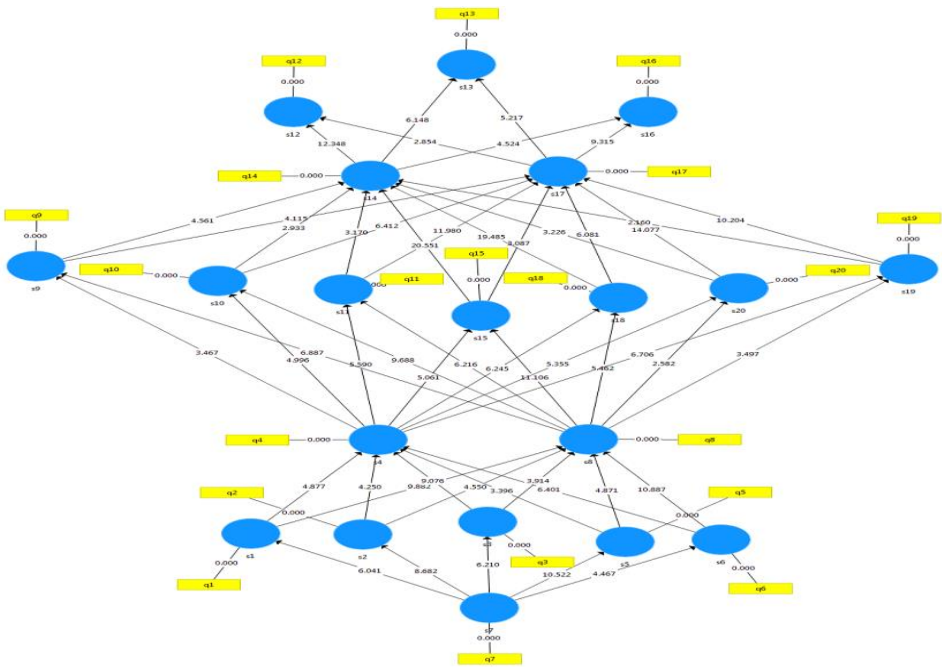

Fig. 4: Proposed Model with Standard Estimates.

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To examine the significance of these coefficients, the corresponding t value of every pathway coefficient has been used. The findings associated with the t value corresponding to the pathway importance are presented in Table 5. The finding related to the t value corresponding to the path coefficients in Table 5 shows that the T value obtained is all greater than 1.96, which can be said at the significance level of 95% that all the obtained path coefficients are significant and as a result, the research model has It has been an appropriate level of significance.

Table 5: The significant relationships of the research variables.

Variables	**T-Test**	**Standard estimation**	**Result**
S7→S1	6.041	0.330	Verification
S7→S2	8.682	0.495	Verification
S7→S3	6.210	0.373	Verification
S7→S5	10.552	0.476	Verification
S7→S6	4.476	0.270	Verification
S1→S4	4.877	0.285	Verification
S1→S8	9.882	0.466	Verification
S2→S4	4.250	0.387	Verification
S2→S8	4.550	0.393	Verification
S3→S4	9.076	0.486	Verification
S3→S8	3.914	0.275	Verification
S5→S4	3.396	0.254	Verification
S5→S8	4.871	0.361	Verification
S6→S4	6.401	0.421	Verification
S6→S8	10.887	0.550	Verification
S4→S9	3.467	0.246	Verification
S4→S10	4.996	0.285	Verification
S4→S11	5.590	0.300	Verification

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S4→S15	5.061	0.288	Verification
S4→S18	6.245	0.367	Verification
S4→S19	6.706	0.389	Verification
S4→S20	5.355	0.348	Verification
S8→S9	6.887	0.441	Verification
S8→S10	9.688	0.462	Verification
S8→S11	6.216	0.343	Verification
S8→S15	11.106	0.530	Verification
S8→S18	5.462	0.323	Verification
S8→S19	3.497	0.185	Verification
S8→S20	2.582	0.150	Verification
S9→S14	4.561	0.200	Verification
S9→S17	4.115	0.247	Verification
S10→S14	2.933	0.171	Verification
S10→S17	6.412	0.338	Verification
S11→S14	3.170	0.204	Verification
S11→S17	11.980	0.497	Verification
S15→S14	20.551	0.865	Verification
S15→S17	3.087	0.246	Verification
S18→S14	19.485	0.829	Verification
S18→S17	6.081	0.455	Verification
S19→S14	2.160	0.122	Verification
S19→S17	10.204	0.536	Verification
S20→S14	3.226	0.252	Verification
S20→S17	14.077	0.713	Verification
S14→S12	12.348	0.537	Verification
S14→S13	6.148	0.450	Verification

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S14→S16	4.524	0.234	Verification
S17→S12	2.854	0.166	Verification
S17→S13	5.217	0.286	Verification
S17→S12	9.315	0.548	Verification

4.4. Fitness of SEM

The path coefficients are the main measure of fitness for structural models. Fig. 4 displays the pathway coefficients of the proposed model. It should be noted that an absolute t-value greater than 1.96 stands for a significant correlation. The measurement and structural models form the SEM. To evaluate the fitness of the SEM, goodness of fit (GOD) was employed as:

$$R^2_{Average} = 0.275 \quad (1)$$

$$AVE_{Average} = 1.000 \quad (2)$$

$$R^2_{Average} x \; AVE_{Average} = 0.275 \quad (3)$$

$$\text{GOF} = \sqrt[2]{R^2_{Average} \text{x} \; AVE_{Average}} \approx 0.52440 \quad (4)$$

GOF values of 0.01, 0.25, and 0.36 respectively represent the weak, medium, and strong fitness of the model. As shown, the proposed SEM was found to have very strong GOF. Finally, the fitness of the measurement model, structural model, and SEM was verified.

5. Conclusion

Considering the successful implementations of GBs across the world, it is important to develop and deploy GBs in Iran. Universities are the primary drivers of the GB movement, and governments are essential to supporting GB development. The criteria and challenges of GB development were identified, proposing several recommendations. Universities and knowledge enterprises are crucial to the production and localization of knowledge and technology, and Iran's scientific capital should be exploited to handle environmental challenges. The government is among the most powerful organizations in Iran and can provide incentives and support by, for example, reducing license issuance fees, tax exemption, permission, traffic access to green buildings, green neighborhood facilities such as pedestrian or biking facilities, cooperation with the banking system in offering no-interest or low-interest loans, comprehensive support for recycling factories, cooperation with the Iran Constriction Engineering Organization to decrease design, monitoring, and construction costs, and lowering the energy prices of GBs. Environmental activists and non-governmental organizations (NGOs) are expected to use the experience of developed countries and implement advertisements to increase public awareness of the advantages of GBs, including occupant

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health, reduced pollution, return on investment, and energy saving, in green construction development. This study reviewed the literature and identified GBRS criteria based on expert views. Then, ISM was adopted to measure the relationships between the GBRS criteria. Table 1 provides the GBRS criteria in the well-known international standards selected to develop an Iranian GBRS. Then, the ISM was validated using SEM. The findings can be brief as follows:

1) The ISM indicated that "region-specific conditions" are the fundamental criterion for GB rating in Iran; "climatic details" and "land use" were the second-most important criteria. Finally, "construction cost reduction," "initial cost reduction," and "operation-time cost reduction" were the lowest level of the model and had the highest dependence.

2) The driving power-dependence diagram showed no autonomous criteria. It can be said that all the criteria were important and there were close correlations between these factors. It was found that S3, S5, S6, ans S7 were driver variables with low dependence and high driving power. S12, S13, S14, and S16 were dependent factors with strong dependence and weak driving power. These factors have high dependence and low effects on the system. The remaining criteria were linkages and had high dependence and high driving power; a small change in such criteria substantially changed the system.

3) The ISM was validated using SEM. This can be claimed to be the most important contribution of the present work. ISM is statistically criticized, and a hybrid ISM-SEM was employed for the first time to cope with the challenges of ISM and SEM. The fitting of ISM verified the effects of the first level (i.e., region-specific conditions) on all the factors at the second level and validated the ISM. In general, it can be said that the ISM was verified by SEM.

4) This study provided insights into GBRS criteria in Iran and was an effective step toward enhancing GBRS knowledge. However, it encountered limitations. The basic limitation of current paper is its investigative nature, which potentially exacerbates the biased judgment of experts. Future studies can implement the proposed ISM using another network analysis process and validate the model using SEM.

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