Exploring the Interrelationship Between the Current and Future Sustainable Building Design Factors: UAE Perspective

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Abstract

Sustainability plays an important role in protecting the surrounding environment from adverse impacts. It becomes a spotlight for researchers and engineers. The continuously developing social, economic, and environmental challenges need an evolution of the currentsustainable buildingdesignfactors with maintaining a direct relationship with the past andfuture. Based on reviewing the literature, the current factors are identified. However, there is a lacking in identifying future factors and exploring the interrelationship between current and future factors. This study identifiesthen validatesfuture factors by using the Delphi technique. Moreover, explores the interrelationship between factors by applying the multi-criteria decision making (MCDM), in particular the interpretive structural modeling (ISM) and cross-impact matrix multiplication applied to classification (MICMAC) methods. Finding the interrelationship will help future engineers in making decisions. A five-level model is generated which includes twelve factors, linking current and future factors. This model suggests that location and transportation factor is the key factor in the decision-making of designing sustainable buildings. Moreover, driving and dependence powers will guide the engineers in concentrating on the key factor. Accordingly, the factors are allocated into dependent and linkage clusters. Building space optimization factor has a high dependency on other factors as it is the only factor appears in the dependent cluster. While most of the factors appear in the linkage cluster which are unstable in the system and just transferring the effect. Future research work can consider other MCDM tools in validating theresults.

Keywords
Building Design Factors, Delphi technique, Multi-criteria decision making (MCDM), Interpretive Structural Modeling (ISM),and Cross-Impact Matrix Multiplication Applied to Classification (MICMAC).

1. Introduction
In recent years, the topic of sustainable building design has received growing attention and has become an increasingly popular research area. The benefits of sustainable building design go beyond the environmental and economic impacts, it has also positive effects on the social sector specifically on people's health (Allen et al. 2015). Nowadays, top engineering managers are facing challenges in implementing sustainable designs for the existing and newly constructed buildings by considering all the building design factors, where immense pressure is exerted for

applying the most suitable factors when designing a sustainable building (Kc and Gautam 2021).The need for transforming and changing the current sustainable building design processes resulted from the current challenges that engineers and stakeholders are facing (Beardsley et al. 2017). Indeed, modern sustainability understanding begins with knowing that the development of sustainability should fulfill nowadays needs without negotiating the demands of the future generations.

United Arab Emirates (UAE) is an appealing economic country as it has one of the most open economies worldwide (Emirates 2021). According to The Heritage Foundation for 2021 Index of Economic Freedom, UAE ranked 14th internationally and the 1st among fourteen countries in the Middle East and North Africa region (Foundation 2021).The sustainability trend in the Middle East region has been spearheaded by UAEand Qatar with 65 percent of LEED-accredited buildings (Katkhuda 2019).Towards having a sustainable community, UAE has set various initiatives to encourage the engineers and stakeholders to follow the green designs (Gharzeldeenand Beheiry 2015). The continuously developing social, economic, and environmental challenges need an evolution of the current practices with maintaining a direct relationship with the past as well as with the future (Friedman 2020).This study will draw the guidelines for future engineers in UAE to design buildings according to the sustainability factors by exploring the interrelationship between the current and future sustainable building design factors.

The objectives of this study are to conduct a systematic literature review to identify the current sustainable building design factors. Further, a survey will be conducted to identify the future sustainable building design factors, then validate the identified factors using the Delphi technique. Finally, exploring the interrelationship between the current and future factors by applying the multi-criteria decision making (MCDM), in particular the Interpretive Structural Modeling (ISM) and Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) method.

2. Literature Review

The literature reviewwas conducted to identify the current sustainable building design factors captured in literature. The following used keywords in this study are: “Sustainability”, “Green buildings”, “Sustainable building design factors”, and “Multi-criteria decision making (MCDM)”. The inclusion criteria are (i) the studies focusing on the sustainable factors for building designs, (ii) the scholarly peer-reviewed journal articles, (iii) the books, and (iv) the review articles. The exclusion criteria are (i) not relevant to the topic, (ii) published articles earlier than 2015, (iii) papers that are not written in English, and (iv) the duplications.Around 250 articles were selected for the study and then filtered; 69 articles were not relevant to the topic, 88 articles were published earlier than 2015, then 4 papers were not written in English, and lastly, 10 articles were excluded as they were duplicated. In the end, the final list of the analyzed articles was 79 articles.

2.1 Sustainability

The notion of the ‘three pillars’ is commonly used asa descriptor of sustainability (Cafuta 2015). This conceptualization is illustrated by three intersectional circles, society, economy, and environment, with the sustainability being placed at the middle of the intersections. Although the uses of these three different factors vary from one another, a balance of the trade-offs between their goals will definitely lead to the desirable main goal of sustainability (Purvis et al. 2019).Several impacts on the three previous categories, environment, economy, and society, were measured from the construction sector. Therefore, buildings’ sustainability is such a crucial subject to be understood to cut down the undesirable impacts for now and future(Attia 2016).

2.2 Sustainable Building Design Factors

Based on existed and verified technologies, sustainable building design rating systems estimated the environmental performance, as they compared the building to its life cycle. This comparison led to the initiation of the green buildings’ standards for designing, construction, and even operation (Vierra 2019).The top 12 green building rating systems in 2020 gathered the building design factors that have direct and indirect impacts on the environment related to sustainability. At the beginning of the research, forty-seven factors were collected from all rating systems with proceeding with the study, only eight factors remained. The decreasing range of factors resulted from achieving the aim of having more generalized categories, applying the LEED green building rating system, and using Delphi technique validation. Consequently, the green building design factors, which are summarized in Table 1.

Table 1. Sustainable building design factors

No.	Factors	Short Description	References
1	Location and Transportation	Reducing transportation which is one of the greatest impacts on greenhouse gas emissions, selecting the correct location that enhances the environment and reduces transport, and protecting sensitive sites from harmful development.	(Asdrubali et al. 2015;"LEED Credit library" 2021)
2	Sustainable Sites	Reducing the impact of the building site and its maintenance over time to reduce rainwater runoff, heat island effect, as well as light pollution.	(Asdrubali et al. 2015;"LEED Credit library" 2021)
3	Water Efficiency	Establishing a baseline, forming a design case where a plan is created to meet the reductions of the outdoor as well indoor water consumption, then ending with metering to determine the progress.	(Asdrubali et al. 2015; "LEED Credit library" 2021)
4	Energy and Atmosphere	Increasing the energy efficiency, reducing demand using renewables over fossil fuels, using refrigerants wisely, then monitoring and tracking the progress.	(Asdrubali et al. 2015;"LEED Credit library" 2021)
5	Materials and Resources	Using products that have that life cycle information available with sustainable properties as well. In addition, minimizing health impacts and costs from the extraction phase, production phase, transportation phase, consumption phase, and finally disposal phase.	(Asdrubali et al.2015; "LEED Credit library" 2021)
6	Indoor Environmental Quality	Increasing occupants' health and comfort through proper ventilation, air quality, thermal comfort, access to daylight and views, as well as acoustics.	Altomonte et al. 2019; "LEED Credit library" 2021)
7	Innovation	Recognizing projects for innovative building features and sustainable building practices and strategies to create highly efficient and cost-saving green buildings by achieving significant measurable or quantifiable environmental performance.	(P. Wu et al. 2018;"LEED Credit library" 2021)
8	Regional Priority	Focusing on the location or geography of the project although different geographic locations may have different priorities.	(P. Wu et al. 2018;"LEED Credit library" 2021)

This research will lead to solving the gaps in literature. This willallow the engineers to smoothly transfer from the present to the future in a way that makes design buildings more sustainable. Balancing between the three pillars of sustainability: economy, environment, and society will ultimately lead to the desirable main goal of sustainability.

3. Methods

This study analyzes the interrelationship between the current and future sustainable building design factors. A sequential four-phased research methodology is applied:

- The first phase: Study Definition. The problem statement of the study was identified, then the research questions were placed: What are the current affecting factors in the design of sustainable buildings? What could be the affecting factors in the design of future sustainable buildings? And finally, how are these factors interrelated?
- The second phase: 1st Qualitative Methodology. An extensive literature review was done to determine the current factors.
- The third phase: 2nd Qualitative Methodology. Conducting a survey with experts to identify the future factors. Then, using the Delphi technique for validation.
- The fourth phase: Quantitative Methodology. MCDM was applied to explore the interrelationship between the current and future factors.

3.1 Delphi Technique

The Delphi technique is an interactive forecasting process used to collect and aggregate multiple rounds of expert judgments using questionnaires or surveys on a particular subject (Flostrand et al. 2020). The multiple questionnaires end when reaching the panelists' opinions consensus or when exchanging sufficient data. This technique is used to estimate the likelihood and outcome of future events (Dewangan et al. 2015). The steps for applying the Delphi technique are defining the given problem, selecting the panel of experts, and conducting multiple rounds of surveys as illustrated in Figure 1.

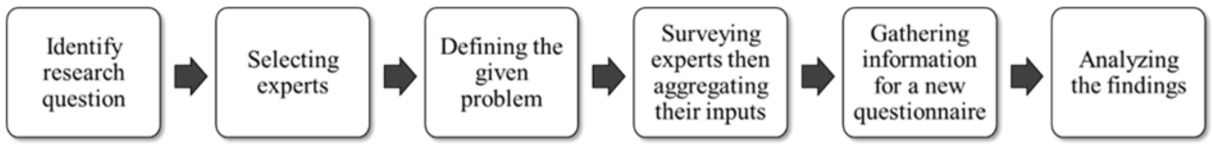

Figure 1. Delphi technique steps.

In order to get a great understanding of the problem, the focus group was selected from three fields, as follows: 1) The academic field, 2) The industrial field, and 3) A combination of both fields. The conducted Delphi survey was performed through two rounds of questionnaires with the participation of 10 experts in the focus group. Five experts were from the academic field, three were from the industrial field, and two have a combination of both fields.

In the first round, some of the experts were conducted through face-to-face interviews, while the others by mailing them. This survey aimed to collect experts' judgments in validating the current sustainable building design factors, plus determining the future sustainable building design factors. All the derived outputs from the first round of surveys were used in structuring the second-round questionnaire. In the second round, experts were requested to evaluate the level of importance of the determined future sustainable building design factors from the first round questionnaire. The analysis of data in round 1 was done by applying coding and indexing, while in round 2 the responses were examined by applying the Content Validity Ratio (CVR).

3.2 MCDM Overview

Finding the interrelationship between the current and future sustainable building design factors is multiple conflicting criteria, in evaluating all the available options in making any decision. Therefore, an operational research sub-discipline method, called Multi-Criteria Decision Making (MCDM), can be used to define the leading path to the final decision (Majumder 2015). To apply the MCDM, there are multi-techniques in the literature that can explore variables' interdependencies with developing their structural hierarchy.One of these techniques is ISM–MICMAC which is relatively indicating the contextual relations and has been well-accepted in literature (Mangla et al. 2018).The ISM-MICMAC method is the most preferable method to be used for this research, as it helps in ordering and directing the complexity of different factors' relationships, creates a simple yet structured model to facilitate the understanding, and has unique characteristics (specifically for the study topic) (Mohanty 2018).

3.2.1 ISM Process

The ISM methodology is an interactive learning process with a set of different structured components in a comprehensive systematic model, that are directly and indirectly related. This model facilitates the understanding of a specific issue because its pattern is designed with graphics and words (Dube et al. 2016). The ISM is an appropriate methodology for determining and even developing the contextual relationships between selected variables in defining the problem, as it provides a fundamental understanding of any complex issue (Ahmad et al.2019; Khan et al. 2020).The followed steps used in this method are:

1. Building a structural self-interaction matrix (SSIM) to obtain the contextual relationship among the identified factors.
2. Checking for transitivity using the reachability matrix which built from the SSIM.
3. Achieving the hierarchy of level partitioning by obtaining the reachability and interaction sets for each level.
4. Drawing adirect graph according to the previous factors' relationships.

The resultant ISM model will present the relationships between the sustainable building design factors and their significance leveling from higher to lower in a hierarchy.

3.2.2 MICMAC Analysis

The MICMAC analysis is divided the factors into four clusters based on two powers, the driving power, and dependence power. The first cluster is called: autonomous factors, these factors have weak or no driving power and dependence power and are relatively out of the system. The second cluster is called: dependent factors, these factors have weak driving power but strong dependence power. The third cluster is called: linkage factors, these connecting factors have strong driving power and dependence power. The fourth cluster is called: independent factors, these factors have strong driving power but weak dependence power. A factor that has strong driving power is considered a key factor (Ahmad et al. 2019; Dewangan et al. 2015; Dube et al. 2016; Khan et al. 2020).

4. Results and Discussion

4.1 Delphi Technique

During the first round of the Delphi survey, we contacted 10 experts (5, 3, and 2 experts were from the academic field, the industrial field, and a combination of both fields respectively), who confirmed their availability to be part of the experts' panel and answer the survey. The conducted interview took around 15 minutes on average. All the opinions on each factor were covered by taking notes. Based on the interview, experts' feedback was transferred into well-organized tables that have meaningful information for the research. The results from the first round included the validation of the listed current sustainable building design factors through literature. In addition, a new set of factors were determined by the experts for the future sustainable building design. Almost all the experts confirmed that all the identified factors are good indicators of a project's sustainability. However, some of them commented that some of these factors are not important to be followed.The following twelve new factors were determined by the experts for the future sustainable building design: occupants' behavior, cost, outdoor environment, greenery, social culture, resiliency, site access optimization, green roof, light pollution, legionella prevention, BIM, AI, & IoT, and community responsibility. Table 2 illustrates the definitions of these newly determined factors.

Table 2. The identified future sustainable factors by Delphi experts

No.	Future Factors	Description	References
1	Occupants' Behavior	The interaction between occupants and building systems improves the overall performance of the building.	(Delzendeh et al. 2017; USGBC)
2	Cost	General costs related to the building (construction, installation, materials costs, etc.).	(Hamad 2020)
3	Outdoor Environment	Every environment apart from the indoors.	(Masterson et al. 2022)
4	Greenery	All types of vegetation either indoors or outdoors.	(Hiemstra et al. 2017)
5	Social Culture	The involvement of social and cultural aspects. How nature is being defined and experienced by humans.	(Soini and Dessein 2016)
6	Resiliency	The ability to adjust easily to changes.	(Marjaba and Chidiac2016)
7	Site Access Optimization	Making the access to the site as much functional and effective as possible.	(Xu et al. 2020)
8	Green Roof	Planted roofs with different vegetations.	(Shafique et al. 2018)
9	Light Pollution	The excessive or inefficient use of artificial light.	(Kyba 2018)
10	Legionella Prevention	The prevention of bacterium flourishing in heating, ventilation, and air conditioning systems.	(Ambrose et al. 2020)
11	BIM, AI, & IoT	BIM stands for Building Information Modeling, AI stands for Artificial Intelligence, and IoT stands for Internet of Things.	(Copeland 2022; Lorek 2022)
12	Community Responsibility	Everyone should cooperate with each other and with the organizations for the benefit of the community.	(Deb 2020)

The validated factors of the current sustainable building design a) by the panel of experts in the first round of the survey, and b) as mentioned in the literature (Table 1) were included in a questionnaire for the second round of the survey. Appendix B contains the listed introduction paragraph of the second survey. Experts were involved in evaluating the importance level of the factors on the five-point Likert scaling from one to five (one is not important to five, extremely important). Factors with a CVR of at least 0.62 (the minimum acceptable CVR for the ten-panel members is 0.62) (Oghabi et al. 2021) were selected as the final responsible factors for this research context. The following formula was used for calculating the CVR for each factor:

Content Validity Ratio (CVR) = $\frac{ne - N/2}{N/2}$

where n_e is the number of experts in the panel indicating the "essential" option and N is the total number of experts (Lawshe 1975). Lawshe(1975) considered three options for each response, including 'essential', 'useful but not essential', and 'not necessary'. All the five-point Likert scaled received responses were comparatively matched with the other scale. Accordingly, in the Likert scale 'extremely important =5' and 'very important =4' equally matched to the 'essential' option, 'moderately important =3' equaled to the 'useful but not essential' option, and 'slightly important =2' and 'not important =1' equaled to 'not necessary' option (Delbari et al. 2016).

Based on the second round of the survey, Table 3 comprises the results of the factors' CVR with the acceptance/rejection status. Factors with CVR higher than 0.62, from the second round, were accepted while others were rejected. Consequently, out of twenty-two collected factors, only twelve are included for the next step of data collection. From the two rounds of the Delphi technique's results; location and transportation, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation, building space optimization, safety, occupants' behavior, resiliency, and BIM, AI, & IoT are the top twelve identified factors for sustainable building designs.

Table 3. Results of acceptance or rejection of sustainable building design factors

No.	Sustainable Building Design Factors	n_e	CVR	Status
1	Location and Transportation	9	0.8	Accepted
2	Sustainable Sites	9	0.8	Accepted
3	Water Efficiency	9	0.8	Accepted
4	Energy and Atmosphere	9	0.8	Accepted
5	Materials and Resources	10	1.0	Accepted
6	Indoor Environmental Quality	10	1.0	Accepted
7	Innovation	9	0.8	Accepted
8	Regional Priority	8	0.6	Rejected
9	Building Space Optimization	10	1.0	Accepted
10	Safety	9	0.8	Accepted
11	Occupants'Behavior	9	0.8	Accepted
12	Cost	5	0.0	Rejected
13	Outdoor Environment	2	-0.6	Rejected
14	Greenery	6	0.2	Rejected
15	Social Culture	6	0.2	Rejected
16	Resiliency	9	0.8	Accepted
17	Site Access Optimization	7	0.4	Rejected
18	Green Roof	4	-0.2	Rejected
19	Light Pollution	1	-0.8	Rejected
20	Legionella Prevention	4	-0.2	Rejected
21	BIM, AI, & IoT	10	1.0	Accepted
22	Community Responsibility	7	0.4	Rejected

4.2 ISM Process

For the ISM methodology, the same identified 10 experts who participated in the Delphi survey were approached. The correlation between the 12 identified sustainable building design factors (as referred to in Table 4) is estimated by determining the contextual relationship between any pair of two factors using "Yes" and "No" questions. For an identified number (n) of factors, the total number of paired comparisons will be nC2. Thus, the total number of paired comparisons will be 66 for the 12 identified factors (=12C2).

4.2.1 Developing SSIM

In order to create SSIM, four symbols (V, A, X, O) were used to express the contextual relationships between factors i and j as follows:

- V: factor i will lead to factor j.
- A: factor j will lead to factor i.
- X: factors i and j will lead to each other.
- O: factors i and j are unrelated.

The SSIM of factors is developed based on the contextual correlations (Table 5). This matrix has been completed with the assistance of two experienced academic doctors in the field.

Table 4. List of sustainable building design factors with corresponding reference code

Serial No.	Sustainable Building Design Factors	Factors Reference Code
1	Location and Transportation	F1
2	Sustainable Sites	F2
3	Water Efficiency	F3
4	Energy and Atmosphere	F4
5	Materials and Resources	F5
6	Indoor Environmental Quality	F6
7	Innovation	F7
8	Building Space Optimization	F8
9	Safety	F9
10	Occupants' Behavior	F10
11	Resiliency	F11
12	BIM, AI, & IoT	F12

Table 5. SSIM of factors

Factors	F12	F11	F10	F9	F8	F7	F6	F5	F4	F3	F2	F1
F1	O	O	V	V	V	V	V	V	V	V	X	X
F2	O	X	V	V	O	X	V	A	X	X	X	-
F3	V	O	O	O	O	X	O	O	O	X	-	-
F4	V	O	A	O	X	X	X	A	X	-	-	-
F5	X	V	O	X	O	X	A	X	-	-	-	-
F6	A	A	X	O	O	A	X	-	-	-	-	-
F7	X	O	O	O	O	X	-	-	-	-	-	-
F8	A	O	O	O	X	-	-	-	-	-	-	-
F9	A	X	O	X	-	-	-	-	-	-	-	-
F10	V	O	X	-	-	-	-	-	-	-	-	-
F11	O	X	-	-	-	-	-	-	-	-	-	-
F12	X	-	-	-	-	-	-	-	-	-	-	-

4.2.2 Developing Reachability Matrix

The above SSIM is then converted to an initial reachability matrix (Table 6) by replacing V, A, X, and O with 1 and 0, as per the following instructions:

1. If the (i, j) entry is V, the reachability matrix of the (i, j) entry becomes 1 and the (j, i) entry becomes 0.
2. If the (i, j) entry is A, the reachability matrix of the (i, j) entry becomes 0 and the (j, i) entry becomes 1.
3. If the (i, j) entry is X, the reachability matrix of both of the (i, j) and (j, i) entries becomes 1.
4. If the (i, j) entry is O, the reachability matrix of both of the (i, j) and (j, i) entries become 0.

4.2.3 Transitivity Principle

Thetransitivity principle has been applied to the initial reachability matrix to fill some of its cells. Transitivity means; that if element 'A' is related to element 'B' and element 'B' is related to element 'C', then element 'A' will be related to element 'C'. In ISM, transitivity promotes conceptual consistency and helps in removing the gaps between the factors (Chand et al. 2020). From Table 6, some of the "0" values will be replaced by "1" after implementing the transitivity rule. The replaced values within the cells have "*" symbols beside them (Table 7).

Table 6. Initial reachability matrix of factors

Factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	Driving Power
F1	1	1	1	1	1	1	1	1	1	1	0	0	10
F2	1	1	1	1	0	1	1	0	1	1	1	0	9

F3	0	1	1	0	0	0	1	0	0	0	0	1	4
F4	0	1	0	1	0	1	1	1	0	0	0	1	6
F5	0	1	0	1	1	0	1	0	1	0	1	1	7
F6	0	0	0	1	1	1	0	0	0	1	0	0	4
F7	0	1	1	1	1	1	1	0	0	0	0	1	7
F8	0	0	0	1	0	0	0	1	0	0	0	0	2
F9	0	0	0	0	1	0	0	0	1	0	1	0	3
F10	0	0	0	1	0	1	0	0	0	1	0	1	4
F11	0	1	0	0	0	1	0	0	1	0	1	0	4
F12	0	0	0	0	1	1	1	1	1	0	0	1	6
Dependence	2	7	4	8	6	8	7	4	6	4	4	6	**66**

Table 7. Final reachability matrix of factors

Factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	Driving Power
F1	1	1	1	1	1	1	1	1	1	1	1*	1*	12
F2	1	1	1	1	1*	1	1	1*	1	1	1	1*	12
F3	1*	1	1	1*	1*	1*	1	1*	1*	1*	1*	1	12
F4	1*	1	1*	1	1*	1	1	1	1*	1*	1*	1	12
F5	1*	1	1*	1	1	1*	1	1*	1	1*	1	1	12
F6	0	1*	0	1	1	1	1*	1*	1*	1	1*	1*	10
F7	1*	1	1	1	1	1	1	1*	1*	1*	1*	1	12
F8	0	1*	0	1	0	1*	1*	1	0	0	0	1*	6
F9	0	1*	0	1*	1	1*	1*	0	1	0	1	1*	8
F10	0	1*	0	1	1*	1	1*	1*	1*	1	0	1	9
F11	1*	1	1*	1*	1*	1	1*	0	1	1*	1	0	10
F12	0	1*	1*	1*	1	1	1	1	1	1*	1*	1	11
Dependence	7	12	8	12	11	12	12	10	11	10	10	11	**126**

4.2.4 Level Partitioning

Achieving the hierarchy of level partitioning is by obtaining the reachability and interaction sets for each level (Chand et al. 2020). At each level, reachability, antecedent, and intersection sets for each factor should be found. This method is repeated until all elements have been assigned. The level partitioning process for the studied factors resulted in 5 levels as follows (Table 8):

- Level 1 has the following factors: 2, 4, 6, 7, 8, 9.
- Level 2 has the following factors: 5, 10.
- Level 3 has the following factors: 3, 11.
- Level 4 has the following factors: 12.
- Level 5 has the following factors: 1.

Table 8. Level partitioning process

Factors	Reachability Set	Intersection Set	Level
F1	1,2,3,4,5,6,7,8,9,10,11,12	1,2,3,4,5,7,11	5
F2	1,2,3,4,5,6,7,8,9,10,11,12	1,2,3,4,5,6,7,8,9,10,11,12	1
F3	1,2,3,4,5,6,7,8,9,10,11,12	1,2,3,4,5,7,11,12	3
F4	1,2,3,4,5,6,7,8,9,10,11,12	1,2,3,4,5,6,7,8,9,10,11,12	1
F5	1,2,3,4,5,6,7,8,9,10,11,12	1,2,3,4,5,6,7,9,10,11,12	2
F6	2,4,5,6,7,8,9,10,11,12	2,4,5,6,7,8,9,10,11,12	1
F7	1,2,3,4,5,6,7,8,9,10,11,12	1,2,3,4,5,6,7,8,9,10,11,12	1
F8	2,4,6,7,8,12	2,4,6,7,8,12	1
F9	2,4,5,6,7,9,11,12	2,4,5,6,7,9,11,12	1
F10	2,4,5,6,7,8,9,10,12	2,4,5,6,7,10,12	2
F11	1,2,3,4,5,6,7,9,10,11	1,2,3,4,5,6,7,9,11	3
F12	2,3,4,5,6,7,8,9,10,11,12	2,3,4,5,6,7,9,10,12	4

4.2.5Formation of ISM

According to the final reachability matrix (Table 7) and level partitioning (Table 8), the structural model is represented with a hierarchical level of nodes (factors) connected by lines. This graph is referred to as a directed graph or digraph. The utilized type of line between any two factors (i and j) defines the relationship's nature. The graph has two types of lines: 1) unidirectional line which is a line with a pointed arrow from one factor to another, and 2) bidirectional line which is a line with two pointed arrows between two factors. If there is a unidirectional relationship between two factors – factor 'i' leads to factor 'j' – then a pointed arrow should be drawn from 'i' to 'j'. While if there is a bidirectional relationship between two factors – factor 'i' leads to factor 'j' and vice versa – then a double-pointed arrow should be drawn between 'i' and 'j'. The ISM model demonstrates the relationship nature between the twelve identified sustainable building design factors including the current factors (blue color) and the future factors (green color) (Figure 2).Location and transportation factor is at the bottom level, which means it is the most important factor in the model. This major factor affects all the remaining factors in the model as it has the highest Driving Power.On the other hand, sustainable sites, energy and atmosphere, indoor environmental quality, innovation, building space optimization, and safety factors are at the top level, which illustrates that they are the most affected factors by others as they have the highest dependence power.

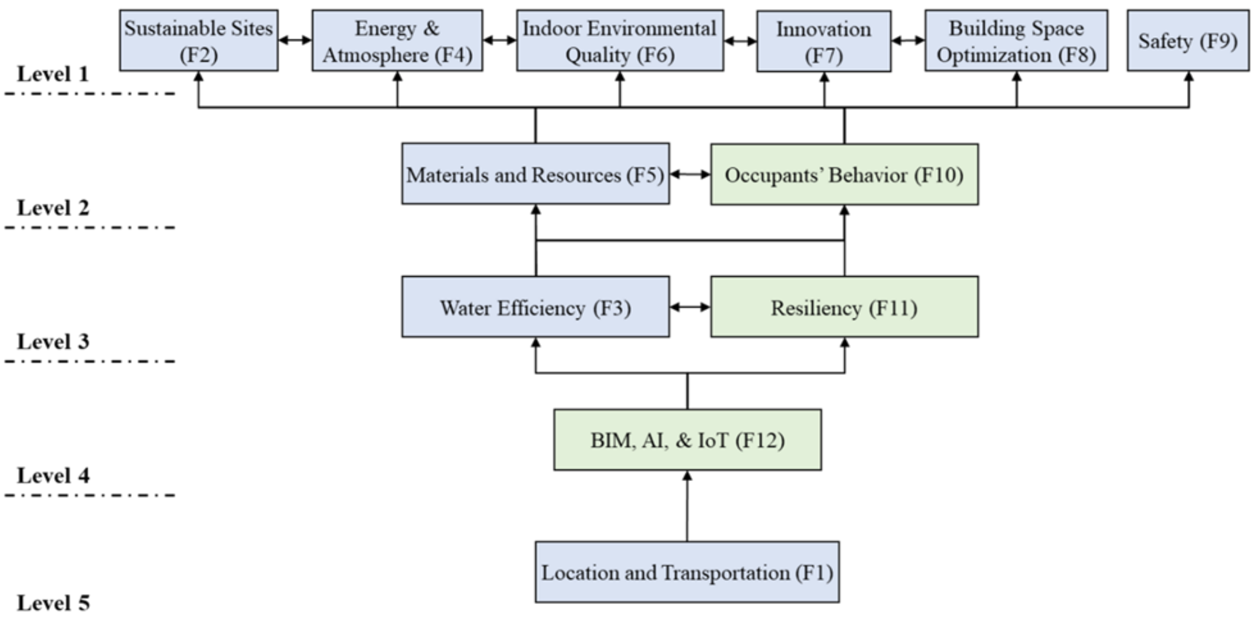

Figure 2. ISM model

4.3 MICMAC Analysis

Based on the research methodology, MICMAC analysis is applied to get the driving power and dependence power for each sustainable building design factor to plot them on the diagram. According to the factors' driving power and dependence power, the factors have been divided into four clusters (Figure 3):

- Cluster I: Autonomous sustainable building design factors. Factors with weak driving power and weak dependence power. No positioned factors were found in this cluster which means that all the factors influence other factors and depend on each other, and they are all connected to the system.
- Cluster II: Dependent sustainable building design factors. Factors with weak driving power but strong dependence power. The building space optimization (F8) factor is positioned in this cluster which means that this factor has a high dependency on the other factors.
- Cluster III: Linkage sustainable building design factors. Factors with strong driving power and strong dependence power. Location and transportation (F1), sustainable sites (F2), water efficiency (F3), energy and atmosphere (F4), materials and resources (F5), indoor environmental quality (F6), innovation (F7), safety (F9), occupants' behavior (F10), resiliency (F11), and BIM, AI, & IoT (F12) factors are positioned in this cluster.These factors are unstable in the system consequently if any change happened to one of them, the rest will be affected (transferring the effect). These factors will affect each other by a relatively different rate of driving and dependence powers.

- ClusterIV: Driving sustainable building design factors. Factors with strong driving power but weak dependence power. No positioned factors were found in this clusterwhich means that there is no main driving factor that will have a major impact on the other factors in the system.

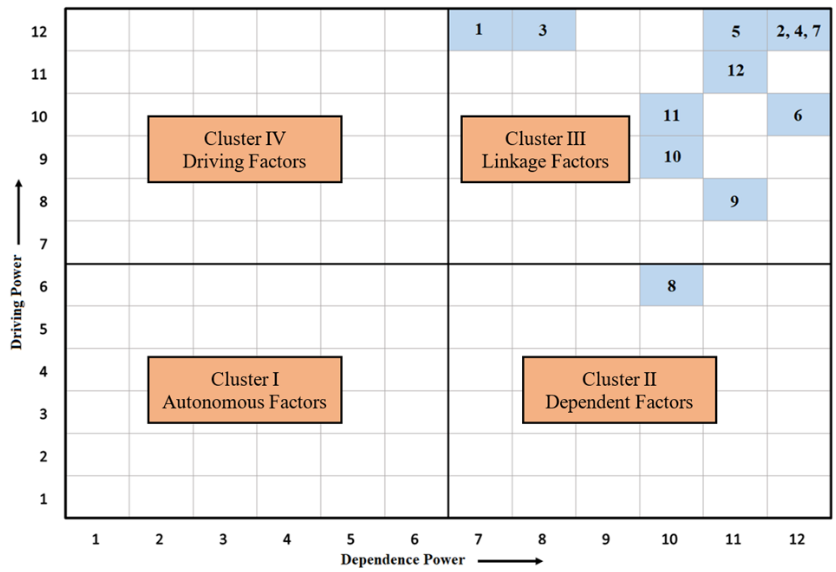

Figure 3. MICMAC analysis diagram of factors

5. Conclusion and Future Work

The goal of this research is to identify then validate theoretical framework the current and future sustainable building design factors. It also attempts to explore the interrelationship between the current and future factors for developing an effective guideline for future engineers in designing sustainable buildings by adopting a unified approach in the decision-making step. The findings from this research will provide a new dimension to an integrated approach to the problem. This study contributes significantly to the current literature by identifying the gaps in literature. The research methodology comprises more than one phase of the decision-making process. Starting with identifying the problem, reviewing the literature, applying the Delphi technique, and ending with implementing the MCDM by doing the ISM-MICMAC analysis. This methodology allows for flexibility in structuring the research problem by merging the academic and industrial fields in exploring the interrelationship between the factors. For future studies,they can be used in other countries to create a more general guideline, other MCDM tools can be applied to validate the results of this research, other factors will be more important for the future, or new factors may appear forwards.

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