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Research Paper

Evaluation of Criteria Influencing industrialized building system in Iran based on Vitruvius's Three Principles of Architecture

Ali Mardani [*]

Department of Architecture, Abadan Branch, Islamic Azad University, Abadan, Iran

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Abstract
The industrialized building system (IBS) has been a common construction method for decades. Today, IBS is employed as a pioneer construction industry in developed and some developing countries. However, IBS has no proper position in the Iranian construction industry. Despite numerous advantages of building industrialization, most constructors adapt conventional techniques rather than building industrialization. This not only imposes human and environmental impacts but also wastes time and cost. The present work mainly aims to evaluate qualitative criteria influencing building industrialization in Iran based on Vitruvius's three principles of architecture so that these criteria could be exploited to enhance building industrialization quality in Iran. Based on Vitruvius's theory, architects should consider stability, utility, and beauty in their designs. Therefore, this theory was adopted as a suitable approach for the analysis and evaluation of industrialized buildings. Also, this study seeks to prioritize the building industrialization criteria based on the significant aspects of Vitruvius' principles. This study reviews the literature and theoretical foundation in the first phase and then adopts a descriptive-survey methodology and field studies. To collect data, a questionnaire was developed based on the Likert scale. The validity and reliability of the questionnaire were verified. The statistical population consisted of academic professors and construction practitioners. The one-sample t-test, paired-sample t-test, and Kolmogorov–Smirnov (K-S) test were carried out in SPSS V.16.0. The findings revealed that the factor of structure in the principle of stability with the components of lateral load (i.e., wind and earthquake) resistance and shear load-resistant connections had the largest effect. Also, the economic factor of principle "utility" with the components of cost-effectiveness, construction time reduction, and mass construction had the second-largest effect in Iran.

Keywords: *Industrialized building system, Firmitatis, Venustatis, Utilitatis, Iran.*

1. INTRODUCTION

Industrialization is not limited to prefabrication today. Industrialized construction involves pre-engineering in developed countries; that is, the building architecture is based on engineer knowledge and user preferences. Building industrialization includes lightweight construction, strengthening, material saving, optimal energy consumption during construction and operation, construction acceleration, construction cost reduction, and the lifespan and quality enhancement of buildings and structural components. To achieve industrialized construction development objectives, it is crucial to select new technologies based on architectural principles. Many theorists have attempted to propose a definition of architecture to determine the governing principles. Vitruvius proposed one of the most durable architecture principle systems (Stein and Spreckelmeyer 1999). To describe and analyze architecture, Vitruvius' principles have been frequently employed. These three principles determine different demands and goals that have to be met in architecture. In architecture quality, it is essential that these principles interact with each other and form a general concept. Building industrialization based on these three principles could bring a significant evolution of views and improve the quality of the Iranian construction industry.

[*] *Corresponding author: ali_mardani4563@yahoo.com*

2. QUESTIONS

What are the factors of building industrialization based on Vitruvius' three principles of architecture?

What are the most influential factors of building industrialization based on the three principles?

3. LITERATURE REVIEW

Azman et al employed the Relative importance index (RII) to prioritize the quality factors of industrialized building system (IBS) projects in Malaysia. They identified a total of 109 factors influencing construction quality management in IBS. It was found that proper equipment and technologies had the largest effect on construction equality with an RII of 0.684. (Azman, Ramli et al. 2019). Zakaria et al investigated contextual, structural, and behavioural factors affecting the adoption of IBS. They classified and measured components and obtained deeper insights into the higher use of IBS and thus the stability and competitiveness improvement of construction industries (Akmam Syed Zakaria, Gajendran et al. 2018). Yunus and Yang studied sustainability criteria for IBS in Malaysia. They showed that an integrated evaluation process and effective cooperation between building designers, constructors, and planners were the IBS sustainability criteria (Yunus and Yang 2011). Ataeian and Asadi performed an adaptive comparison of building industrialization to traditional methods with an emphasis on time, cost, and quality. They provided a practical background to deal with industrialization in architectural buildings and supervise and direct it for integration with traditional construction skills in order to achieve construction goals (Ataeian, Asadi, 2019). Khezrian and Saghafi reviewed the national development plans of Iran and their reflections on building industrialization during 1989-2017. They found that the plans failed to facilitate the consistency of architecture and construction organizations and contribute to the expansion of industrialization mechanisms and the enhancement of construction quality. Therefore, they evaluated the shortcomings of the national development documents of Iran and examined factors impacting the building planning process of Iran (Khezrian and Saghafi 2018).

4. INDUSTRIALIZED BUILDING SYSTEM (IBS)

Nowadays, industrialization has a wide range of definitions. Therefore, it is necessary to determine precisely what industrialization is. In its latest report on industrialization, the Construction Industry Development Board (CIDB) defined industrialization as construction using mechanical power and tools, steering system and computer tools, continuous production, productivity improvement, product standardization, prefabrication, modulation, and mass production (CIDB, 2010). Table 1 presents some of the definitions of IBS from the perspective of experts.

5. BUILDING INDUSTRIALIZATION CHARACTERISTICS

Today, conventional construction methods cannot meet high demands due to slowness and expensiveness (Badir, Kadir and Hashim 2002). Also, despite recent advancements in other industries, such as manufacturing, the construction industry is lagging. A review of historical data demonstrated that the productivity of construction has declined by nearly 5%, while the production of all non-agricultural industries has experienced a twofold enhancement in 40 years (Demian and Walters 2014). Building industrialization could provide a more rapid and cost-effective construction system with higher quality. Although the industrialized construction of buildings is mechanized, architectural criteria and values are inevitable in industrialized construction (Vafamehr, 2013). The six characteristics proposed by such theorists are considered building industrialization characteristics, including industrialized fabrication, transportation and assembly, on-site construction, mass construction, planning-standardization, and process integration. However, other characteristics could be introduced:

Industrial production: is a process that increases system output and optimizes the operation of equipment, facilities, and technology by improving the quality, construction time, and use of labour. Therefore, when talking about factories that produce all kinds of parts to be installed in construction. The main goal of this production method is to improve safety, quality, cost, and output levels (Mapsa, 2020).

Transportation and assembly are processes in which the prefabricated components of a building and its accessories are produced in a place other than the construction site. Besides, assembly in industrialization through mechanized processes decreases the amount of waste production and environmental impact.

On-site construction: design, production, and on-site setting are closely linked and should be considered part of a convergent process and thus planned and coordinated.

Mass production: is the manufacturing of large quantities of standardized products, often using assembly lines (Hashemian 2005). An automated mechanical process carries out this production of large quantities of a standardized product. The benefits expected from industrialization are often achieved in high-volume production (Vafamehr, 2013). This process has had a positive impact on construction speed and quality essentially and has become one of the main principles in this regard.

Planning and standardization: are components involved in IBS that require standardization for production to achieve modular coordination (Trikha 1999). Modular coordination and standardization are the features required for the successful implementation of industrialized buildings. To meet the requirements of modular coordination, all components of IBS must be standardized. Therefore, the standardization program and its components in standardization are incredibly crucial, significantly to help the production process.

Process integration: includes components and factors that affect industrialized construction are coordinated and complete each other so that the complete chain of the construction industry is formed by joining all the valuable links in it. There should be high coordination between various parties related to the designer, builder, owner, and contractor to achieve favourable results. This is achieved through an integrated system where all these parties are done under a single integration (Warszawski 2003). Given the necessity of improving productivity, sustainability, quality, and safety, it is imperative to use novel methods (e.g., automation and robotics) to eliminate this problem (CIDB, 2016). (fig1).

Table 1. Literature of Industrialized Building System (IBS) according to experts

Expert(s)	analytically	categories
(Abd Rashid, Abdullah and Ismail 2018)	Either IBS is defined as a construction system that consists of a combination of components manufactured on-site or off-site, then positioned and assembled into structures. The benefits of IBS construction include labor cost reduction, support a desirable environment, maximize efficient use of resources, and waste minimization towards sustainable construction.	
(Mohamed, Mohammad et al. 2018)	IBS is a construction method that refers to the components manufactured in a controlled environment (on or off-site), transported, positioned, and assembled into a structure with minimal additional site works.	Off site
(Chung and Kadir 2006**)**	IBS is the mass production of building components either in a factory (off-site) or at the construction site (on-site).	
(Rahim and Qureshi 2018)	IBS can be described as a method to construct a building using prefabricated components manufactured systematically through machinery and mould in the factory. They are then transported and assembled on site.	
(Nawi, Noordin et al. 2019)	It is a system or method in which parts are manufactured in factories or on-site and are installed on construction sites under the control, transportation, and installation with minimal use of workers.	
(Fathi, Abedi and Mirasa 2012)	IBS is a construction method of building components either in a factory or at the site and then assembled on the construction site.	perfabrication
(Kamar, Abd Hamid and Azman 2011)	IBS is the concept of industrialization as a prefabrication process in construction.	
(Gibb 1999)	It is a prefabrication process, organization, and completion of the final modules before installation into the location.	
(Parid,2003)	It refers to an industrial system of producing components or assembling a building, or both.	
(Berawi 2017)	IBS is an integrated process involving all subsystems, components, manufacturing, and construction processes, requiring efficient management.	
(Lessing 2015)	IBS refers to an integrated production and manufacturing process made by managing the organization and managing activities.	Process integrity
(Junid 1986)	IBS is an integrated software and hardware system, and the building components are designed, built, transported, and assembled on-site.	
(Marsono et al., 2006)	IBS is a construction method using the best construction machinery, equipment, materials, and extensive planning.	
(Vafamehr, 2013,17)	It is a set of technological factors, tools and machines and human skills, and technical knowledge	Mechanization

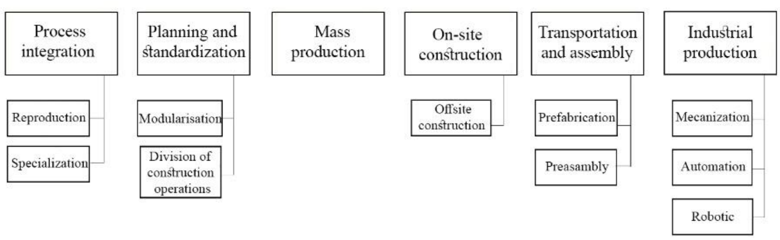

Fig 1. Six features of IBS presented from the perspective of experts

6. BUILDING INDUSTRIALIZATION IN IRAN

The industrialized construction of buildings began in the 1950s and has a history of more than six decades. Building industrialization efforts were begun by the former Construction Bank, Rima Construction Company, and some foreign companies in 1954. The Solid Housing Project 1969 was a significant step toward the industrialization of buildings and encouraged the former Ministry of Housing and Urban Development of Iran to industrialize construction in 1970 (Memarzia 1995). Then, the first prefabrication factory was founded by the French. It was designed by the Housing Organization through the German Casting System (Vafamehr, 2013). Building industrialization is not widely applied in Iran. New equipment is mostly adopted in the construction of concrete structures with prefabricated components and new panels and blocks (STINO, 2020). This arises from the lack of sufficient infrastructure and leaves incomplete construction. Iran has numerous faults, the movement of which releases significant energy and imposes frequent earthquakes with considerable damage and casualties in urban areas. Also, the semi-arid climate of Iran substantially decreases the resistance of buildings to heat and corrosion. worn urban fabric in many urban areas emphasizes the necessity of an attitude change and the physical modification of construction in industrial construction systems.

7. VITRUVIUS AND THREE ARCHITECTURE PRINCIPLES

Vitruvius was an architect in ancient Rome who proposed principles for use in all cases. Vitruvius based the principles on natural rules to yield unique outcomes. For example, Vitruvius observed how some principles of the human body, such as symmetry and proportionality, represented perfection. The human body was a significant source of inspiration to him. Vitruvius even believed that the principles of the human body should be utilized in the design of gardens and buildings since it would have an excellent outcome: a combination of beauty, stability, and utility (Greefhorst, Proper et al. 2011). Vitruvius was the first to regulate the entire discipline of architecture systematically (Bani masud, 2005). Many theorists attempted to propose a definition of architecture so that the governing principles of architecture could be determined; however, Vitruvius proposed one of the most durable architecture principle systems (Stein and Spreckelmeyer 1999). The three architecture principles of *utilitatis*, *firmitatis*, and *venustatis* have been the most important theory of Vitruvius that has been discussed by different approaches. In states in the third chapter of his book (De architectura), he states that architecture should hold loyal to these three principles. In Vitruvius' view, the practical comfort of a building, from the placement of rooms in a house to the location of the building in the city, the consideration of stability, comfort, and beauty in architecture, and the relationship between architecture and humans were important to other Roman theorists and used in their works. In the Middle Ages, Vitruvius' ideas were utilized to describe the physical architectural characteristics and the proportion between beauty and construction (Gharibpour 2013).

Firmitatis: It involves stability, firmness, building, and materials. Vitruvius divided his first category into two subcategories: structure and materials. The current structural calculation methods did not exist in the era when Vitruvius lived, and dimensions were found through general proportionality rules. Concerning foundations, arch vaults, and roof beams, Vitruvius stated sentences such as "as high as the building size needs" or "as much as needed." Nevertheless, to ensure that column capitals and portals would not crack, the column thickness and distance were determined by more accurate rules, and such rules were integrated into more general proportionality rules. Concerning materials in Vitruvius' second book, there are concerns about proportions based on which materials and elements were combined to create mortars and bricks; the strength and durability of bricks and mortars would be dependent on these proportions (Capon 1999).

Utilitatis: It deals with comfort, building efficiency, and ensuring the performance of buildings. Vitruvius' second category relates to the comfort of a building in practice, from the order of rooms in the house to the location of the building in the city. Vitruvius discussed the associations between public and private rooms, room orientation for receiving daylight, and specific requirements of different classes, such as nobles, merchants, judges, and farmers (Capon 1999).The economy is another aspect that should be considered under the category of Utilitatis. Vitruvius believed that the association between the functions and economy was dependent on practical conditions and required a trade-off based on saving costs and wisdom in fabrication (Capon 1999).

Venustatis: Vitruvius believed that nature was an expression of cosmic order based on universal rules, and that architectural quality would be achieved when the architectural design was based on these rules and when architecture imitated the natural cosmic order. A contemporary understanding of this concept relates to the spatial and aesthetic conditions of architecture, such as proportions, light-shadow game, heaviness-lightness conflict, textural qualities, structural patterns, and rhythm. Venustatis have experienced a variety of expressions from the ancient ages to the modern era, and such expressions have become architectural styles. The characteristics of architectural forms could represent aesthetic, artistic, symbolic, and poetic dimensions of architecture that serve as decorations in architecture. Venustatis could arise from the manifestation of the two other dimensions (Firmitatis and Utilitaties) or can be expressed as a complementary individual characteristic represented by proportions, decorations, view, and color (Zotic, Alexandru and Puiu 2010), as shown in Fig 2.

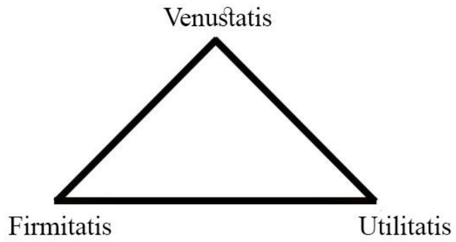

Fig 2. The Three Principles of Vitruvius

8. RELATIONSHIP BETWEEN VITRUVIUS' THEORY AND BUILDING INDUSTRIALIZATION

The Merriam-Webster dictionary has five definitions for the term "theory," three of which state that theory makes it possible to predict a phenomenon by explaining similar phenomena. Also, a theory proposes methods to test general rules. Vasari (1558) used the term "theory" in art. Vasari considered a theory as a set of views that had to be implemented by artists. Claude Perrault translated the Latin term "ratiocination" (meaning reasoning, calculation, rational thinking, and theorization) into theory (Mallgrave 2010).The architectural theory seeks to discover systematic functions, patterns, and structures and identify causal relationships between phenomena in an artificial environment. Then, the roles of these discovered rules in designs are investigated, and they are exploited to improve the quality of the environment and predict and solve future phenomena and problems (Asgharzadeh 2014). Furthermore, it is defined as realizing characteristic and common architectural rules from different formic and conceptual aspects and attempting to develop these principles in the form of goal models. The architectural theory involves any architectural writing system, whether comprehensive or incomprehensive, based on aesthetic or functional classifications. Architectural theory and history have the same meaning, and the current situation represents a period of a historical trend, and architectural theory should be viewed as a principle in its entire historical context (Kruft 1994). Vitruvius' ten architectural books written in the early first century AD are a prominent example of ancient architectural theory. In fact, Vitruvius' books have been the core of all efforts made to develop and systematize the scientific fundamentals of architecture. Apart from the definition of architectural theory, it is important to consider architecture theory as a principle in its historical context (Asgharzadeh 2014). From a phenomenological perspective, in order to make design decisions, designers build theories, use different techniques to arrange design components, or adopt heterogeneous and contradictory theories separately or collectively and impose effects on the design. Therefore, design is a subject dependent, influencing and structuring theory The diversity of theories and their effects on the success of a design demonstrates the importance of theories in design. Also, theory and design are mutually dependent on each other in the design process (Pourdeyhami, 2014). Moreover, many factors are involved in the design of industrialized buildings, such as fabrication, economy, and human factors. Apart from the function-oriented and economic nature, the approach to architecture in the design of industrialized spaces could determine the importance of design factors. Some major factors include (1) economic aspects, (2) functional requirements, (3) security and safety, (4) human resource-related aspects, (5) aesthetics, (6) socio-cultural aspects, (7) higher rules and regulations, (8) technology, and (9) environmental aspects. These factors can be classified into the three aforementioned principles of Vitruvius based on Battista's views as the most important theoretical tradition of the modern era, as shown in Fig 3.

9. CLASSIFICATION OF VITRUVIUS' PRINCIPLE CRITERIA IN BUILDING INDUSTRIALIZATION

Based on Vitruvius' three principles, one can develop and code a list of Vitruvius criteria and building industrialization components with the highest effects in the views of experts, as reported in Table 2.

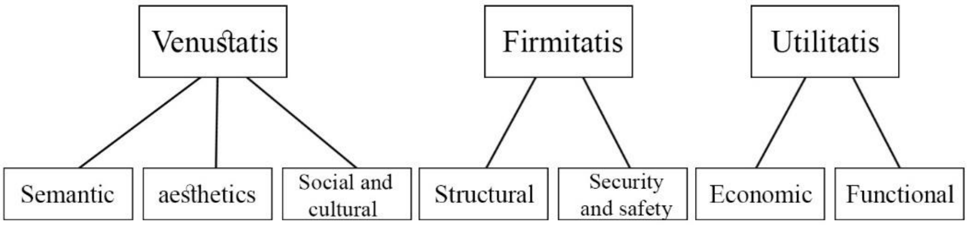

Fig 3. Division of Vitrovius Principles

Table 2. Coding of industrialization factors based on the three principles of Vitrovius

Venustatis			Firmitatis			Utilitatis		
Criterion	Factor	code	Criterion	Factor	code	Criterion	Factor	code
Semantic	Convenient visual landscape	V-01	Security and safety	The long useful life of the building	F-01	Functional	The proportion of manpower to production	U-01
	The presence of nature	V-02		Ability to recycle materials	F-02		The convenient location of the building in the city	U-02
	Identity-building elements	V-03		material availability	F-03		Placement of spaces without restrictions	U-03
	Visual and perceptual correlation	V-04		Fire safety	F-04		Production planning	U-04
	Proper organization between spaces	V-05		Coherence and integration between components	F-05		No delay in project scheduling	U-05
	High quality design of spaces	V-06	Structural	Resistance to lateral forces such as earthquakes and winds	F-06		Preparation of very detailed architectural plans and structures and facilities	U-06
	Perceptibility of form	V-07		Consumption of consumable materials against environmental erosion	F-07		non-employment of inexpert workforces	U-07
	Readability in visual perception	V-08		shear strength of connections	F-08		production support regulations	U-08
	Creativity in design	V-09		Ability to load a variety	F-09		Ability to use efficient and up-to-date technology	U-09
aesthetics	Proportion between components	V-10		Resistance to compressive forces	F-10	Economic	mass construction	U-10
	Coordination and harmony between building components	V-11		The lightness of materials compared to bearing	F-11		cost-effectiveness	U-11
	Variety in form design	V-12					Reduce production time, including the cost of raw materials and production and wages	U-12
	Visual decorations on the facade	V-13					Reducing energy consumption	U-13
	Variety in materials	V-14					Land occupation optimization	U-14
Social and cultural	Matching spaces with activities Humans	V-15					financial and legal support from organizations and the government	U-15
	Production at various scales	V-16					construction time reduction	U-16
	Elegance in detail	V-17					Reduce resource waste	U-17
	The fit between the building and the needs of the users	V-18						
	Psychological connection of users with the building form	V-19						
	Coordination of material appearance with culture and social identity	V-20						
	Proper visual compatibility with other buildings	V-21						
	Ability to be symbolic	V-22						
	Communicating semantically with the audience	V-23						

10. METHODOLOGY

This study sought to evaluate criteria influencing building industrialization in Iran based on Vitruvius' principles of architecture. The first phase of the study reviewed studies on industrialization and Vitruvius' principles. The second phase was survey research and adopted a questionnaire with 51 items with the five-point Likert scale, including 23 beauty-related items, 11 stability-related items, and 17 utility-related items. The validity of the questionnaire was tested by experts. The modified questionnaire was delivered to the respondents. Also, Cronbach's alpha was calculated to be greater than 0.7 in SPSS V.16.0 for all three criteria (Table 3).

Table 3. Cronbach's alpha

principles	questions	Cronbach's alpha
Venustatis	23	0.88
Utilitatis	17	0.836
Firmitatis	11	0.885

This demonstrated the proper reliability of the questionnaire to collect data. The respondents were asked to evaluate the importance of the criteria in Table 1. Hence, the present study is theoretical research in literature and an empirical work. It is also survey research in terms of the context and applied research in terms of objectives. A total of 35 questionnaires were delivered, 28 of which were received in responded form (i.e., 93.3% participation). 53.57% of the respondents were construction engineers, 35.71% were academic professors, and the remaining 10.72% were construction contractors (Fig 4). Furthermore, 39.29% of the respondents had master's degrees, 25% had Ph.D. degrees, and 35.71% had bachelor's degrees. 53.57% of the respondents had an age of 35-45 years, 39.28% were 25-34 years old, and the remaining 7.15% were above 54 years of age.

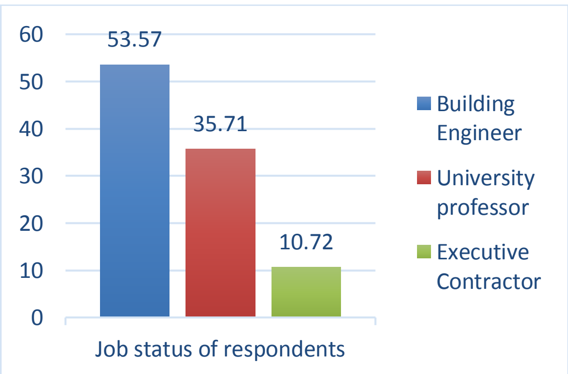

Fig 4. job status of the respondents

11. DATA ANALYSIS

The most important criteria of utility, stability, and beauty could be ranked based on the responses. The average scores of the factors of the principles were calculated using the one-sample t-test, as shown in Fig 5. As can be seen, stability was found to be the most important criterion, while utility and beauty ranked second and third, respectively.

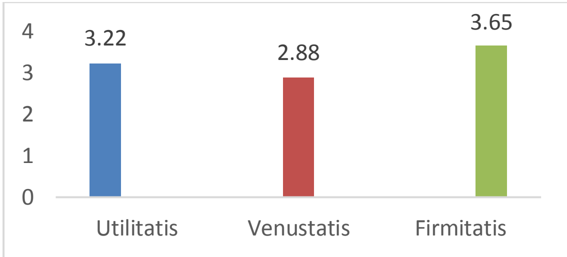

Fig 5. The average score of efficiency, strength and beauty using one-sample T-test (t-test)

The paired-sample t-test was used to investigate the significance (sig.<0.05) of differences between the variables, as reported in Table 4.

Table 4. The significance of the difference between the variables

	Utilitatis	Venustatis	Firmitatis
Utilitatis	0		
Venustatis	-3.80*	0	
Firmitatis	-4.52**	***-6.12	0
*Sig:0.001	**Sig:0.00	*** Sig:0.00	

The normality of data distribution was examined using the Kolmogorov–Smirnov (K-S) test. The p-value was found to be higher than 0.05, suggesting a normal data distribution. The K-S results showed that all the variables had normal distributions, as shown in Table 5.

Table 5. Normality of the data

	Firmitatis	Venustatis	Utilitatis
Kolmogorov–Smirnov	0.172	0.157	0.088
Sig	0.034	0.20	0.075

Based on the responses, the 51 most important factors of utility, beauty, and stability were identified, calculating the scores of the factors, as shown in Table6. The trend investigation of the average scores revealed breakages at three points in the linear curve of the average scores. Thus, these factors could be divided into four importance levels (Fig.6). The highest level of importance included resistance to lateral loads (such as an earthquake- and wind-induced loads), the shear strength of connections, cost-effectiveness, construction time reduction, and mass construction for the principle of utility.

Although this trend line determines the importance of the factors through a simple ranking based on their average scores, it does not consider the consensus among the responses of the participants. To find the relationship between the importance of factors and the consensus among the respondents, the average scores and standard deviations were normalized to be compared. Fig. 7 represents the distribution of two normalized variables (data and standard deviation), in which the average value of each axis was used to divide the factors into four groups based on their effects (i.e., importance and consensus).

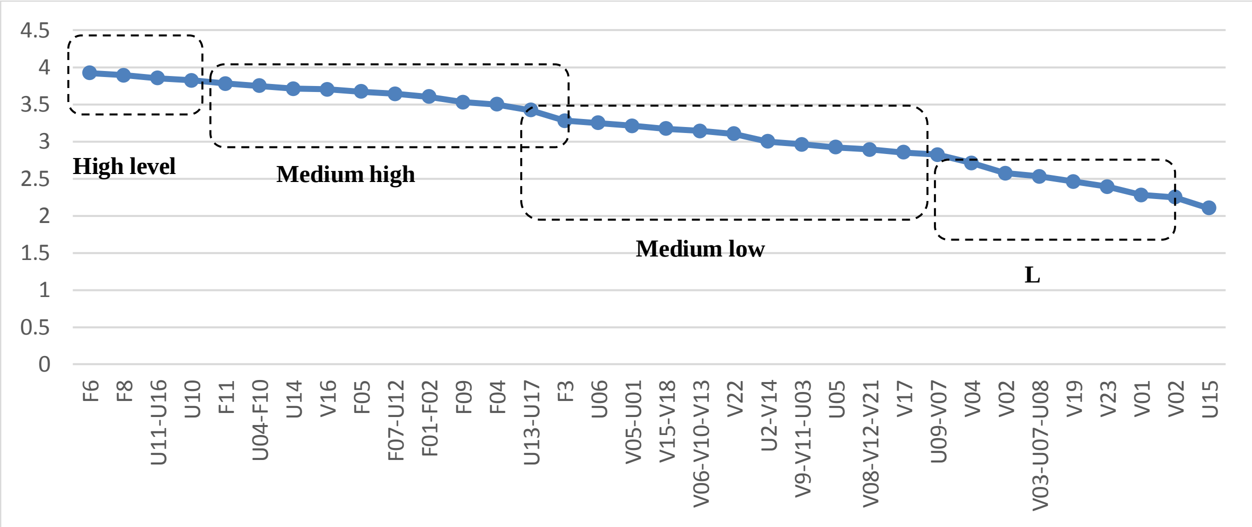

Fig 6. The level of importance of the criteria of the three principles of efficiency, strength and beauty

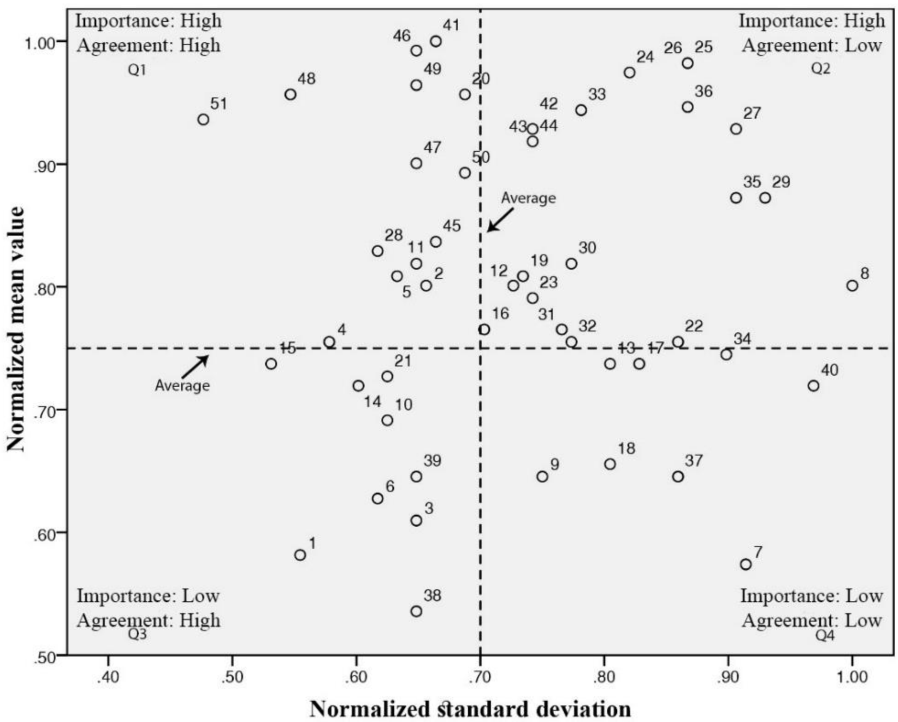

Fig 7. normalized standard deviation

As can be seen, 14 of the 51 factors high levels of importance with significant consensus among the participants, including fabrication at a variable scale, properly organizing spaces, the suitability of buildings for user requirements, the proportionality of components in terms of beauty, providing accurate architectural, structural, and installation drawings in terms of utility, resistance to lateral loads such as an earthquake- and wind-induced loads, the shear strength of connections, high bearing capacity/weight ratios, high compressive strength, integrated components, the capability of resisting different loads, fire safety, and material availability in terms of stability. These factors of the three principles have the highest potential to influence the implementation of building industrialization in Iran.

12. RANKING SUSTAINABLE DEVELOPMENT FACTORS IN THE INDUSTRIALIZATION OF OFFICE BUILDINGS

Based on the ranks, stability factors were found to be the most influential factors, including high building service life and lateral load resistance (e.g., earthquakes and wind). The next ranks involved the building location in the city, proper arrangement of spaces, proportionality of workforces and fabrication in the principle of utility. The highest-scored factors of the beauty principle included consistency of the appearance with socio-cultural aspects, while the remaining factors were not found to have a high level of importance (Table 6).

Table 6. Ranking the factors of the components of the three principles of beauty, efficiency and strength based on the respondents (MH=medium high/ML=medium low/H=high/L=low)

Vitruvius's Three Principles		Mean Value	Standard deviation	Overall Importance Based on Fig 6	Overall Influence Based on Fig 7
Venustatis					
V-16	Production at various scales	3.70	0.99	MH	Q1
V-05	Proper organization between spaces	3.21	0.83	ML	Q1
V-15	Matching spaces with human activities	3.17	0.81	ML	Q2
V-18	The fit between the building and the needs of the users	3.17	0.81	ML	Q1
V-06	High quality design of spaces	3.14	0.84	ML	Q2
V-10	Proportion between components	3.14	1.23	ML	Q1
V-13	Visual decorations on the facade	3.14	0.93	ML	Q2
V-22	Ability to be symbolic	3.10	0.95	ML	Q2
V-14	Variety in materials	3.00	0.90	ML	Q2
V-09	Creativity in design	2.96	0.74	ML	Q2
V-11	Coordination and harmony between building components	2.96	1.10	ML	Q3
V-08	Readability in visual perception	2.89	1.03	ML	Q3
V-12	Variety in form design	2.89	0.68	ML	Q4
V-21	Proper visual compatibility with other buildings	2.89	1.06	ML	Q4
V-17	Elegance in detail	2.85	0.80	ML	Q3
V-07	Perceptibility of the form	2.82	0.77	ML	Q3
V-04	Visual and perceptual correlation	2.71	0.80	ML	Q3
V-02	The presence of nature	2.57	1.03	L	Q4
V-03	Identity-building elements	2.53	0.96	L	Q4
V-19	Psychological connection of users with the building form	2.46	0.79	L	Q3
V-23	Communicating semantically with the audience	2.39	0.83	L	Q3
V-01	Convenient visual landscape	2.28	0.71	L	Q3
V-20	Coordinating the appearance of materials with culture and social factors	2.25	1.17	L	Q4
Utilitatis					
U-11	cost-effectiveness	3.85	1.11	H	Q2
U-16	construction time reduction	3.85	1.11	H	Q2
U-10	Mass production capability	3.82	1.05	H	Q2
U-04	mass construction	3.75	1.00	MH	Q2
U-14	Land occupation optimization	3.71	1.11	MH	Q2

U-12	Reduce production time, including the cost of raw materials and production and wages	3.64	1.16	MH	Q2
U-13	Reducing energy consumption	3.42	1.19	MH	Q2
U-17	Reduce resource waste	3.42	1.16	MH	Q3
U-06	Preparation of very detailed architectural plans and structures and facilities	3.25	0.79	ML	Q1
U-01	Proportion of manpower to production	3.21	0.99	ML	Q2
U-02	Convenient location of the building in the city	3.00	0.98	ML	Q2
U-03	Placement of spaces without restrictions	2.96	0.99	ML	Q2
U-05	No delay in project scheduling	2.92	1.15	ML	Q4
U-09	Ability to use efficient and up-to-date technology	2.82	1.24	ML	Q4
U-07	non-employment of inexpert workforces	2.53	1.10	L	Q4
U-08	production support regulations	2.53	0.83	L	Q3
U-15	financial and legal support from organizations and the government	2.10	1.24	L	Q3
Firmitatis					
F-06	lateral loads such as earthquake- and wind-induced loads	3.92	0.85	H	Q1
F-08	shear strength of connections	3.89	0.83	H	Q1
F-11	Lightness of materials compared to bearing	3.78	0.83	MH	Q1
F-10	Resistance to compressive forces	3.75	0.70	MH	Q1
F-05	Coherence and integration between components	3.67	0.61	MH	Q1
F-07	Consumption of consumable materials against environmental erosion	3.64	0.95	MH	Q2
F-01	Long useful life of the building	3.60	0.95	MH	Q2
F-02	Ability to recycle materials	3.60	0.95	MH	Q2
F-09	Ability to load a variety	3.53	0.83	MH	Q1
F-04	Fire safety	3.50	0.88	MH	Q1
F-03	material availability	3.28	0.85	L	Q1

13. CONCLUSION

Among the three principles of Vitruvius, stability was found to have the highest level of importance, which includes structural, security, and safety factors in building industrialization. Stability had the largest importance. Among the factors of stability, resistance to lateral loads such as an earthquake- and wind-induced loads (F-06) and the shear strength of connections (F-08) had the highest importance in the responses. Given that Iran is an earthquake-prone country and stability is the most important criterion in the views of experts, industrialization could be adopted as a proper approach to natural disasters. Moreover, material availability (F-03) had the lowest rank in the principle of stability. To facilitate the availability of materials across Iran, all the relevant organizations are required to provide investment and support. The utility was found to be the second most important principle in the responses. Among the factors of utility, cost-effectiveness (U-11), construction time reduction (U-16), and mass construction (U-10) had the highest ranks. These three factors of the principle of efficiency by being included in the economic criteria of industrial buildings show that the economic potential of these buildings can be considered due to the conditions that exist today due to the increase in construction costs in Iran. In the principle of utility, the non-employment of inexpert workforces (U-07), the lack of production support regulations (U-08), and the lack of financial and legal support from organizations and the government (U-15) are industrialization problems that need higher attention from relevant organizations and authorities. Beauty was ranked third. The low rank and its beauty standards indicate the lack of architectural beauty views in the design of IBS. Given that beauty is a key principle of architecture, it is required that designers consider beauty as much as the two other principles so that not only beauty is brought in building industrialization but also consumers are encouraged to use industrialized buildings. Overall, it can be said that industrialization and Vitruvius' principles and criteria are of great importance and are in a positive, direct relationship in the Iranian construction industry. Given the shortage of water and natural resources, environmental degradation, and earthquake proneness in Iran, building industrialization could be adopted as a proper and sustainable approach. It is possible to take a step toward the development of building industrialization in Iran by implementing the regulations, standards, and methods, meeting requirements to encourage investors to make investments, providing sufficient legal and financial support, transferring knowledge, and employing approved system codes.

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AUTHOR (S) BIOSKETCHES

A. mardani., *Department of architecture, Abadan Branch, Islamic Azad University, Abadan, Iran*
Email: *ali_mardani4563@yahoo.com*

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