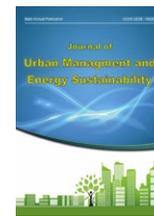


Journal of Urban Management and Energy Sustainability (JUMES)

Homepage: <http://www.ijumes.com>



ORIGINAL RESEARCH PAPER

Explaining the role of cast shadow on the perception of architectural form

Mahnaz Sadat Hashemi, Azhang Baghaei*, Reza Afhami

Department of architecture, Faculty of art, architecture and urbanism, Islamic Azad university of Kerman branch, Kerman, Iran

ARTICLE INFO

Article History:

Received 2022-07-16

Revised 2022-10-17

Accepted 2022-12-18

Keywords:

Architectural building

architectural form

cast shadow

Delphi method

perception

ABSTRACT

Perception is a process based on the combination of sensory information and expectations based on experience through which a person selects the necessary data based on his needs from his surrounding environment. Cast shadow, as the concept of light passing through the architectural form, plays a significant role in the viewer's understanding of the building. This research is of a descriptive-analytical type, which has a development aim. Still, its fundamental characteristic can be pointed out, especially in explaining the depth of the theoretical foundations, the proposed model, and the framework. The collection method was library and survey, and sampling. To express the role of shadows in the perception of architecture, this research tried to describe the factors and indicators that are effective in the perceptual process. After examining the basic structure, factors were extracted from the research framework, using the Delphi method as the final indicator. A proposal is presented in the form of a structural model. Finally, it was found that the volumetric structure, time, roughness, and depth indexes have the highest scores with an average of 5.96, 5.30, 5.21, and 5.20, respectively, and as a result, they have the most significant impact. In future research, methods such as HSE were used to examine the qualitative states of the respondents and the type of interview and its testing. They evaluated its results in a specific architectural building.

DOI: [10.22034/jumes.2022.1990302.1118](https://doi.org/10.22034/jumes.2022.1990302.1118)

Running Title: The role of cast shadow on the perception of architectural form



NUMBER OF REFERENCES

21



NUMBER OF FIGURES

04



NUMBER OF TABLES

04

*Corresponding Author:

Email: azhang.baghaei@gmail.com

Phone: +989132965351

ORCID: <https://orcid.org/0000-0001-5312-2763>

1. Introduction

Human perception is one of the crucial issues investigated from different aspects today. Human perception of architectural form depends on various light conditions, and the type of light that enters changes our perception of the volume of architecture. Shadow, an element applied in architectural and landscape design, can decorate, neutralize, or even strengthen the volume. The shadow can also make the design look lively and memorable. The effects of shadow break the visual limitation and increase the concept of artistic perception of architectural volume (Ghasemi, 2018). As the light shines on the front surface of the building and pushes the shadow back, the volume of the shadow is very effective in understanding the building's form, shape, depth, and hierarchy. The intelligence of shadows strengthens this thinking to understand shadows. A tool must first be introduced to make our understanding sensitive and active in understanding shadows so that it can be evaluated in this approach of studies. Research shows that there is a direct and positive relationship between the quality of architecture and shadows, and knowing the interaction between the two is of particular importance in increasing the productivity of architecture. (Shah Tahmasebi and et al., 2013) The way we classify shadows is based on the way we perceive them. (Alder-Golden and et al., 2002). There is a difference between what exists as an architectural form and what the observer perceives from the form in different conditions. The current research intends to express the role of cast shadows in the perception of architecture. There is an attempt to describe the factors and indicators affecting the perceptual process so that case examples can be evaluated by obtaining a specific structure. The main questions that are investigated in this research are in the Field of what and how the process and perceptual components of the form are from the perspective of the observer who mediates the level and type of his understanding of the shadow. The main question is; What are the indicators of the influence of cast shadows in the understanding of architectural form?

The necessity of investigating the extent and manner of this effect and many architectural styles by obtaining the scope and importance of the cast

shadows' impact on the architectural building can be mastered. So in this aesthetic quality that occurs without light, the element can be a more significant, more attractive architectural form.

2. Materials and Methods

Perception is a process based on the combination of sensory information and expectations based on experience through which a person selects the necessary data based on his needs from his surrounding environment. Therefore, this process is purposeful and depends on the culture, attitude, and value that governs the thinking of the perceiver. Environmental perception occurs from the interaction of sensory perception and cognition experienced in the human mind. In this process, the environment's role is considered a fundamental factor in growth, development, and, finally in, learning. The human visual system operates in a natural visual environment and perceives the structure of light and shadow. The fact that the visual system is sensitive to this scene feature and corresponds to the visual perception is logical and wholly based on the human perceptual system. Assumptions regarding the position of the light source, e.g., the sun, which has a direct effect on the process of shadow perception, show that the form details of each surface are a substrate that causes different sensory perception due to the material and form of the character and whether there is a matte or three-dimensional surface. (Khuu and Khambiye, 2012; Khuu, Moreland and Phu, 2011; Kleffner and Ramachandran, 1992; Ramachandran, 1988; Yonas, 1979) Therefore, by creating continuity in the surfaces shadow type, a doubt with a dimension in the level of perception can be made. (Dee and Santos, 2011). In a way, the shadow can evoke in mind the kind of human perception resulting from the form by its regular passage over the surfaces with texture and shape (indentation and depression). In a way, it can be considered a characteristic of the form itself. (Gombrich, 1995; Mamassian, 2004) The three-dimensional position created for the objects on the wall form also indicates marking a dimension in mind. (Allen, 1999; Hubona, Wheeler, Shirah; Brandt, 1998). cast shadow plays an essential role in the architectural form perception like an actor can in

the mental perception of the audience in a way that the levels of depth and details for the desired level are considered the characteristic of the building's architectural wall. (Kersten, Mamassian; Knill, 1997). The visual system can understand the cast shadow as a three-dimensional sequential sign, and the position of objects according to the direction of their movement in the viewer's mind can be considered as the details of the building. (Khuu, Gordon, Balcomb; Kim, 2014). Objects in question, e.g., particular decoration in historic buildings, are the primary source of the shadow.

The correspondence between an object and the cast shadow on it is mainly derived from a comparison between their edge structures, and the main criterion for Paying attention to it is the type and amount of depth it creates. (Casati, 2008). And in fact, the exact match between the boundary lines of the object and the shadow falling on it is very important because the nervous system, due to its analytical power, sometimes cannot recognize the boundary between the object and the shadow falling on it. (Mamassian, 2004) In this way, this stunning contrasts, which cause pleasure in the perception of the details of the architects of the surfaces of historical buildings, can be understood more. (Figure 1) According to the mentioned example, it is clear that the behavior of the cast shadow in the form

of falling during the hours of 9 to 6 in the evening somehow has differences in the perception by the viewer in the six areas specified in the image.

When the sunlight after sunrise has greater intensity and a lower angle, it casts a shadow on all six areas from the outer edge of the columns to the exterior brick decorations. After that, the shadow starts to move inward and increase the depth. This depth is more visible behind the columns of the door facades and the wooden surface of the door itself. Therefore, depth and surface change can be explained as the two main features of falling shadows in creating interconnected perceptions. At the same time, the existing contours on the surface of the decorations represent each dynamic unit for changing the behavior of the shadow. But both the light and background level direction is effective in the movement type and shadow perception. (Dee and Santos, 2011). Research by researchers has recently shown that the nervous system of the human brain perceives spatial lines by serially connecting elements of the substrate that have similar characteristics as a gestalt whole. (Field, Hayes; Hess, 2018; Hess and Field, 2019) The ability of the visual system to distinguish two-dimensional lines is well explained by the association field model presented by Field et al. (1993) expresses the degree of integration of the surface elements of

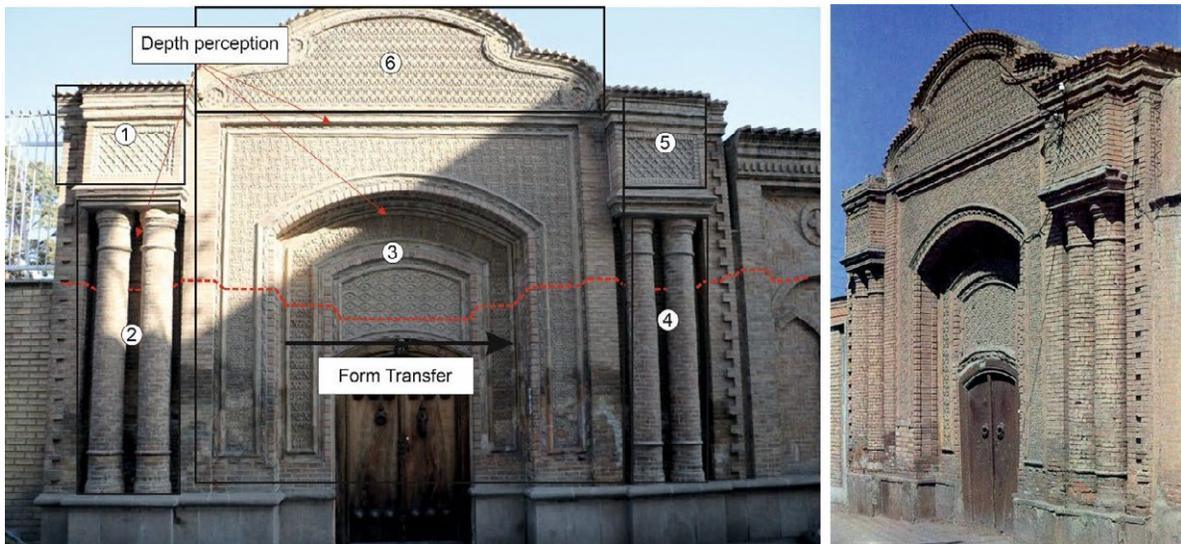


Fig. 1: Main entrance door of Balurchian house, belonging to the Qajar period, Tabriz, Iran

the form (to form a contour) based on a grouping. These factors include similarity in substrate surface orientation, proximity, and location. The nervous system has a structure that integrates a network of connections and horizontal elements between oriented units in the vicinity of each other in the cerebral cortex. The high level of detail and contour in each of them, in addition to changing the type of shadow, has a different perception of time and quality. For example, [Hess and Field \(1997\)](#) experimented with the audience's perception with me of simple surfaces without details and surfaces with contours. It was found that surfaces with details and texture have more time for perception. (Figure 2)

In the continuation of the research, it has been well shown that the shadow may facilitate the process of integrating details and contours and create a unified form in the audience's mind. A study by [Rensink and Cavanagh \(2004\)](#) showed that it is possible to use the shadows cast on elevated surfaces to identify by visual patterning, in which elements in different orientations exhibit specific and predictable behavior in They have the same shade. In general, this behavior can be perceived in the fundamental changes in the architectural form and in its details. In an experiment conducted by [Khuu et al. \(2016\)](#), it was

found that the shadow falls in two experiments brought exciting results.

- 1- In the first experiment, the signals sent from the audience's brain and the subject's brain in detecting the contour were more inclined according to the depth factor.
- 2- Changing the shadow by shaking and changing the position of the surface affects how it is perceived. A significant amount of nervous system function is involved in both tests, bringing different results.

As a result, we can mention the scale and the volumetric structure of the surface, which is very important in form perception. In addition, the general importance of architectural style, which, in addition to the type of approach in form design, has a direct impact on the volume structure of the building. ([Pettet, 1999](#)) In this subject, the modern architectural style mainly has the shadow of fall in its whole and explains the amount of depth in the change of mass volume. ([Mathes and Fahle, 2007](#)) But in classical styles such as Gothic, Romanesque, and especially Art Nouveau, the structure of the building is introduced with details in which the movement of the shadow can travel a specific path and help to understand its beauty more. ([Jacobson and Werner, 2004](#)) The symmetry plane in the facade

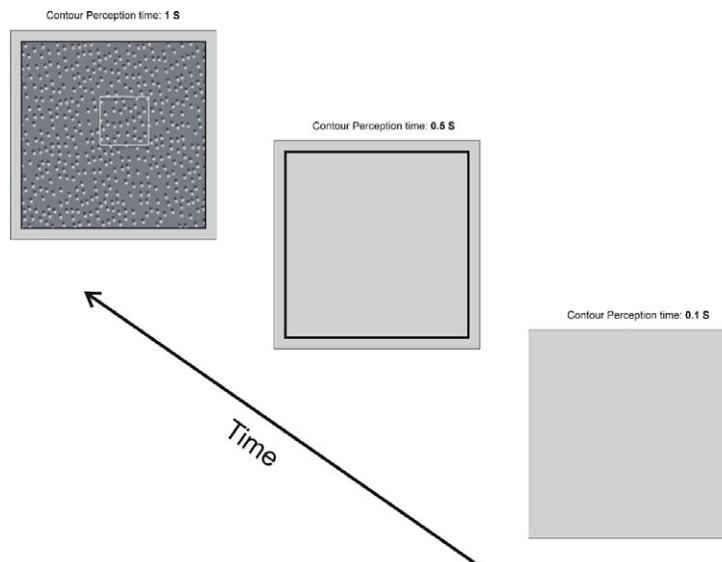


Figure 2: Perception time difference in three different surface types, reconstructed image ([Hess & Field, 1997](#))

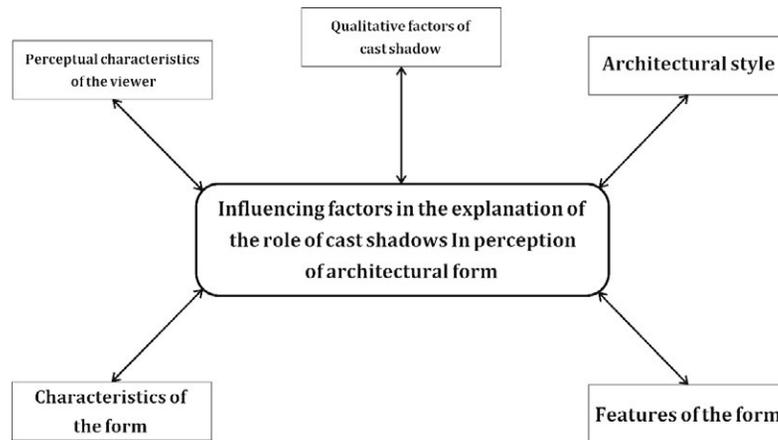


Figure 3: Components influencing the explanation of the role of shadows in the perception of architectural form

makes it possible to perceive the cast shadow in a greater depth and at a different time in styles with great details. Texture, materials, texturing design in the facade, the degree of porosity, and the type of openings can be effective in understanding the architectural form with the movement of shadows. (Ramachndran, 1999) Therefore, based on summarizing the theoretical foundations, a conceptual model can be presented for the components influencing the understanding of architecture by explaining the role of the cast shadow. (Figure 3)

Continuing the conceptual model explanation of the cast shadow effect on architectural perception, some points can play a significant role in the continuation of the research:

- The viewer's perceptual characteristics are considered the central pillar of this model. the viewer, with the type of awareness level and his mental patterns from the architectural styles of the buildings around him, obviously looks at the new architectural form with a kind of background. When someone analyzes the structure in mind, they try to create a pattern from the history of this type of form. This action in the audience's mind is scientifically called "synesthesia," which determines perception with this type of mind reading.

- Architectural style directly affects the perception of architectural form, and according to the audience's mentality, it is clearly in line with the type of culture and memories of the person.

The volumetric structure, plan features, texture, type of materials, etc., affect the form's cast shadow type. This architectural style determines what type and size of decorations will be in the form.

- The features and characteristics of the form are effective in their effect on the viewer, which, by taking into account that type of shadow, by taking its features, determines the perception in the audience's mind. Contrast, homogeneity, contrast, similarity, etc., are all perceived in a gestalt process, and the shadow is immersed in, the size or smallness of each part is defined, and the depth is increased or decreased so that the viewer can understand the volumetric structure.

3. Methodology

This research is of a descriptive-analytical type, which has a development aim. Still, its fundamental characteristic can be pointed out, especially in explaining the depth of the theoretical foundations, the proposed model, and the framework. The method of collecting information is in the form of a library and field from references such as the architecture department of academic institutions and international data and at the field level. First, we examine the theoretical foundations and the research background in procedure and content, where there is an emphasis on clarifying the goal, not repeating it. Factors are extracted from the research framework using the Delphi method to

Table 1: Round 1 of the fuzzy method in compiling the proposed indicators of the role of cast shadows on the perception of architectural form

No.	Factors	Number of responses	Average	Standard deviation	Min.	Max.
1	Volumetric structure	18	4/96	0/35	3	5
2	Direction of light	19	4/48	0/37	2	5
3	Light intensity	22	5/21	0/27	3	5
4	Type of surface	22	2/42	0/55	1	3
5	Surface change	18	4/10	0/37	2	4
6	Features of the plan	20	2/20	0/40	1	4
7	Material	23	2/45	0/25	1	5
8	Time	25	5/30	0/27	3	5
9	Background	22	2/21	0/45	1	4
10	Mental pattern	18	3/11	0/52	1	4
11	Distance vision	21	4/11	0/38	2	5
12	Height	22	2/48	0/42	1	4
13	Symmetry	23	5/41	0/47	1	5
14	Scale	21	2/40	0/60	2	4
15	Similarity	22	4/45	0/28	2	5
16	Homogeneity	24	4/25	0/41	2	5
17	Contrast	21	4/12	0/32	2	5
18	Position	22	2/32	0/35	1	5
19	Duration of vision	19	2/18	0/69	1	4
20	Proximity	21	4/15	0/45	2	5
21	Depth	22	4/85	0/28	3	5
22	Texture	20	4/65	0/36	2	5

provide the final indicators proposed as a model. We developed a Delphi method by an elite board of 11 people¹, including professors, specialists, and researchers in architecture, and provided a digital questionnaire using Google tools with a link for answers. The type of answers is also based on the Likert spectrum as very low, low, medium, high, and very high impact. The number of influencing factors on the architectural form perception is mentioned concerning the fall of the shadow. After going through stages including the specified average limit and calculating the Kendall coefficient for the answers, polling is stopped when a certain average is reached. The final indicators are proposed as a research

1. The panel of elites and experts includes 11 faculty members of Tehran University, Tabriz University of Arts, Isfahan University of Arts, as well as researchers of Islamic Azad University and Karaj University of Arts Research Institute.

framework. It will be given. In the following, the extracted indicators are explained as the primary model of the research as a result of using intermediate analysis.

4. Findings and Discussion

4.1. Findings of the implementation of the Delphi method

In the first round, the panel members identified eight factors out of 22 that were extracted from successful research as having a significant effect in formulating the framework of the role of shadow on the perception of architectural form. The detailed and extended results related to implementing the first stage of questionnaire distribution are given in the following table. The factors of surface type, plan features, material, background, height, scale, position, and duration of view have been removed from the Delphi

process due to their average importance of less than 2.5. (Table 1)

After the first stage, implementation of investigation and evaluation of the panel experts' opinion panel regarding the factors proposed and extracted from the theoretical bases and also receiving the suggestions of the panel members, in this round, to observe caution.

Extracted elements were again analyzed with the average opinion of the first round and the previous opinion of the same person. The panel members identified ten factors out of 14 elements present in the second round as having a high and very high impact (with an average greater than 3) on the proposed framework of the concept of the role of shadows on the perception of architectural form. The detailed and extended results related to the implementation of the second stage of questionnaire distribution are given in the following table. Kendall's coefficient of coordination for the members' answers about the order of the factors that had a high and very high influence in this round was 0.765, among which the factor of light intensity, mental pattern, similarity, and proximity has been removed. (Table 2)

In the third round of compiling the proposed indicators framework, the role of cast shadows on

the perception of the architectural form concept, together with the average opinion of the members in the second round and the previous opinion of the same member, was provided to all panel experts. The detailed and extended results related to implementing the third stage of questionnaire distribution are given in the table below. Kendall's correlation coefficient for members' answers about the order of the six factors was 0.790. (Table 3)

5. Result and Conclusion

5.1. Reasons for stopping polling

The results of the three rounds of implementing the Delphi method in the research show that a consensus has been reached among the panel members for the following reasons, and the repetition of the rounds can be ended:

1- In the second round, more than 50% of members, 14 influential factors in developing the proposed indicators framework, chose the concept of the role of shadow on the perception of the architectural form, which had an average greater than 2.5 among their factors.

2- The members' answers' standard deviation on the importance of the factors in the third round has decreased significantly compared to the previous rounds.

Table 2: Round 2 of the fuzzy method in compiling the proposed indicators of the role of CAST shadows on the perception of architectural form

No.	Factors	Number of responses	Average	Standard deviation	Min.	Max.
1	Volumetric structure	18	4/96	0/35	3	5
2	Direction of light	19	4/48	0/37	2	5
3	Light intensity	23	2/21	0/27	3	5
4	Surface change	18	4/10	0/37	2	4
5	Time	25	5/30	0/27	3	5
6	Mental pattern	18	2/98	0/52	1	4
7	Distance vision	21	4/12	0/39	2	5
8	Symmetry	23	5/41	0/48	1	5
9	Similarity	22	2/45	0/29	2	5
10	Homogeneity	24	4/25	0/41	2	5
11	Contrast	21	4/12	0/33	2	5
12	Proximity	21	2/15	0/46	2	5
13	Depth	22	4/85	0/29	3	5
14	Texture	20	4/65	0/36	2	5

Table 3: Round 3 of the fuzzy method in compiling the proposed indicators of the role of CAST shadows on the perception of architectural form

No.	Factors	Number of responses	Average	Standard deviation	Min.	Max.
1	Volumetric structure	18	5/96	0/35	3	5
2	Direction of light	19	448	0/37	2	5
3	Surface change	18	4/10	0/37	2	4
4	Time	25	5/30	0/27	3	5
5	Distance vision	21	4/11	0/38	2	5
6	Symmetry	23	5/21	0/47	1	5
7	Homogeneity	24	4/25	0/41	2	5
8	Contrast	21	4/12	0/32	2	5
9	Depth	22	5/20	0/28	3	5
10	Texture	20	4/65	0/36	2	5

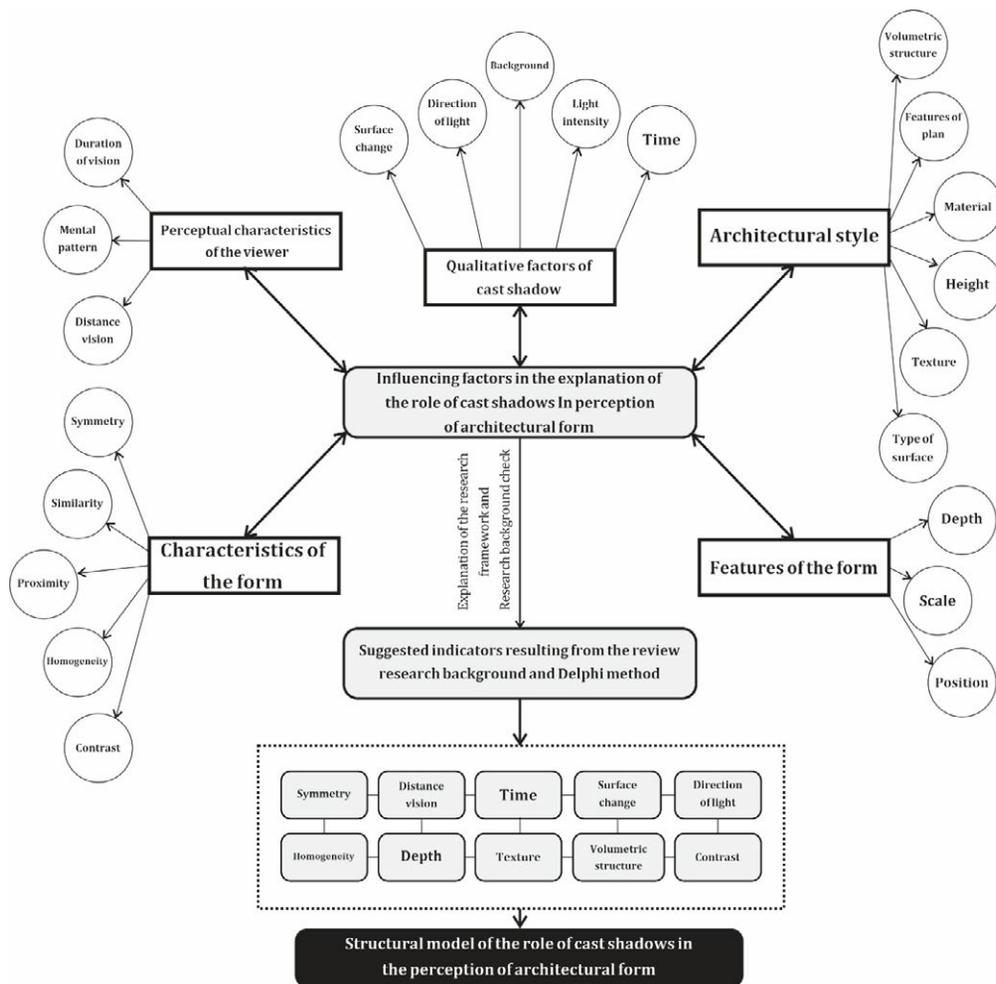


Figure 4: Structural model of the concept of the role of cast shadow on the perception of architectural form

Table 4: Indicator, index and evaluation tool as suggested indicators of the concept of the role of cast shadow on the perception of architectural form

Subject	Indicator	Index	Evaluation tool
Functional indicators of the role of cast shadow in the perception of architectural form	Direction of light	The angle of the sun on the surface	Quantitative method
	Contrast	The amount of difference in shapes	Analytical graphics
	Surface change	Changing the height figure	Quantitative method
	Time	The rate of change over time	Quantitative method
	Distance vision	The viewer's distance from the building	Quantitative method
	Symmetry	The degree of symmetry of shape	Analytical graphics
	Volumetric structure	Volume usage	Analytical graphics
	Texture	The amount of change in details	Analytical graphics
	Depth	The amount of light penetration	Quantitative method
	Homogeneity	Change the size of areas	Analytical graphics

3- Kendall's coordination coefficient for members' answers about the order of factors in the third round is 0.790. Considering that the number of panel members was more than ten, this amount of Kendall's coefficient is quite significant.

4- Kendall's coordination coefficient for the arrangement of the ten influential factors in compiling the proposed indicators of the role of cast shadow on the perception of architectural form in the third round compared to the second round only increased by 0.025. This coefficient or the degree of consensus between the panel members. Consecutive rounds do not show significant growth.

5- The points given to the factors by the experts and elites indicate that the indicators of volume structure, time, depth, and depth have the highest score and, as a result, the most impact in explaining the concept of the role of shadows on the perception of architectural form in the process of developing the framework of indicators. There are suggestions for form perception, which can be based on the structural model and the research framework (Figure 4) (Table 4).

According to the research process and examination of the theoretical foundations and use of the research background in the Delphi method to achieve the influential factors on the concept of shadow falling in the perception of architectural form, it is possible to predict the extent of the limitation of this type of structure. But in general, the effects of the final indicators of the kind of perception clearly have an impact

in addition to the type of example based on the psychology of the viewer, the level of awareness, and the status of the specialized advertisement. This type of impact on a person's mind can also be investigated according to the kind of observer and the environment. Finally, the proposed indicators can provide a specific structure of the type of analysis for the role of cast shadows in the understanding of the form in the first stage. In future studies, methods such as HSE It was used to check the qualitative conditions of the respondents as well as the type of interview and testing and evaluated the results in a certain way.

References

Adler-Golden, S.M.; Matthew, M.W.; Anderson, G.P.; Felde, G.W.; Gardner, J.A. (2002) In Algorithm for De-Shadowing Spectral Imagery; International Symposium on Optical Science and Technology; International Society for Optics and Photonics: Bellingham, WA, USA, pp. 203-210. <https://doi.org/10.1117/12.451691>

Allen, B. P. (1999). Shadows as sources of cues for distance of shadow-casting objects. *Perceptual and Motor Skills*, 89, 571-584. <https://doi.org/10.2466/pms.1999.89.2.571>

Casati, R. (2008). The copycat solution to the shadow correspondence problem. *Perception*, 37, 495-503. <https://doi.org/10.1068/p5588>

Dee, H. M.; Santos, P. E. (2011). The perception and content of cast shadows: An interdisciplinary review. *Spatial Cognition and Computation*, 11, 226-225. <https://doi.org/10.1080/13875868.2011.565396>

Field, D., Hayes, A.; Hess, R. F. (2000). The roles of polarity and symmetry in contour integration. *Spatial Vision*, 13, 51-66. <https://doi.org/10.1163/156856800741018>

Ghasemi, E. (2018). The Evolving Role of Digital Technology

- in Architectural Design. Online Journal of Engineering Sciences and Technologies, 1(3), 1-6. <http://www.ojest.ir/issue.aspx?id=6>
- Gombrich, E. H. (1995). Shadows: The depiction of cast shadows in western art. London, England: National Gallery Publications.
- Hess, R. F.; Field, D. J. (1995). Contour integration across depth. Vision Research, 35, 1699-1711. [https://doi.org/10.1016/0042-6989\(94\)00261-j](https://doi.org/10.1016/0042-6989(94)00261-j)
- Hess, R. F., Hayes, A.; Kingdom, A. A. (1997). Integrating contours within and through depth. Vision Research, 37, 691-696. [https://doi.org/10.1016/S0042-6989\(96\)00215-5](https://doi.org/10.1016/S0042-6989(96)00215-5)
- Jacobson, J.; Werner, S. (2004). Why cast shadows are expendable: Insensitivity of human observers and the inherent ambiguity of cast shadows in pictorial art. Perception, 33, 1369-1383. <https://doi.org/10.1068/p5320>
- Kersten, D., Knill, D. C., Mamassian, P.; Bulthoff, I. (1996). Illusory motion from shadows. Nature, 379, 31. <https://doi.org/10.1038/379031a0>
- Khuu, S. K.; Khambiye, S. (2012). The influence of shape-from-shading information on the perception of global motion. Vision Research, 55, 1-10. <https://doi.org/10.1016/j.visres.2012.01.004>
- Khuu, S. K., Gordon, J., Balcomb, K.; Kim, J. (2014). The perception of three-dimensional cast shadow structure is dependent on visual awareness. Journal of Vision, 14, 1-16. <https://doi.org/10.1167/14.3.25>
- Khuu, S. K., Moreland, A.; Phu, J. (2011). The role of shape-from-shading information in the perception of local and global form in glass patterns. Journal of Vision, 11, 20, 1-13. <https://doi.org/10.1167/11.7.20>
- Kleffner, D. A.; Ramachandran, V. S. (1992). On the perception of shape from shading. Attention, Perception and Psychophysics, 52, 18-36. <https://doi.org/10.3758/BF03206757>
- Mamassian, P., Knill, D. C.; Kersten, D. (1998). The perception of cast shadows. Trends in Cognitive Sciences, 2, 288-295. [https://doi.org/10.1016/S1364-6613\(98\)01204-2](https://doi.org/10.1016/S1364-6613(98)01204-2)
- Mathes, B.; Fahle, M. (2007). Closure facilitates contour integration. Vision Research, 47, 818-827. <https://doi.org/10.1016/j.visres.2006.11.014>
- Pettet, M. W. (1999). Shape and contour detection. Vision Research, 39, 551-557. [https://doi.org/10.1016/S0042-6989\(98\)00130-8](https://doi.org/10.1016/S0042-6989(98)00130-8)
- Ramachandran, V. S. (1988). Perception of shape from shading. Nature, 331, 163-166. <https://doi.org/10.1038/331163a0>
- Rensink, R. A.; Cavanagh, P. (2004). Influence of cast shadows on visual search. Perception, 33, 1339-1358. <https://doi.org/10.1068/p5322>
- Shahtahmassebi, A.; Yang, N.; Wang, K.; Moore, N.; Shen, Z. (2013) Review of shadow detection and deshadowing methods in remote sensing. Chin. Geograph. Sci., 23, 403-420. <https://doi.org/10.1007/s11769-013-0613-x>

COPYRIGHTS

©2022 The author(s). This is an open access article distributed under the terms of the Creative Commons Attribution (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, as long as the original authors and source are cited. No permission is required from the authors or the publishers.



HOW TO CITE THIS ARTICLE

Sadat Hashemi, M.; Baghaei, A.; Afhami, R. (2022). Explaining the role of cast shadow on the perception of architectural form. J Urban Manage Energy Sustainability, 4(2): 235-244.

DOI: [10.22034/jumes.2022.1990302.1118](https://doi.org/10.22034/jumes.2022.1990302.1118)

