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A STUDY ON VISUAL QUALITY INDEXES IN RESIDENTIAL COMPLEXES THROUGH SPACE SYNTAX WITH A PERCEPTUAL AND BEHAVIORAL PERSPECTIVE

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Abstract

This work aims to measure the impact of different spatial arrangements in residential blocks to improve the indicators of comfort, visual quality, and daylight distribution in residential complexes. The effect of various variables on the layout of residential complexes in Iran as a case study is considered by a combination of desk work and field survey, Depthmap software, Isovist tool, Relux software, and statistical analysis. The typology and classification of these residential complexes via Formic analysis, based on a quantitative method have been done. Then, the obtained layouts have been homogenized by the "normalization" method to prevent the impact of around inconsistent urban space as an intervening factor. In the next step, the visual quality indicators of the layouts include the Connectivity index, the Maximum Radial Line, and the Visual Mean Depth using the Isovist tool as well as Illuminance and Uniformity rate indices have been carried through Relux software. The results show that the physical-spatial arrangements of each layout of residential complexes are effective elements in the uniform distribution of daylight and improving the space's visual quality. Furthermore, the correlation between Isovist indicators (indicating the visual quality of layouts) and daylight variables are seen. Among the nine studied layouts, singular layouts provide an acceptable space in terms of visual quality indicators and daylight. Indeed, singular layout B is known as the optimal layout. This research can also lead to the development of optimal architectural designs among students and architects in educational and research centers.

Keywords: Isovist analysis, Daylight, Residential complex layout, Relux software, Visual comfort.

I INTRODUCTION

The visual environment of residential complexes is an important part of the human-understandable environment whose quality significantly impacts people's perceptual experience of the environment [1, 2, 3, 4]. In addition, increasing the perceptual quality of residential spaces -which includes many items such as their visual quality - is an increasing necessity that has engaged designers such as architects and urban planners. Therefore, presenting a tool to measure the visual quality of residential complexes is necessary and can be an effective step in developing the users' visual perception quality. In this way, some theories such as "Kaplan's information model",

"evaluative image", and "landscape-shelter theory" indicate that human experience of the environment and his visual perceptual experience depends on the physical and spatial characteristics of the environment. Therefore, the method should be able to evaluate the visual quality of the environment through its physical and spatial characteristics. In this regard, the theory of "space Syntax" is an analytical tool in architecture and urban planning which provides the environment analysis and understanding based on physical-spatial characteristics. Also, visual context analysis (or Isovist) is one of the main components in the theory of spatial arrangement, which is used to measure the environment's visual quality.

Numerous studies have shown the relation between Isovist characteristics and people's perceptual experience of the environment [5, 6]. Furthermore, the existence of possible minor errors for this relation and its generalizability in all societies not only has not diminished the value of this tool and its applicability but only indicates the need to adapt this tool to its used contexts. Also, the literature in the field of urban planning and architecture indicates continuous efforts to achieve methods for analyzing the environment through its physical and spatial characteristics. On the other hand, looking for an analytical tool in this field became effective in "space syntax" theory. Spatial arrangement is an analytical theory and tool in architecture and urban planning. Its origins can be found in Bill Hillier's first book is called “The Social Logic of Space”. In a general definition, space syntax is a theory that focuses on the structural aspect of space. The important point is that space syntax theory and its method are not just a simple modeling tool; Rather, it is a way for understanding the urban complexities, morphological logic, and pattern of development, as well as the patterns of behavior in the urban spaces [7].

Based on this theory, several methods have been developed to analyze the various aspects of cities. Among the items that have been created, invented, and developed to analyze the visual quality of the environment, we can mention Isovist and line analysis. To find the application of Isovist in perceptual domains, Benedict and Burnham demonstrated the influence of Isovist components on the perception of space and proved that "spatial" perception is related to the complexity of the visual context of space[8]. In this regard, Taher and Brown analyzed the traditional houses of Mumbai and showed that the visual background of the houses (their Isovist characteristics) is related to the privacy needs of the occupants[9]. Also, Franz and Weiner sought the relationship between the experimental qualities of space and their visual backgrounds (Isovist). They showed a significant relationship between spatial properties and perceptual response to space[10]. Continuing research on the application of Isovist in architecture has provided researchers with powerful analytical tools. In this regard, Dawes et al. Examined and demonstrated the landscape-shelter theory using the Isovist tool in Frank Lloyd Wright's textile-block houses, despite Hildebrand calling these houses a prominent model of the landscape-shelter. Knows But there is no quantitative evidence to suggest the existence of this particular pattern in them. Furthermore, Dezbek showed that the perceptual response of the participants in the virtual experiments was significantly correlated with the Isovist area indices. He also showed in another study that the area of Isovist is correlated with the perception of spatiality, and the number of Isovist vertices is negatively correlated with sociability [11]. In this context, Wiener et al. Acknowledged the usefulness of Isovist analysis and showed that this method is a promising tool for predicting the experimental quality of architecture and the exploitation movement in space[12]. Summarizing the theories and research done on Isovist indicate its importance in the analysis of the constructed environment, based on the audience's visual perception. At the same time, despite numerous researches in this field, the authors' search for a study that used Isovist in measuring the visual quality of residential complexes did not yield any clear results, which indicates a research gap in this field. On the other hand, ignoring the solar rights of buildings and open spaces

can also cause discomfort and discomfort [13]. In addition, solar radiation is an important component of climate and human comfort in indoor and outdoor environments. So that ignoring the sunlight in buildings and open spaces can cause discomfort[14].

Many studies have been done in the field of daylight in general, which due to the lack of sufficient space to mention their topics, has only been mentioned in this field[15-18]. On the other hand, the use of natural light and heat of the sun by using appropriate solutions during the day and night can largely meet the energy needs in the field of cooling, heating, and especially lighting, as well as maintaining balance in the field of environment[19]. In total, the literature survey indicates that the visual quality of residential complexes can be investigated via techniques optimized through continuous and sequential research, such as Isovist. Furthermore, lighting simulators tools such as Relux software can also measure daylight indexes in different residential complexes. Although these methods have each been used separately in different studies, the authors' search to find some studies that have used these two methods in combination with each other for the visual quality analysis of residential complexes did not contain any results. Therefore, this research method is the visual quality analysis of residential complexes based on a research gap in this field. The proposed method of this research is first used in the case study (Kermanshah), and then its validity and reliability are tested for other situations. On the one hand, field measurements have provided the quantitative data necessary to analyze the visual quality of residential complexes in Kermanshah. Moreover, they have made it possible to investigate the validity of the method based on a correlation test. In fact, the present study has been formed for using and refining Isovist as a tool to measure the visual quality of residential complexes in the Kermanshah city and how it relates to the daily light distribution of space. It has also studied the effect of various spatial arrangements for residential blocks on the improvement of visual comfort and quality as well as daily light distribution. On the other hand, in educational and university centers, one of the most important topics is the design of residential complexes. In this regard, with more and better knowledge, it can be achieved the more optimal designs in terms of daylight and visual comfort of space, which are two important categories in architecture and energy consumption. In fact, a significant step will be taken in order to teach the design of residential complexes to architects and students via an optimal architectural design approach.

2 Theory

2.1 Isovist

One of the most important parts of space syntax theory is the visual context, which is mainly used to analyze architectural spaces and urban neighborhoods. It seems that the word Isovist (visual contexts) was first coined by Tandy. In his view, Isovist is a way to "permanently record site information (architecture or landscape)". In the following years, Benedict developed the Isovist specification to describe the environment quantitatively. In his view, Isovist contexts are associated with the ability to measure some basic spatial qualities in the environment; Qualities whose conscious or unconscious perception provides a more basic perception and a complete description of the environment. Accordingly, he defined space as "a set of visible points from a point in the same space". Isovist consists of a polygon and a set of characteristics, including circumference, range (or region) of the Isovist, the minimum and maximum radius of view, the angle of inclination, the magnitude of impulse, and the edges. Isovist creates a regular geometric grid in the building, and Isovist polygons form a grid from the center of each square[20]. Which is usually located at eye level. The mathematical properties of this polygon (quantitative values of the aforementioned properties) are recorded and can be analyzed in comparison with the values obtained from other Isovist locations. In this analysis, the view and shape are uniformed with respect to the geometry of the observer's space and location [6]. Subsequent research after Benedict and

Davis led to the development of a precise method for generating Isovist polygons, defining mathematical measurements and improving the graphical representation of data, and creating a more accurate understanding of Isovist[20].

2.2 Daylight

Among the important factors in the natural light distribution in space, the intensity of light and the rate of uniformity must be considered. Medium brightness is the average amount of light intensity on a particular surface from which the brightness should not be less. Another definition of light intensity is the amount of luminous flux received by a given surface in lux units (lumens per square meter). A luxury; The intensity of light received from a standard candle at a distance of one meter by the surface of one square meter[22]. The environments are the main goal to achieve visual comfort. Visual comfort also improves when visual messages are received from the visual environment. The design of the building should help to achieve comfort. In this regard, another indicator that is studied in the field of daylight quality and visual comfort and determines how light is distributed in the space is the uniformity rate, which is equal to the ratio of the minimum daylight factor to the average daylight factor in space. To create visually appropriate conditions in space, the uniformity rate should not be less than 0.6 [23].

3 Material and Methods

The present research has been carried out through a combination of desk work and field surveys, visual quality tools, and software such as Depthmap, Relux, and Isovist. Field surveys for residential complexes in Kermanshah due to their typology and identification of dominant layouts. Also, these layouts have been normalized to reduce the role of environmental interfering factors, and their visual quality has been investigated by extracting Isovist indexes. This study aims to measure the comfort-visual quality of residential complexes in Kermanshah and how it is related to the daily light distribution. Furthermore, the effect of the different spatial syntax of residential blocks as an independent variable on the improvement of visual-comfort quality and daily light distribution as dependent variables have been studied. For this purpose, case studies (residential complexes in Kermanshah) are sorted. Then, Isovist analysis will be performed via Depthmap software, and daylight indexes will also be examined by Relux software. Finally, the correlation test between the results of the analysis of Isovist indexes, namely Connectivity (C), Maximum radial line (RL (L)) and the Visual Mean Depth, and the results of daylight indexes (Illuminance) (Lux), also the uniformity rate (Uniformity rate (Uo) are done. In addition, the effective parameters on the access of solar radiation in urban blocks have been identified using library studies and field measurements. Then, as a case study, an urban area, including several residential blocks, has been selected. Field measurements are performed by a lux meter as well as computer simulations via Relux software. Fig. 1 shows the research process of this paper.

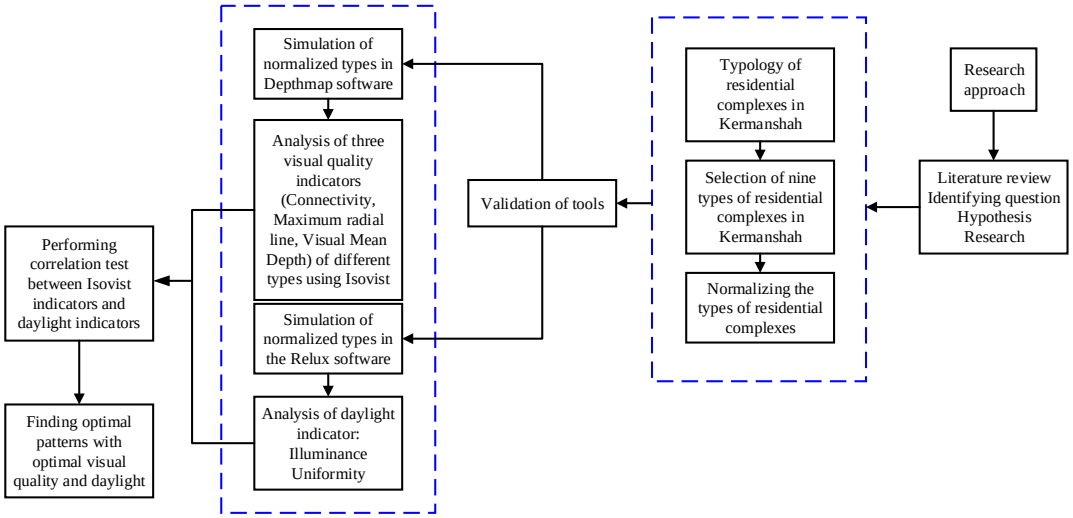

Fig. 1. The research processes.

3.1 Validation

The visual quality of each type is explained by extracting small amounts of Isovist indicators and lines of vision and then analyzing them. Among the set of Isovist indicators, according to the purpose of this study and also, the proximity and overlap of some of these indicators and also to prevent duplication, and finally, according to the type of spatial experience associated with each Isovist index, three indicators include 1) connectivity 2) maximum radial line and 3) visual mean depth are extracted directly from the Depthmap computing software. In order to measure these three indices, after networking the Isovist background pattern into squares with dimensions of four meters by four meters, in the center of each square of the grid, quantitative values of all indices are calculated and extracted. Then, the data is transferred to SPSS software for statistical testing. Table 1. explains the relationship between Isovist indicators and spatial experience based on studies, which indicates the validity and scientific basis of this tool in research [5,6] .

Table 1. Visual quality indicators related to spatial experience[3,4].

Indicator	**Description**	**Spatial experience (visually)**
Connectivity (C)	The degree of connection of axial lines of vision, the number of accesses leading to the observer station point (leading to the desired space)	**Spatial access and communication**
Maximum radial line (RL(L))	The length of the longest radial line is seen from the observer station point.	**vision**
Visual Mean Depth	Separation of the observer point from the overall configuration	**The space has become separate**

In order to measure the validity of the lighting software of Relux, the intensity of light in a real sample has been measured. For this purpose, a real architectural space has been considered with the help of a luxmeter to measure the light intensity in different places. The results show that the data obtained from field measurements and the data obtained from the simulation have the same behavior towards each other and there is a slight difference between them.

3.2 Case Study: Residential Complexes

By examination of the researches in the field of typology of residential complexes, two main axes can be identified. The first is how residential complexes (as part of the urban context) relate to the surrounding urban context. The second is how the residential complex's communication and internal organization are. Both axes have important effects on the formation of residential complexes spices. In both axes, the

organization layout form is mainly based on of combination of open and closed spaces. Accordingly, Biedaloff presents a specific typology of residential complexes based on the association of open and closed spaces in them, which includes four patterns: " periphery ", "linear", " singular", and " hybrid " which is seen [24]. The effect of different combinations between open and closed space in residential complexes, besides the natural ventilation and differences in the supply of light and illumination of indoor spaces, makes differences in the amount of aristocracy and open view of the units to the open space of the complex or around it. At the same time, to identify different compositions in residential complexes, two categories of urban morphological analyzes are used, including formal and quantitative analyses. The formal analyzes of residential complexes emphasis on the overall organization of the complex form (type of components, number of components, and their relative position in the residential complex)[25]. Therefore, it is possible to identify the effective indicators on the typology of residential complexes. Otherwise, utilization of all the indicators simultaneously can cause the multiplicity of layouts. However, according to the basic principles of typology, the number of layouts should be reasonable, limited, and necessary[26]. Due to achieving basic layouts, residential complexes are first classified into two categories, one-side and two-side, in terms of how the building relates to the open space in the general classification and based on the results of previous studies. One-sided layouts are collections combined to open space only from one side (inside or outside the building) and their other side is closed. Some factors, including inconsistent spaces in the urban block and surrounding buildings, may affect layouts adversely. This interfering factor in the simulation results may not reflect the actual visual quality of the layouts. In contrast, layouts normalization creates a homogeneous framework in all layouts by removing details, items unrelated to the shape of the layouts, and inconsistent spaces. Therefore, the visual quality of all layouts, without interfering factors, is in a homogeneous and comparable framework, and their investigation leads to generalizable findings. One of the most common methods in layouts normalization is the innovative method of Zang et al., Called "normalization and replacement". This method is used in most environmental simulation studies that aim to evaluate its performance from a specific aspect and emphasize formic configuration [27, 28].

As a result, in the present study, the method proposed by Zang et al. has been served in layouts normalization. Explaining the visual quality of layouts is achieved by extracting quantities values of Isovist indicators and sightlines as well as analyzing them. Among the set of Isovist indicators, according to the purpose of this study and also the proximity and overlap of some of these indicators as well as to prevent duplication, and due to the type of spatial experience associated with each Isovist index, three indicators include: Connectivity(C), Maximum radial line (RL(L)), and Visual Mean Depth, are extracted directly from Depthmap computing software. The Isovist background pattern is networked into squares with dimensions of four meters per four meters to measure these indicators. In the center of each square, quantitative values of all indicators are calculated and extracted. Then, the data are transferred to SPSS software for the statistical test. In order to extract the layouts, first, the information of residential complexes in Kermanshah city is collected.

Residential complexes in this study refer to complexes that are designed by a team and integrated, with a number of floors of four and more, and on a plot of land with dimensions of more than 6000 square meters (to ensure having a visible combination in outdoor and indoor spaces). So that, a number of residential complexes were not initially selected because they were less than 6,000 meters and did not have a coherent spatial composition. Finally, nine layouts are identified among the case studies according to Fig. 2 and 3. Moreover, in order to normalize the layout, in the first stage, the shape of the site was turned into a square with dimensions of 100 meters per 100 meters. While the orientation, ratio, distance between buildings, and the ratio of full and empty spaces were preserved. Also, the design of

buildings and the spatial relationships between them, and the relationship with the site boundary were preserved. Therefore, the normalized residential complex is almost equal to the original case geometric and spatial characteristics. By considering that all layouts are 4 stories, the height of the normalized layouts is also four stories. Therefore, the number of stories index is not considered due to its constancy in all studied layouts. In this way, fig. 4 shows the aerial image of one of the residential complexes before normalization and after that.

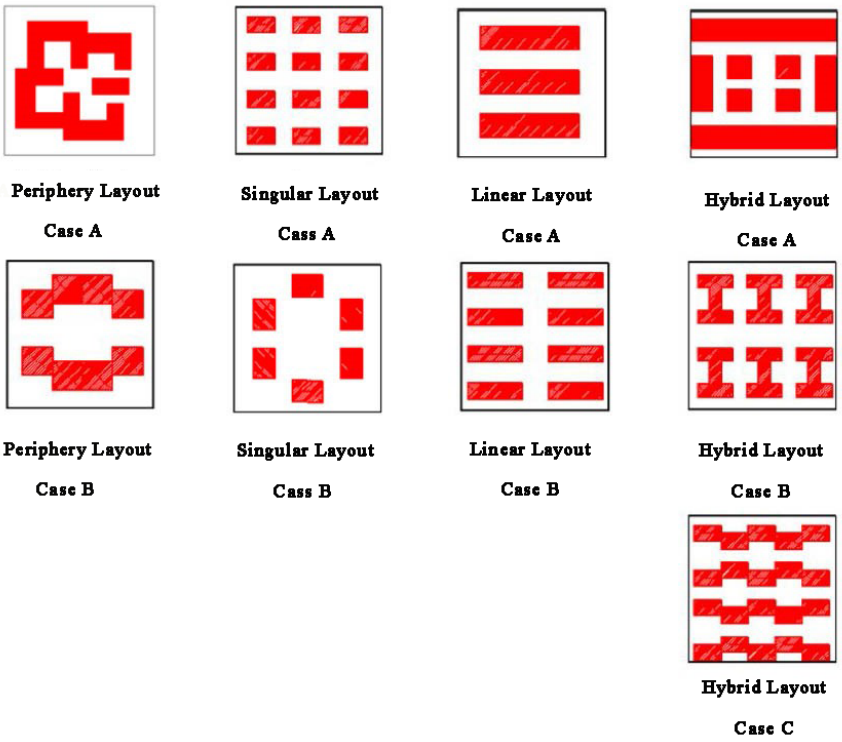

Fig. 2. The normalized layouts extracted of residential complex.

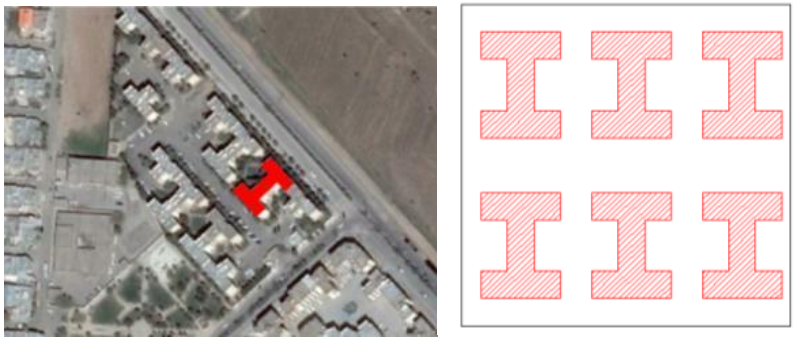

Fig. 3. Normalizing the residential complex from hybrid layouts 2.

4 Discussion

4.1. Isovist Visual Quality Indicators

In the following, Isovist visual quality indicators for each of the nine layouts of residential complexes have been calculated and extracted. The studied indexes in the Isovist analysis of each layout are three indexes whose quantities values have been obtained by modeling the normalized layout through Depthmap software. In order to investigate the correlation between indices of Isovist and daylight, their quantities values are entered in SPSS software, and the necessary tests are also performed. After that, the data obtained from indices of Isovist and daylight, as well as the correlation relationship between them in each normalized layout, are presented. In the

meantime, the highest line of sight index studies the highest possible line of sight in space and is related to the experience of having a perspective.

Figs. 4-7 show results for nine residential complex layouts. Due to the results obtained in different layouts for this index, it has been seen that periphery case A layout has the lowest average data of this index. Also, the layouts: Periphery case A, hybrid case A, hybrid case B, Periphery case B, and hybrid cases 'C' are in the lower range of this index. In fact, hybrid and periphery layouts have not provided very acceptable results in terms of the index of Maximum radial line (RL(L)). This indicates that in these layouts, the largest observer's radius of view at any given internal point of the complex is generally lower than other layouts. Therefore, they will have less perspective on the surrounding environment. Also, layouts: singular case A, linear case A, and linear case C are in a relatively acceptable range of this index. Furthermore, singular layout B (one-side units) has the highest numerical average of this index, so that it provides a larger radial of view for the observer in more points.

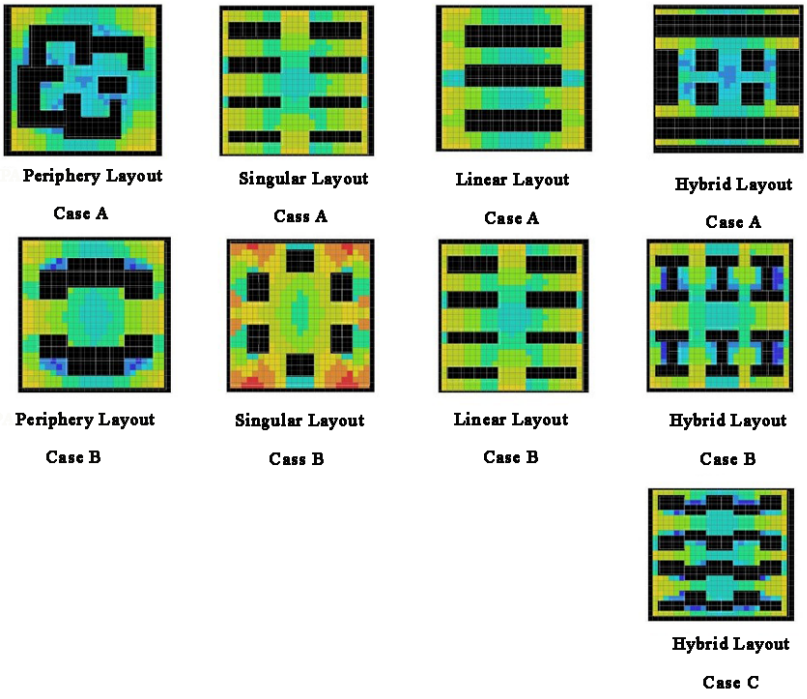

Fig. 4. The Maximum Radial Line (RL (L)) index results for nine residential complex layouts.

Also, the connectivity index shows the number of accesses leading to the observer station point (leading to the desired space), which is related to the quality of access. This index also has the highest value in singular layout B. In contrast, for layouts: Periphery case A, hybrid case A, hybrid case B, and hybrid case C, low values of this index can be seen. Also, layouts: singular A, linear A, Periphery case B, and linear B are in a relatively acceptable range as well as hybrid case C has the lowest value. In fact, it can be said that hybrid and peripheral layouts have not provided good results in terms of visibility connectivity index compared to other layouts.

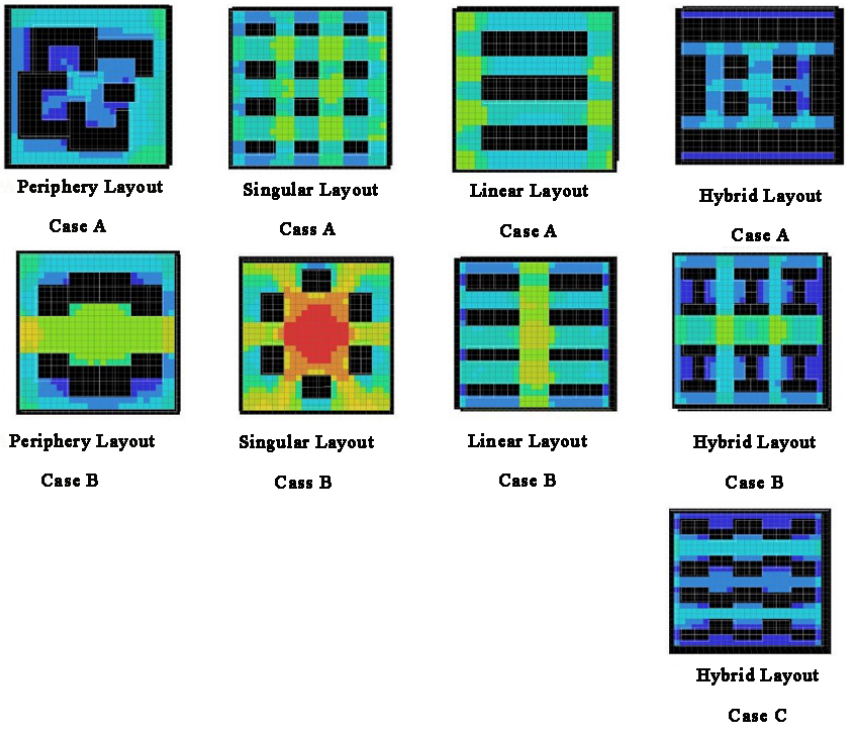

Fig. 5. The Connectivity (C)index results for nine residential complex layouts

Moreover, the visual Mean Depth index also shows the separation of the observer point from the overall configuration which is connected with the experience of separate space. This index has the highest value in periphery layouts A and hybrid layouts C; otherwise, hybrid layouts A and singular layouts B have the lowest index value. In fact, hybrid and periphery layouts have the highest value for this index, while in singular layouts, the separation of the observer from space is in a more acceptable range than other layouts. Finally, it can be stated that in the study of Isovist indicators, singular layouts (A and B) have presented better results in terms of improving the visual quality of the space for the observer.

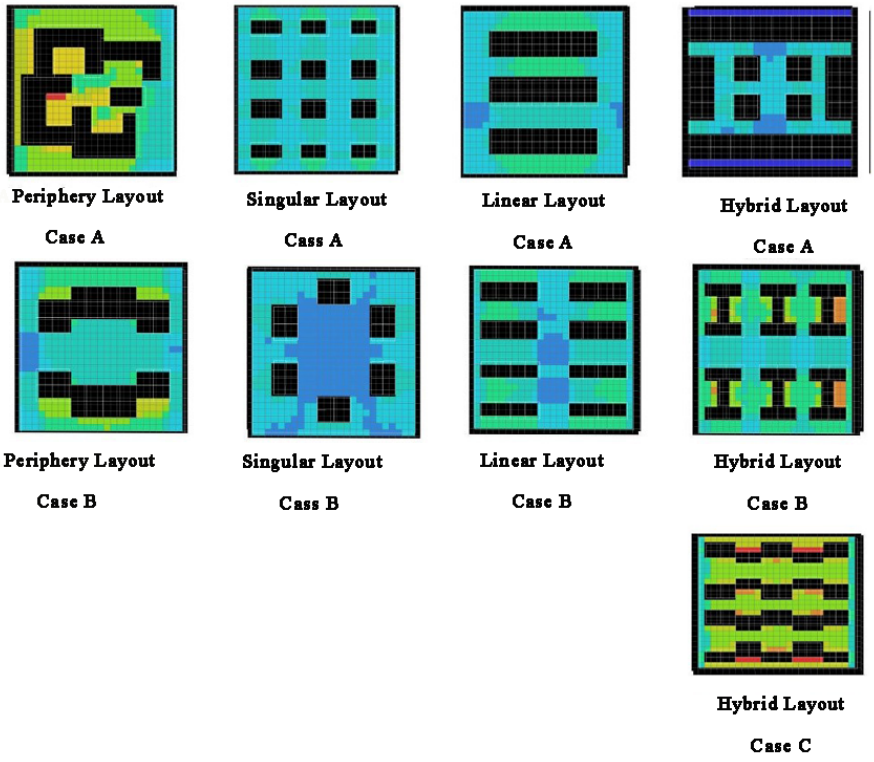

Fig. 6. The Visual Mean Depth index results for nine residential complex layouts.

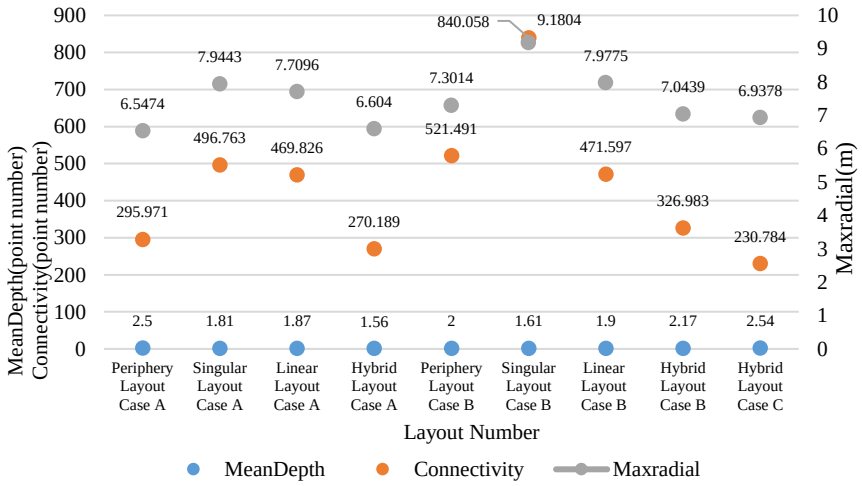

Fig. 7. Isovist visual quality indexes average values for nine residential complex layouts.

4.2 Illuminance (Lux) and Uniformity Rate

In order to investigate the distribution of daily light for the layout of the residential complex studied in this section, simulation of case studies and data analysis have been performed by using the Relux lighting software. According to Figs. 8 and 9, in the investigation of daylight variables, the distribution of illuminance and uniformity rate in some layouts is better provided. In others, it has a mineral range. In this way, the uniformity rate index for the nine layouts has shown that in layouts: Periphery case A, hybrid case A, singular case B, and linear case B, it is not in the acceptable range compared to its standard value (the range of 0 to 0.6). While for layouts: linear case A, singular case A, Periphery case B, hybrid case B, and hybrid case C, this amount is in the acceptable range. Furthermore, layouts linear case A and periphery case B are more appropriate than their standard level compared to other layouts. Besides, the illuminance index (Lux) in layouts: periphery

case A, linear case A, hybrid case A, periphery case B, singular case B, linear case B, and hybrid case B, is in the range of low and high values, while layouts: singular case A, linear case B, and hybrid case C are in the more appropriate range. In total, it can be found that among the layouts of the residential complex studied, the case of the singular layout A has provided a more suitable visual quality for users both in terms of uniformity rate index and illuminance index. According to the results obtained in the investigation of Isovist indicators and daylight variables, it should be stated that singular layouts have been able to provide a more suitable environment in terms of visual quality indicators and daylight. As a result, singular layouts case A is presented as an optimal layout.

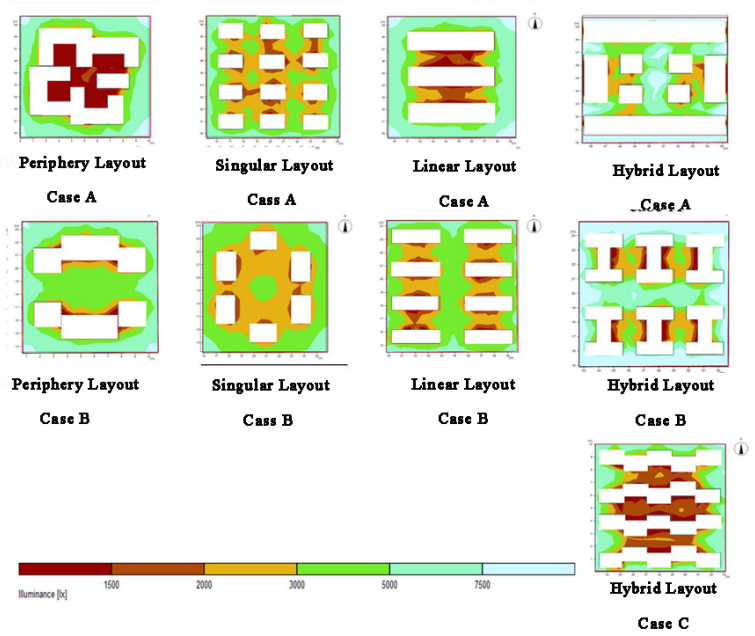

Fig. 8. Illuminance (Lux) index results for nine residential complexes.

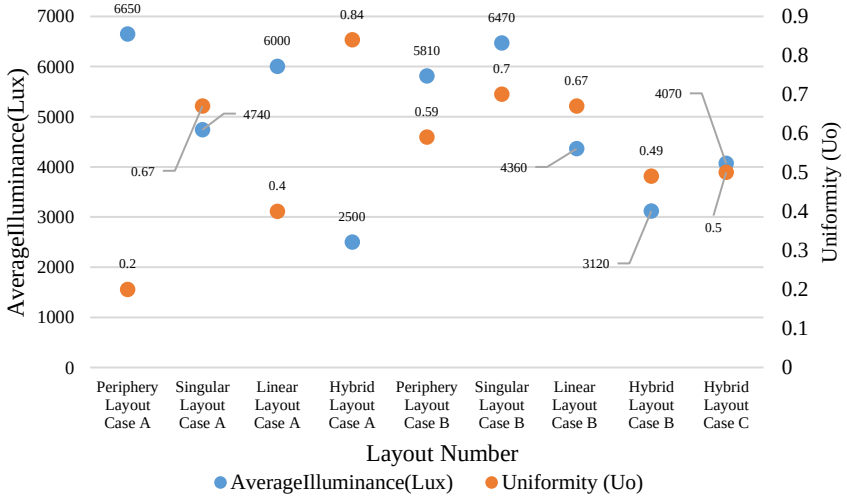

Fig. 9. Illuminance and uniformity rate values for nine residential complex layouts.

4.3 Correlation of Research Variables

In order to determine the relation between Isovist indicators and daylight indices, according to the nature of the data, the Pearson correlation test is performed at a significance level of $\alpha = 0.01$ and $\alpha = 0.05$. The correlation coefficient between two variables is displayed with ρ, so that the closer it is to 1, the higher the correlation between the two variables in the

direct direction, and the closer ρ is to -1, the higher the correlation in the reverse direction. Also, when ρ = 0, there is no correlation between the two variables.

The results of the Pearson correlation test indicate that at a significance level of 0.01 and 0.05, there is a correlation between all Isovist indices and daylight indices. Findings of Pearson correlation test indicate that at a significance level of 0.01 and 0.05, there is a correlation between all Isovist indices and daylight indices. The index of the highest radial line of Isovist vision in single species 2 has the highest value. In this species, the volume of perceived space anywhere in the open space is greater than in other species. This index, which is related to the visual experience of openness and spatiality (Table 2), has a direct and strong correlation with lighting.

Table 2. The correlation of Isovist indicators and daylight indices

Correlations					
	Max Radial	Connectivity	Mean Depth	Average Illuminance	Uniformity
Max Radial	1	.934**	-.546	.417	.361
Connectivity	.934**	1	-.579	.562	.313
Mean Depth	-.546	-.579	1	.124	-.778*
Average Illuminance	.417	.562	.124	1	-.506
Uniformity	.361	.313	-.778*	-.506	1
**. Correlation is significant at the 0.01 level (2-tailed).					
*. Correlation is significant at the 0.05 level (2-tailed).					

5 Conclusion

This research investigates the effect of different spatial arrangement patterns of nine residential complexes layouts in terms of improving the space visual quality and optimal daylight distribution. The research is based on an analytical-descriptive method, desk work and field survey, Depthmap software, Isovist tool, Relux lighting simulator software, and SPSS statistical software. Visual quality indicators of layouts using the Isovist tool in Depthmap software, based on Connectivity (C) indicators, Maximum Radial Line (RL (L), and Visual Mean Depth are investigated. Furthermore, Illuminance (Lux) and Uniformity rate (Uo) indices are evaluated with Relux software. It is found that by the analysis of Isovist indicators, a new approach is introduced in assessing the visual quality of urban and architectural spaces. In fact, the purpose of this study is to measure the visual quality and distribution of daily light as dependent variables due to various residential layouts of spatial syntax as the independent variable in 9 residential complexes layouts.

As a result, in terms of optimal distribution of daylight, singular layouts case A and periphery layouts case B scenarios provide a more balanced of illuminance, uniformity rate, and better visual quality. Investigation of visual quality indicators through the Isovist analysis in Depthmap software has also been obtained those singular layouts case B has the highest value of Maximum radial line (RL(L)) index. According to the theory of mental focus reconstruction, this will make the space more desirable. The average depth-of-field index, which indicates the separation of the observer point from the overall configuration, is related to the spatial experience of the separated space. This index has the highest value in hybrid layouts case C. Also, the index of the amount of visual connection in singular layouts case A has the highest value. In sum, in both visual quality and daylight, it can be said that singular layout case A provides more optimal conditions in both respects. In fact, according to visual indicators and daylight results, this layout has been able to create a more acceptable visual quality. In addition, the correlation test of different research variables indicates that there is a significant relation between Isovist indices

and daylight indices. The research findings indicate two main issues. First, the results of the method used to assess the visual quality of residential complexes in Kermanshah city are parallel with the results of a valid method which can be a witness on the accuracy of the method used, although are as a necessary condition and not sufficient. Obviously, this proof requires further detailed research. Second, it appears that quantitative indicators related to the form of the complex contain information about the environment's visual characteristics. Analysis of data from descriptive and inferential statistics shows the high accuracy of quantities values for Isovist indicators in residential complex layouts. These analyses show the amount and manner of changing indicators in the types of residential complex layouts that can show each layout's positive and negative points. So that these indicators can be used to identify appropriate alternatives in the design. This research cannot provide any layout absolute or relative superiority in terms of visual quality; However, it analyzes the visual features of each layout. Furthermore, it provides a tool for designers to give the desired visual qualities to their designs. The results of this study show that the arrangement and arrangement of interior elements is an important and effective element on the proper distribution of natural light and the quality of visual comfort of environmental users. Also, the correlation between the indicators studied in this study shows the overlap of visual quality variables and the amount of daylight received in the studied scenarios; So that in future research it is possible to formulate and present this relationship. In fact, this research can lead to the optimal design of residential complexes in terms of daylight and visual comfort of space and take an important step in order to teach the optimal design of residential complexes to architects and students.

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