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Urban square design with pedestrian approach based on space syntax method (Case study: Aysan project area of Tabriz)

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Abstract--Pedestrianism and spending time in urban space is one of the most basic and necessary parts of human life, so that most human needs such as buying and selling, spending leisure time, etc. are removable in urban spaces. It is important to understand the components of urban space and their relation with the design of an urban square. Moreover, we assume in this article that all components of urban elements are directly or indirectly associated with each other. Our purpose is to create an integrated method using salingrose's theories and space syntax method to design an ideal urban square while expressing the effect of different parameters. In this integrated method, we transform the urban spaces into diagrams, and then analyze Salingrose theories and space syntax. In this research, we analyze the urban space in two parts, one as the whole area, which includes the access network in a specific radius and the second a site as a square. In the study of the field site, we promoted two types of methods to advance the research: first, the analysis by the method of space syntax and second, the configuration of the space of the field by the method of Salingrose' theories. In the whole area, all space users, including individuals and registration plates, are among the research variables; we have studied a variety of parameters for these variables and their effect on each other. Combining theories and analyzes of space syntax and those of Salingrose in the design of an urban space, we conclude that partial changes in one parameter such as access can lead to wider changes and effects in other parameters such as movement, behaviors and activities.

Keywords---*urban design, space syntax, pedestrianism, urban square, Tabriz.*

Introduction

Post-constitutional changes, despite their many benefits for the urban population, caused many problems for many historical and old neighborhoods of cities (Moayedfar and Ishaqi, 2019, p. 142). Now that the importance of urban space for city dwellers has become more apparent, it also needs a street, a node or an urban square for the presence of people. Urban squares have long been an important gathering place for people to trade, hold ceremonies, or even perform a historical event. Urban squares are places that, by creating a collective memory in the minds of space users, bring a kind of identity and dependence to that place for their citizens. This collective memory can be the function of the square, the type of architecture and even the existence of some sub-spaces and partial spaces. The city is like a machine in which all its components are interconnected, all move together, and a defect in one part of it makes this movement impossible. The worn-out and unplanned texture of Tabriz is no exception to such an event; it requires an efficient method for planning in the design and construction of urban thoroughfares and squares for pedestrianism and sequencing. An example of an urban square redesigned by the space syntax method is London Trafalgar Square, which had problems in form and function. Humans are active depending on their individual or group needs and offer their own behavioral patterns (Rezaei Varzard and Babaei Morad, 2018, p. 1). It is important to understand the components of urban space and their placement through the design of an urban square. In the life of the city, the actions and activities depend on its people. Walking, dating appointments, business activities, even enjoying and relaxing in that urban space, are all part of it and play a role, however small. This role is or is not observable at first glance. However, another important issue is how the urban space syntax of the square affects the movement of pedestrians, and how the urban space syntax of the square affects the activity of its users. Therefore, designing an urban space implies a space that has a bed of order and prediction of users' behavior, as well as the existence of attractiveness for the public.

Research background

There are numerous researches on the areas of urban design process, square, space syntax and pedestrianism. However, excerpts from these researches include research on activities, methods and approaches, psychology in the city, and access to city design. Night activities in important urban spaces that cause the presence of people make these areas more attractive to visitors (Ghazanfarpour et al., 2019, pp. 87-106). Traditional methods of urban planning and design can no longer meet the growing needs of sustainable urban planning due to factors such as complexity and many details, and these limitations lead to new approaches (Daneshpour and Ghaffari Azar, 2020, p. 6). Non-compliance of the square space with the needs and behaviors of the people causes many issues and difficulties (Alipour Zibaei, 2018, pp. 1-19). Urban spaces such as recreational and cultural complexes can play a major and constructive role in spending leisure time and special occasions of the citizens of a city such as official ceremonies and special

days (Aghaei and Karimifard, 2020, pp. 1-15). The most important part of urban space is a space in which the sense of dynamism and happiness has a manifestation; this is a result of a good thinking of an architect in the correct application of visual elements and design of urban elements (Mehrvarzin and Mohebbi, 2020, pp. 1-22). Any intervention in the urban spaces of the past requires more knowledge of cities and their history (Mir Mozaffari and Abdollahzadeh Tarf, 2017, p. 25). Proper access is one of the most important characteristics of a good public space and improving access to urban spaces in order to improve its quality is one of the main goals of the space creation approach (Mahvari et al., 2020, pp. 47-60). The similarities and differences in the appearance of governmental and non-governmental squares have special and general features (Hooshmand Shabanabadi et al., 2020, pp. 43-54). Improper design of buildings and urban spaces poses a threat to the lives of citizens (Aulia Malik, 2021, pp. 11-25). The urban space of the square is an open space where people can display their daily activities (Ansam and Lanai, 2018, pp. 1-30). Sufficient knowledge of the historical texture and its structures can reduce the existing weaknesses of the space and improve security and safety in the historical textures (Arabi et al., 2020, pp. 519-533). Using a shared street for pedestrians and drivers, as well as having a visual sequence, can enhance pedestrianism. The visual perspectives and human scales together also improve pedestrianism (Friedman, 2020, pp. 1-18). Adopting more narrow lanes for car use and bus use alone can potentially increase the share of auto mode and save total network travel time (Yan Huang and Li, 2020, pp. 187700-187712). Satisfaction with a place can lead to attachment (Li et al., 2020, pp. 338-356). Land grabbing strategy, design of outdoor spaces and providing leisure and accommodation have a positive effect on optimizing the city's resources and creating a successful tourist destination (Nolasco-Cirugeda et al., 2020, pp. 1289-1303). Urban design can lead to the moderation of the temperature of a particular urban space by adopting appropriate urban planning policies (Ouali et al., 2020, pp. 1-40). Urban rail transportation needs to adopt an algorithm that connects land uses such as commercial and public spaces (Xiaoyu Huang et al., 2021, pp. 1103-1115). Designing the space of an urban network requires a comprehensive design strategy to plan attractive and convenient public transportation space systems for pedestrians (Yang et al., 2021, pp. 67-81). Flexibility in a space occurs in two modes, including "change of its current functions" and "change in the structure of the space" to respond to the needs of users (Kiai et al., 2019, pp. 63-76). Spatial use of the square is highly dependent on visibility, and access (visual access) and connection to the environment are key parameters of its performance (Bendjedidi et al., 2019, pp. 125-142). The design process consists of dimensions and backgrounds that are interconnected and overlapping (Mir Mozaffari and Abdollahzadeh Tarf, 2018, pp. 25-38). Areas and pedestrian paths are supposedly memorable and identifying elements in today's cities (Drablo and Darskhan, 2018, pp. 1-10). In higher resolution paths, we can receive more visual information. This means that these spaces are more transparent and more predictable, and establishing a visual connection between the body and space, while taking into account functional considerations, has a direct impact of the body on social activity (Sajjadzadeh Et al., 2020, pp. 79-106; Majidi et al., 2018, pp. 237-249). Space syntax method is one of the powerful patterns of space syntax that can interpret the spatial pattern based on social and economic backgrounds (Khumri et al., 2018, pp. 5-16). Types of sidewalks include

temporary, experimental, permanent, cross-section or plaza and continuous sidewalks (Khosravi and Bagherpiri, 2017, pp. 57-70). The degree of interconnection of a space in the system means more access; each node indicates that it has a higher degree of interconnection value (Karimkhah and Moradi, 2017, pp. 1-14). Axes with more shops are more likely to have a high level of interconnection and pedestrian density (Babapourfatehi et al., 2017, pp. 41-62). In an article entitled "Development of a model for predicting the movement of pedestrians in urban spaces by combining space syntax and polynomial evolutionary regression, Abbaszadegan and Babapourfatehi's experiments show that the space syntax method can provide models that can interpret and predict the movement of pedestrians in relation to urban morphology (Abbaszadegan & Babapour, 2012, pp. 27-39). The space syntax method examines the sequence of the arrangement of all spaces and their relationship with each other, presents them in a form of graphical diagrams and quantitative mathematical values and proves that the arrangement of spaces to each other has a significant impact on the use of spaces (Abtahi et al., 2017, pp. 1-10). Pakzad divides urban design into two categories of design: the ability of the designer and design of the appendages of systematic processes (Pakzad et al., 2018, p. 156). According to Pakzad, the characteristics of an urban square are spatial determination, vitality and flexibility (Pakzad, 2018, pp. 50-54). Urban design is a process of designing and shaping the physical characteristics of cities, towns and villages and planning to provide urban services to residents and visitors (Mota and Gameren, 2018, pp. 33-49).

Theoretical foundations

Bill Hillier and Julien Hansen at UCL developed Space Syntax theory in the late 1970s. It was developed during the 1980s and 1990s. Space Syntax is not a software but an analytical method. Software such as DepthmapX as one of the well-known software in this field performs the analysis of this method. In *A Theory of Architecture*, Salingrose sees methods and rules from different angles, and then acknowledges methods and rules from an architectural point of view and relates them together.

Vision navigation: Movement through space creates action and reaction with other people in space. Movement is essentially a linear activity. A person's action and reaction requires a convex space in all places where s/he can see all other people. At each point in space, a visual field becomes into existence that is changeable by displacement called isovist (Kim et al., 2019, pp. 74-87; Yu and Ostwald, 2018, p. 19; Esfandiari and Torkashvand, 2020, pp. 19-32; Al-Hesabi et al., 2012, pp. 60-69; Karimi Consultant et al., 2015, pp. 33-42).

Spatial depth and configuration: Human space is not just a single space with a number of features. It is rather the internal connections between the many spaces that make up the structure of a building or a city as a whole we call it spatial configuration. This means that there is a simultaneous connection between parts of a whole. Space syntax does not mean that there is simply a connection between the two parts in a space, but rather it tries to get a picture of a whole set of relations and their effects on each other (Daneshpour et al, 2017, p. 27 -36; El-

Darwish, 2021, pp. 1-7; Latfia et al., 2019, pp. 57-76; Shahbazi et al., 2018, pp. 21-40).

Connectedness or integration: Connectedness is an index that is sensitive to any changes in the city map. When a graph is shallow at some degree of connection, that graph is integrated and has a high degree of connectedness. If the graph has depth in some degree of relation, that graph is discrete. Thus, we can describe each space numerically in terms of its relation to other spaces. This type of measurement is configurational (Major and Dalton, 2018, p. 34; Paliou et al., 2014, pp. 236 and 248; van Nes and Yamu, 2021, pp. 27-28; Vaughan, 2018, p. 205-294; Jabbari et al., 2018, pp. 13-40; Heidari and Kiai, 2019, pp. 61-76).

Clarity: Clarity means understanding urban spaces together and the possibility of arranging spaces together in people's minds. The goal is not always to maximize clarity because it destroys the hierarchy of realms and thus reduces security (khaled Jendy et al., 2019, pp. 29-44; Liao et al., 2019, p. 361-370; Pachilova and Sailer, 2019, pp. 493-511).

Natural movement: The most important factors in creating movement in a city are the points of origin and destination. According to space syntax theory, the choice of intermediary space to reach the destination is directly in relation with the syntactic structure of urban spaces. Natural movement in the city is a movement the juxtaposition of certain spaces creates it, not the space user chooses it because of its special features. According to the logic of natural movement, movement in space is more than any other factor under influence of the arrangement of spaces to each other (Garau et al., 2020, pp. 1-23; Hillier, 2007, pp. 213-217; Koohsari et al. Et al., 2019, pp. 1-5; Omer and Kaplan, 2017, pp. 57-67).

Research methodology

We collected the research data by library, field and combined methods from both studies. We carried out the preliminary studies through Internet sites, books in the library and articles related to the field of research. We have performed field studies through observation and photography (combined method). Then, we analyzed the studies using primary library studies and secondary (field) studies, through space syntax method based on Salingrose' theories. We have performed square analysis in two parts: analysis in macro-area and square site analysis. In Figure 1, the Aisan project with an area of 0.04 square kilometers is observable exactly in the center of the whole area (we have shown the whole area beside the map) and the location of the Aisan project is marked in red on the map.



Figure 1: Location of Aisan project

Analysis of information obtained from the methods discussed earlier is qualitative and quantitative. We extracted aerial images through Google Maps and used AutoCAD software to create a raw map, update it and in DXF format. The field visit method is usable for taking photos and updating the map, after which the required map is loaded in DepthmapX 0.50 software to prepare the needed maps and diagrams.

Analysis in a macro-area

To perform the analysis, we must first prepare a map in DXF format in AutoCAD software. After generating the map, we must first convert the map in the DepthmapX software environment to an axial line map so that the software can recognize it in graphing form. Using the performed analyzes, we can create the integrity index (a criterion for accessibility), the continuity index and the comprehensibility index.

We can obtain comprehensibility index when the indicators of continuity and integrity are examined in relation to each other. Thus, the users determine the comprehensibility of the paths. Higher value of this index means that people in that space have a better understanding of the area under study. To examine the comprehensible index, we must create a diagram of integrity at the supra-local scale and continuity. The closer the value R^2 is to 1, greater is the comprehensibility of the area.

Field analysis

To analyze the square, we have used the space syntax method as well as the space configuration. In this way, through the following equations, we configured the space and calculated the number of sub-spaces and the area of each of them:

$$(1) n = 1 + \ln X_{\max} - \ln X_{\min}$$

$$(2) X_{\min}, eX_{\min}, e^2X_{\min}, \dots, e^{n-1}X_{\min} = X_{\max}$$

In this method, X max is equal to the total area of the square, which is called A_1 , and X min will be the minimum value of comprehensible space.

In this method, if the k scale for subspaces is less than 2, the subspaces will be so close to each other that the comprehensibility of space does not occur for the user of the space. If this value is much higher, for example, the value is 10, then such a hierarchy will not become into existence and space users will not be able to make visual connections at successive levels at this scale, because there is too much distance between the spaces. If the number k has a certain scale like $e=2.7$, it will be a good value (Salingrose and Mehaffy, 2006, pp. 1-16).

Square analysis based on space syntax method

In the space syntax method, the analysis of visions in the square has occurred as a readability analysis in the square environment. In this analysis, the most visible points tend to be red (warmer colors) and the less visible points tend to be blue (colder colors).

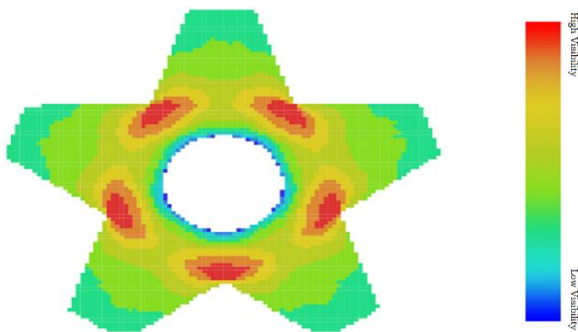


Figure 2: Analysis of readability in a star-like space

Visual Step Depth¹ Analysis

This analysis talks about changing directions, which means that if a person who uses space wants to start from one point in the environment of an urban space and reach another point, s/he must change directions several times to reach the desired space. In Figure 3, the green areas that have a visual depth 1 indicate that to reach this area from the origin with zero depth, we must change the direction once, and for the red areas, the change of direction is equal to 2 times. Important point is that this depth may be higher or lower in complex spaces, and the more inclined the colors to warm colors, the deeper the urban space. If an urban space has too much depth, we will consider it undesirable.

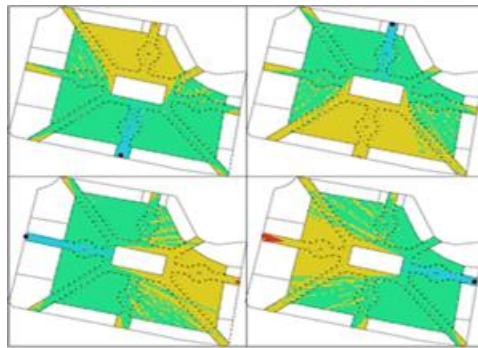


Figure 3: Visual Step Depth¹ Analysis from the Aisan project area in entrances of square

Combining Visual Step Depth analysis with VGA² analysis to understand the relationship between space components

By combining these two analyzes of space, we can examine the depth of all points compared to other parts of the area in general and show the points that are more and less visible. In this color analysis, the points of the space that are better connected to each other tend to warmer colors, and if the relationship is weaker (harder) or deeper, they tend to cooler colors.

Discussion and conclusion

- Interconnectedness index analysis

According to our analysis and Figure 4, the connection in the streets of Imam Khomeini, Shariati North and South, Palestine, Quds, Air Force, Tawhid, Bazaar and Rasteh Koucheh is more than other streets. In Figure 5, the Streets of Tawhid, Bazaar, Rasteh Koucheh, North and South Shariati, Palestine, Air Force, most of Quds, Khorramshahr Boulevard and Imam Khomeini Street have the most interconnectedness at the macro level.

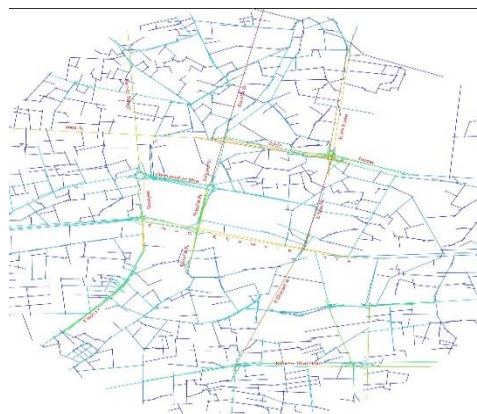


Figure 4: Connection at the macro level

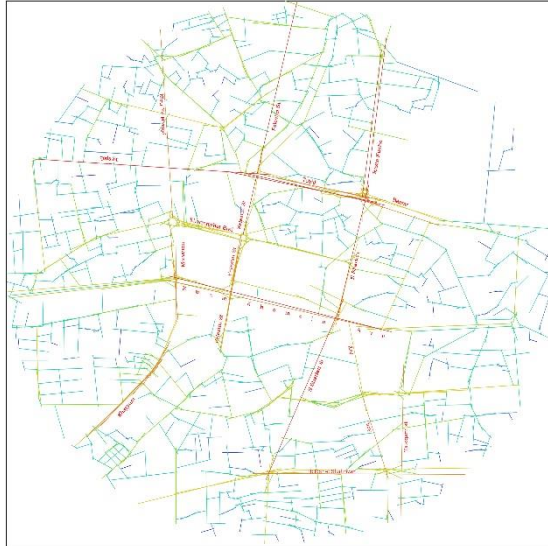


Figure 5: Interconnectedness at the macro level

- Comprehensibility index analysis

Comprehensibility index is obtainable by comparing the two indicators of connection and interconnectedness in a diagram.

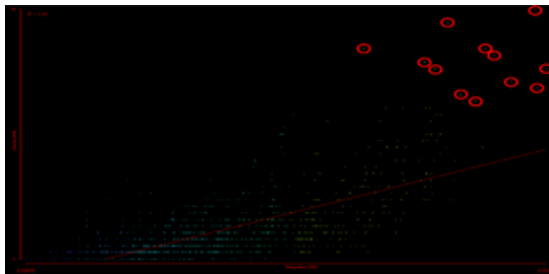


Diagram 1: Comprehensibility – Source: Authors

According to Figure 1, in the lower parts of the diagram, the number of axes has a dense state and in the upper parts of the diagram, it has a scattered state and possesses higher numbers. Now, if we examine the 12 axes specified in diagram 1, these axes will have the following appearance (Figure 6):

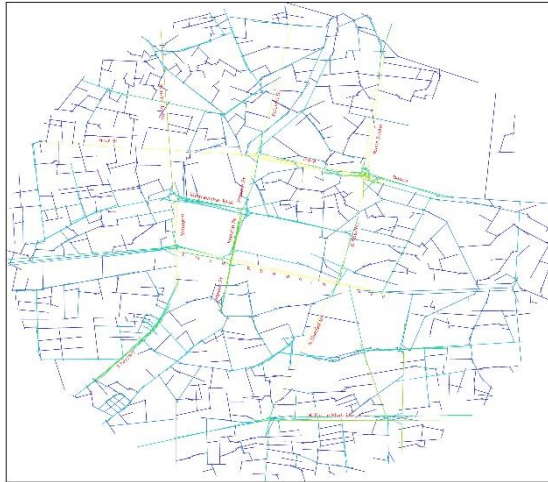


Figure 6: Comprehensibility map in the area

These axes are the streets of Quds, Tawhid, Monajem, Imam Khomeini, South Shariati and Rasteh Koucheh; they have the highest comprehensibility and the color yellow.

Square analysis

- Determining the number of subspaces

$$X_{\max}=4000 \quad X_{\min}=16\text{m}\times 16\text{m}=256\text{m}^2 \quad e=2.7$$

$$n=1+\ln(X_{\max})-\ln(X_{\min})$$

$$n=1+\ln(4000)-\ln(256)=6.05=6$$

In the above formula, the total area of the Aisan project is equal to 40,000 square meters and the size of the smallest sub-space is 256 square meters, where n is equal to the number of 6 sub-spaces. This means that there should be 6 subspaces in the area. Now to determine each of the subspace areas we have:

$$X_{\min}, eX_{\min}, e^2X_{\min}, \dots, e^{n-1}X_{\min}=X_{\max}$$

$$A_1=4000$$

$$X_{\min}=256 \rightarrow s_1=256$$

$$eX_{\min}= 695 \rightarrow s_2=440$$

$$e^2X_{\min}= 1891 \rightarrow s_3=1195$$

$$e^3X_{\min}= 5141 \rightarrow s_4=3250$$

$$e^4X_{\min}= 13977 \rightarrow s_5=8835$$

$$e^5X_{\min}= 37993 \rightarrow s_6=24016 \rightarrow \sum s=A_1=4000 \rightarrow s_6=26024$$

Because the number (e) is an approximate number, the sum of the areas does not correspond to the total area, and the obtained total area must overlap with area A_1 ; so the remaining area is for a larger subspace.

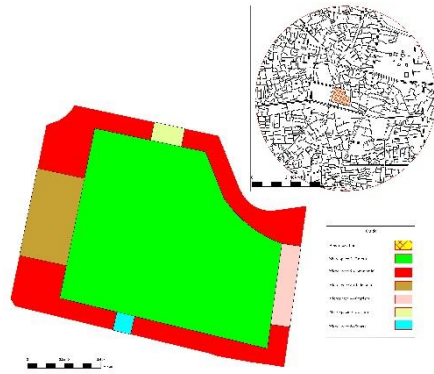


Figure 7: Configuration of sub-spaces

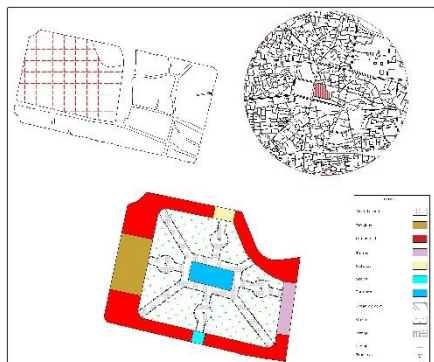


Figure 8: Analysis of sub-spaces

VGA analysis

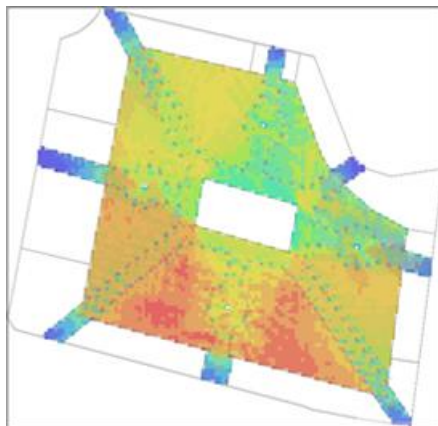


Figure 9: VGA analysis from the area Aisan

Combining VGA analysis and Visual Step Depth

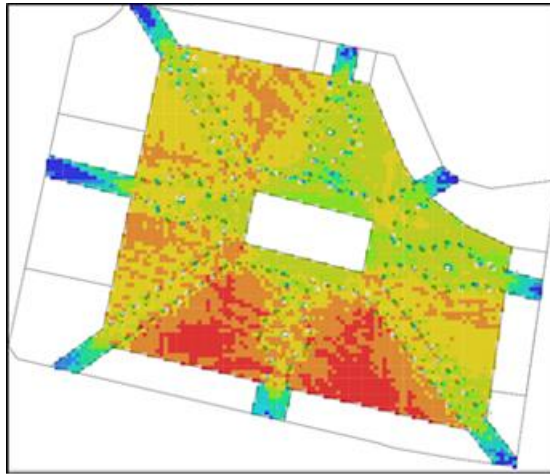


Figure 10: Combining VGA analysis and Visual Step Depth

In this research, we have done two types of study and analysis, first for the access network in a specific radius from the perspective of space syntax and second, study and analysis of an area as a square site based on Salingrose' theories. Therefore, we presented conclusions in two parts.

From the point of view of space syntax, the area of important uses as a sign and the existence of important routes as the main arteries for pedestrians and drivers creates a space in the area that leads to readability of the area. Thus, we can predict that this area will act as a pole of attraction despite the previously mentioned conditions.

Now, according to the analysis of the space syntax, enclosing the Aisan project with four more readable routes is of great importance in this area. Thus, in order to create an urban space suitable for public use, we can consider the Aisan project site as a center to create a vibrant urban space in the area. It can have direct and continuous effects on the movement, activities, behaviors and presence of people in the area and create a variety of uses that play a skeleton role and create urban attractiveness and access.

According to the space syntax theories, in the analysis of AISAN project space analysis as an urban field, we can identify and predict users' movement and behavioral patterns, but we can base the division of sub-spaces in a space, including commercial, religious, green spaces on Salingrose' theories. In the analysis of the space syntax, we can identify legible points and base each of these subspaces on Salingrose' theories according to whether a subspace needs more or less population. In this way, we can design also each of the partial spaces (such as e-commerce or grocery store) in the required location.

According to the above results, we can present the following tables that show the proportions of various parameters for space users, including the created texture and the affected people in the area:

Table 1: Effect of each of the parameters of the first column on the parameters of the first row of the table, which includes without effect, unilateral effect (1) and bilateral effect (2). In these tables, first the effect of each of the parameters of texture-texture, individuals-individuals, and of the parameters of texture-individuals, individuals-texture is observable.

	Attractiveness	Usage	Access
Attractiveness	Without effect	1	1
Usage	1	2	2
Access	1	2	2

	Movement	Behavior	Activity
Movement	Without effect	1	1
Behavior	1	2	2
Activity	1	2	2

	Movement	Behavior	Activity
Attractiveness	2	2	1
Usage	2	2	2
Access	2	Without effect	2

	Attractiveness	Usage	Access
Movement	2	2	2
Behavior	2	2	1
Activity	1	2	2

By referring to each of the parameters in Table 1, we can predict the effect of each parameter on the other. We can measure the consequences and events affecting each of the parameters in two ways of space syntax and Salingrose, and according to the consequences of each change, we can take appropriate action to create a favorable urban space and urban square. Assuming that in an urban space, by changing the parameter of attractiveness, the movement of people and direct and dependent access will also be subject to change, the parameter of behavior and activity of users will be under influence unilaterally and continuously.

Critiques and Suggestions

According to the results of the research and Figure 1, as a result of the state of comprehensibility of the area under study, the R^2 has value of 0.47, also the line $x = y$ is much higher than the linear state (high slope) and has a scattering mode. The compaction of the points at the bottom of the diagram indicates that high-perception paths are less for space users than low-perception paths. Consequently, the area under study has a weakness in comprehensibility. In the macro area under study, as for the routes with high comprehensibility for users:

1. There are signs of appropriate scale along them.
2. There are changes in the length and width of the spaces.
3. There is a more continuous network of routes around them.



Figure 11: A sample of urban spaces with high comprehensibility

Moreover, using the calculations of space syntax theory, the value of $R^2 = 0.47$ shows that the area has weaknesses in its readability, but this weakness for the area is a strength that indicates the area has a capacity for quality. The important point is that the purpose of modifying accesses should not be entirely in favor of readability because:

More readability = value R^2 closer to 1 = presence of more people = loss of residents' privacy and loose realms

Less readability = value R^2 closer to zero = less presence and seclusion of the area = creating a ground for delinquency or confusion in finding the desired path

Now to improve the quality of the visual area, we should:

1. Increase interconnection level for enhancing comprehensibility.
2. Standardize the changes in the length and width of urban spaces.
3. Configure the Aisan project area through the Salingrose calculation.
4. Design the field in such a way as to anticipate and prepare for the events and consequences of any change according to Table 1.

Obviously, with the specified measures, we will have a higher quality, safe, secure and tourist-friendly urban space.

Postscript

1. Visual step depth
2. Vision diagram analysis.

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