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Original Research Article

Impact of Mental Components on the Analysis of Space Syntax Using a Weighted Graph

(Case Study: Iranian Artists' House-Tehran)*

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Abstract

Problem statement: As a logical research system, the architectural space syntax method has been profoundly developed in recent decades. However, despite all its advantages, it has received serious criticism such as negligence of the individual and mental characteristics of the built environment, existential integrity of the human in the space, and analysis of the behavioral patterns based on the space configuration. The present study attempts to understand how such characteristics of space can be investigated simultaneously with the space configuration. This article assumes that using a weighted graph instead of a simple graph allows for determining the unique value of each space, leading to more precise and reliable results.

Research objective: The article seeks to take into account the impact of mental components of space, apart from space configuration, on the movement and, consequently, the behavior of a human in an architectural building. The simultaneous analysis of the weights of mental components and space syntax can correct some defects of the current approach in space syntax analyses.

Research method: The analyses performed in the study were both qualitative and quantitative. The integration and agent-based analyses, as two parameters related to the research subject, were performed to study the spatial organization of the Iranian Artists' House through two approaches. The weights of the mental components were first determined using a simple graph and the depthmap software. In the second method, they were calculated using the AHP method and considered in the space syntax calculations. Eventually, the reliability of the outcomes was compared using the gate count method.

Conclusion: The comparison of the two methods revealed that the results obtained from the weighted graph were more precisely in line with the movement flows in the space of the Iranian Artists' House.

Keywords: *Space syntax, Natural movement, Weighted graph, Integration.*

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Introduction

Over recent years, architecture and urban planning have had many common points with other sciences, including psychology, sociology, environment, and mathematics. All sciences seek to turn a man-made space into an appropriate environment for the living of humans. In this regard, computers have aided researchers, and logical systems have been developed in architecture and urban planning. The space syntax theory is one of these logical systems, founded and developed in the Bartlett School of Architecture, UCL. The main theoretician of this theory, Bill Hillier, took advantage of mathematics and, in particular, graph theory to identify the social logic of space. The space syntax makes an effort to find patterns that justify the individual and collective occurrences in every space through analyzing the relationships between spaces, regardless of their individual characteristics. The frequent use of this theory in a wide range of architectural and urban planning studies, such as architectural design, architectural morphology, historical evolution of architecture, spatial analysis, praxeology, and spatial cognition, as well as urban development analyses, has made the space syntax a widespread subject in architectural studies (Hamedani Golshan, Behzadfar & Motallebi, 2015, 64). Hillier and his colleagues have been able to properly publish their intellectual foundations in scientific circles by presenting their scientific resources and holding biennial symposiums; thus, this theory has been developing at a rapid pace over recent years. Nevertheless, critics attribute fundamental flaws to it. According to the space syntax theory, the relationship between activity and space can be understood and defined more through the relationship between spaces, i.e., spatial configuration and the relationships between contacts, rather than the individual characteristics of each space (Rismanchian & Bell, 2010). Hillier (2007) shows that prior to any individual characteristic of space, including the form, shape, color, and fabric, what impacts the experience of a built environment is the way spaces are related, which is called spatial configuration. This approach is based on the vision and movement of the user in the space. On the other hand, other theoreticians reject the attention to one sense for experiencing and understanding the space. For instance, Merleau-Ponty discusses that we cannot consider space an external object separated from the body. The space and body redefine each other and integrate with the perception process. Therefore, perception is like a dialog between an incarnate subject and its world (Piravi Vanak, 2010, 101). As we cannot separate the user's spatial perception of space, we cannot divide a spatial experience into discrete senses since the senses are integrated. How the perception of mental components, which are among the individual characteristics of each space, forms is not the subject of this article. However, in this study, it is assumed that each component involved in our perception process more or less influences our behavior and movement patterns. Accordingly, it investigates how the individual characteristics of each space, which impact the feelings of the user and can be experienced and perceived by their minds, can be assessed simultaneously with the analyses of space syntax, as well as the space configuration characteristics. Moreover, it studies what changes in the ultimate analyses of the space will be made in case these characteristics are added. The current analyses of the space syntax consider all spaces with the same weight, and the connection between spaces only determines the importance of each section in the whole system. However, it seems that by adding the unique characteristics of each space, the spatial units would not have the same weight anymore, and each space would have a unique weight. Accordingly, by developing a new computation model, the accuracy of this theory's output, which is the basis for future analyses, can be remarkably enhanced. The article also assumes that analyses based on weighted graphs can have more significant and direct relationships with the natural movements of the users of the space.

Research Methodology

The present study seeks to achieve more

reliable results by involving mental factors in space syntax calculations. Therefore, both qualitative and quantitative approaches were employed in the research. Since the configuration is the most important factor of movement in space, according to space syntax theories, the component of integration was evaluated along with the agent-based analyses. Hence, the mental factors effective in the formation of agents were considered in evaluating the weighting of the spaces. The weighting was performed using the hierarchical cluster analysis. Given the need for the pairwise comparison of spaces based on the determined criteria and theoretical mastery of the specialized terms used in the questionnaire, the study sample was chosen among academic experts with at least Ph.D. degrees. According to the literature, in this stage, 14 criteria that impact the movement of a pedestrian in an architectural space and are detectable based on the individual and unique characteristics of each space were chosen. These criteria included space readability, flexibility, contrast, confinement, scale, permeability, visual variety and rhythm, detectability, resolution, light, sound, fabric and material, furniture, and distance. To optimize the questionnaire and achieve the research objective, among the 14 criteria mentioned, readability, flexibility, permeability, confinement, and light were chosen as the main five criteria for the assessment. These criteria have the greatest impact on the formation of the movement pattern of pedestrians in the space of the Iranian Artists' House. After determining the weight of each space separately, the experts compared the criteria pairwise within 22 micro spaces of the Iranian Artists' House to determine the total weights of criteria in each space. To this end, in the designed questionnaire, the priority of each criterion among spaces was questioned in pairs. The level of priority in the AHP questionnaire was considered between zero and nine, indicating equal priority and maximum priority, respectively. Based on the unique weight obtained for each space, the weighted graph was plotted, and its output was compared with that of the common approach.

The field measurement of the two computation approaches was performed using the gate count method. This method is used to determine the movement flow of individuals in sampled spaces inside an urban or architectural space throughout a day to compare the integration values (Grajewski, 1992). In this method, a spectrum of spaces with high, medium, and low uses, as well as boundary areas of the considered region, should be involved in the test. Each gate is an assumed line, and an observer should count all pedestrians passing through it. The duration of observation for each gate is 2.[5] to 5 minutes, and it can be performed at different intervals, such as on working days or holidays. Counting the number of movements aids in discovering the relationship between spatial structure and human behaviors (Al-Sayed, Turner, Hillier, Iida & Penn, 2018). Eventually, using the linear regression model, the significance of the relationship between the integration of spaces was evaluated based on simple and weighted graphs with the movement pattern obtained from the gate count method.

Literature Review

The first attempts to identify the spatial structures may be attributed to Euler. To solve the problem of the Seven Bridges of Königsberg, he used the geometry of position instead of distance measurement for the first time. The geometry of position is what we call graph theory today. Martin and March (1972) and, in particular, Steadman (1983) were the pioneers of using topology and graphs in analyzing the built space. However, Bill Hillier is undoubtedly the most important face in this regard. The topological calculation methods developed by him and his colleagues in the 70s resulted in the space syntax theory. In 1984, Hillier and Hanson published the book "Social Logic of Space," which defines the syntax theory for space organization in buildings and housing. They argue that buildings, cities,

and counties have specific spatial characteristics known as sociological roles. In a study on the Hampstead Garden using the questionnaire, sketch, and space syntax method, Kim and Penn (2004) assessed the relationship between configuration and perception and behavior in space. In a study on spatial configuration and spatial behavior, Lay et al. (Lay, Reis, Dreux, Becker & Ambrosini, 2005) stated that the role of spatial configuration could be combined with spatial perception and experience. The relationship between the architectural space and society has also received attention from theoreticians like Giddins, Lefebvre, Grutter, and Merleau-Ponty. In his thesis entitled "An investigation of the relation of space to society: a discussion on A. Giddens, H. Lefebvre and space syntax," Mavridou (2003) studied the relationship between space and society from sociological and architectural perspectives based on the structuration theory of Giddens, the theory of the production of space of Lefebvre, and theory of space syntax. According to the results, while the three theories explore the relationship between space and society in different ways, they only provide the potential to create a relationship between sociological and spatial concepts and the environment, making the relationship between space and society the main component of environment design (Rashidzadeh, Tahmasbi & Habibi, 2019). Defining spatial cognition as the process of human's perception of geographical space in a study on the neighborhoods of Dezful, Iran, Dideban, Pourdeihimi and Rismanchian (2013) stated that the simultaneous perception and clarification of spatial configuration and spatial cognition of the built environment require a suitable approach that can meet the requirements of both aspects. To quantify and gain a clearer understanding of the spatial configuration, there are various methods for analyzing the built environments, most of which rely on the visual and physical aspects, metric distances, and geometric aspects of the configuration. These methods are mostly unable to consider the relationship between spatial configuration and social behavior (Mohareb, 2009). Employing Roger Barker's theory of behavior settings and collecting the behavioral data of two neighborhoods in Tehran, Hamedani Golshan, Behzadfar & Motallebi (2020) made an effort to overcome the drawbacks of space syntax and precisely identify spatial-behavioral patterns. Investigating the space from the perspective of both theories and adapting them produced reliable outcomes. In a study on the formation of justified graphs using convex and crossover methods, Hajian and Alitajer (2017) assessed the effect of the formation of graphs on the integration results of spaces. Despite its frequent uses in the analysis of the built space, this theory has received several criticisms since it was put forward. Carlo Ratti made some criticisms against this theory, which the Bartlett School of Architecture answered. Ratti doubted the results of the theory in orthogonal grids since, in such fabrics, broad streets are depicted in a form more effective than they are and disturb the human meanings of other components. Ignoring the topography, height of buildings, and views is another drawback attributed to this theory by Ratti (Ratti, 2014). Given these criticisms, more complex algorithms have received attention over recent years to correct the flaws of this theory from different perspectives and put forward a more comprehensive theory that includes the goals set by Hillier.

Theoretical Foundations

• Architectural space and its mental characteristics

The clearest definition of the space that can be provided seems to be "a vacuum that can be filled with or is full of objects." Accordingly, space does not have a concise definition (Kurt Grütter, 2014, 147). The scientific and philosophical investigation of space indicates that it is a more mental subject. Meanwhile, the empirical perception of space indicates that it is not an object, but a relationship between objects or their containers or reflections (Arnheim, 2009, 33). Researchers like Rapoport (1969) have described space as a meaningful

cultural factor. Therefore, the recognition of space organization patterns should be taken into account as a means to identify the relationship between built spaces and cultural and semantic aspects (Thungsakul, 2002). Schopenhauer mentioned this capability in his note on architecture entitled "The World as Will and Representation". He states that in the first stage, the architecture exists in our spatial emotional perception and, thus, relies on our intuitive capability, which is prior to any experience (Forty, 2000, 258). What occurs in the space, which is called an event, stems from the mind, which is the main element in confrontation, interaction, and movement. In fact, this is the mental perception that stimulates human interaction with the environment, as mentioned by Merleau-Ponty. The theories of Merleau-Ponty about space are summarized in his phenomenological studies on the role of perception in environmental understandings. By "perception," he means the phenomenological and movement aspect of our physical existence in the world, i.e., the emotional perception that has a close relationship with the physicality of the subject. In this regard, the body is the main means of perception and the catalyst between the subject and object (Ghahramani, Piravi Vanak, Mazherian & Sayyad, 2014, 23). Merleau-Ponty believed that human experience could not be decomposed to separate senses. Still, it has a general structure whose independent components have meaning in relation to the whole. "The five senses that are our primary tool to access the world are not separate. They constitute a structure organized in a general configuration. The body is eventually a whole object. The bond between the components of the body and the visual and tactual experiences cannot be obtained gradually and synergistically" (Piravi Vanak, 2010). Merleau-Ponty believed in the unity between human senses, among which vision and other senses are not discrete and unrelated. Accordingly, perception does not consist of a set of data obtained from the visual, tactual, or auditory senses. It is received by the existential integrity of the human.

Henri Lefebvre argued that human space and human time are half in nature and half in abstraction. The space and time lived and produced socially depend on physical and mental concepts and structures. Hence, we have a conceptual triad consisting of spatial practice, space representations, and representation spaces. Accordingly, the space can be dealt with from three perspectives as a perceived, imagined, and lived matter (Rashidzadeh et al., 2019). Lefebvre stated that those who control how the space is represented also control how it is produced, organized, and consumed. This schema can be analyzed from three perspectives. Firstly, spatial practice is perceived as an interconnected chain or network of activities or interactions that rely on the physical form, structure, and built environment depending on their roles. Secondly, space representations are perceived as an organizer schema with a reference framework to form interactions and communications that allow for spatial orientation and, thus, define the activity at the same time. Thirdly, representation spaces are a means to transfer meaning. Accordingly, a kind of spatial symbolization is formed that presents social norms, values, and experiences.

From the phenomenological perspective of Heidegger, phenomena do not exist as an external reality outside us. However, we are an indispensable part of realities, being inside the phenomena from the beginning (Pourali, 2011, 23). Putting a greater emphasis on temporality and spatiality, Heidegger believed that our interpretation of the vision is based on our foregrasp of architectural works (Partovi, 2008, 54), so it emphasizes the relationship between the space and spatiality. Bill Hillier (2007) considers space as a machine. He believes that buildings can receive information from society through space configuration and return it to society through the same means. The space syntax has been developed based on two major presumptions. Firstly, space is not considered a means for activity; it is the intrinsic characteristic of the activity. Accordingly, the movement occurs in a linear space, social

communications are defined in a convex space, and the visual domain of the user is determined based on their movement and viewing angle variations. Each of these geometric ideas is capable of describing our activity in space. According to the second presumption, characteristics of spaces like color, fabric, and light are not individually as important as the way they are when combined with other spaces of the system in forming the behavior of the user. This relationship is the spatial configuration.

The review of the literature on space (Table 1) indicates the continuity and indispensability between the objectivity and subjectivity of the built environment in the human's perception and experience of the space. The presumption regarding the invisibility of the form in the space syntax and delaying the reasons for the formation of social processes to the time after movement in the space mean to ignore a major part of the human characteristics as a being with five senses and mental backgrounds. As long as the space is investigated, the difference between its components and characteristics is not the case. The reason is that we face a whole whose objective and subjective aspects and place in the spatial system are continuous, and each human activity originates from the entire thing the space carries in itself and its place in a general system. The emphasis of the space syntax on the priority of the configuration in the occurrence of social events and behavioral patterns of users makes the human's vision and movement in the space the beginning point of experience and interpretation of the built environment's space. Afterward, the space configuration and society affect each other in a bidirectional relationship. Although the importance of spatial configuration in forming social behaviors cannot be ignored, the human's perception of their surrounding space and their performance in this space happen using all their senses. Not as an observer, but as a complete being, the human analyzes the space through their entire emotions and awareness of the space and forms behavioral patterns proportional to all behavioral patterns (Fig. 1). The space is where the human communicates first with their surrounding environment and then with other humans. Such spaces can be classified as man-made environments that have a mental aspect, as well as objective and visual aspects. Therefore, in the first stage, humans have been definitely involved in the formation of space.

- **Space syntax**

The form analysis of the building and perception of the relationships between spaces existing in each spatial configuration is referred to as a science known as space syntax in architectural subjects (Memarian, 2002). This science, which is also called the space syntax technique, was founded by Bill Hillier (Hillier, Hanson & Peponis, 1984). This technique is crucial since it can be used to reveal and perceive the social and cultural logic formed within the architectural configuration of each space (Hillier, 2007, 77). In general, the word "syntax" refers to the order of words in a sentence. The closeness of the origin of this word with the syntactic aspect of semiology indicates its similarity with literary, linguistic, and semiological principles (Memarian, 2002). The space syntax has proved the relationships between the mathematical description of the space and the presence of individuals in it (Ma, Omer, Osaragi, Sandberg & Jiang, 2019). The spatial models of human activities are not random. This proves a particular kind of spatial order (hierarchy) in societies using specific territories. Nevertheless, it should be emphasized that while the space syntax cannot predict individuals' behavior, it can be used to analyze the impact of spatial configuration on different types of collective behavior (Lamprecht, 2002). Thus, the route chosen by an individual cannot be predicted, but the one used more than the others is detectable.

- **Space configuration**

Configuration can be considered the most important concept in space syntax theory. Accordingly, this section discusses the precise identification of this concept and its relationship with space.

Table 1. An investigation into the ideas and attitudes of different theorists toward space. Source: Authors.

Theorist	Theory about the space	Attitude toward the architectural space
Rapoport	Space, time, communications, and meaning impact the organization of the environment.	Considering the built environment as a relationship between objects and people
Schopenhauer	The intuitive ability of humans to perceive space is prior to anything else.	Attention to the spatial emotional perception in the formation of architectural existence
Lefebvre	He discusses three dimensions of the space: 1. Mental space (the space of architects), 2. Physical space (where we live), 3. Social space	The space and time lived and produced socially depend on physical and mental concepts and structures.
Kurt Grütter	The living space is a semi-mental space perceived through a set of emotional and mental perceptions.	The architectural space can be perceived objectively, felt directly, and identified through its defining elements.
Martin Heidegger	The relationship between the human and the space is nothing but rather a residence. Heidegger emphasizes the fundamental relationship between space and place (Heidegger, 1971, 154)	Human action and demand give meaning to the space and turn the empty space into an experienced place (Afroogh, 1998, 1).
Maurice Merleau-Ponty	Human is the same as their body. The active presence of the body in the world is not a set of interactions with a pre-assumed space. The body is immersed in space and, at the same time, is its creator.	The spatial experience of the human is formed from all senses by their existential nature.
Bill Hillier	The space is the primary core of the way social and cultural events occur (Hillier, 2007).	The space forms through social, cultural, and economic processes and is usually considered a means for social and cultural activities such that its form is generally ignored and assumed invisible (Rismanchian & Bell, 2010).

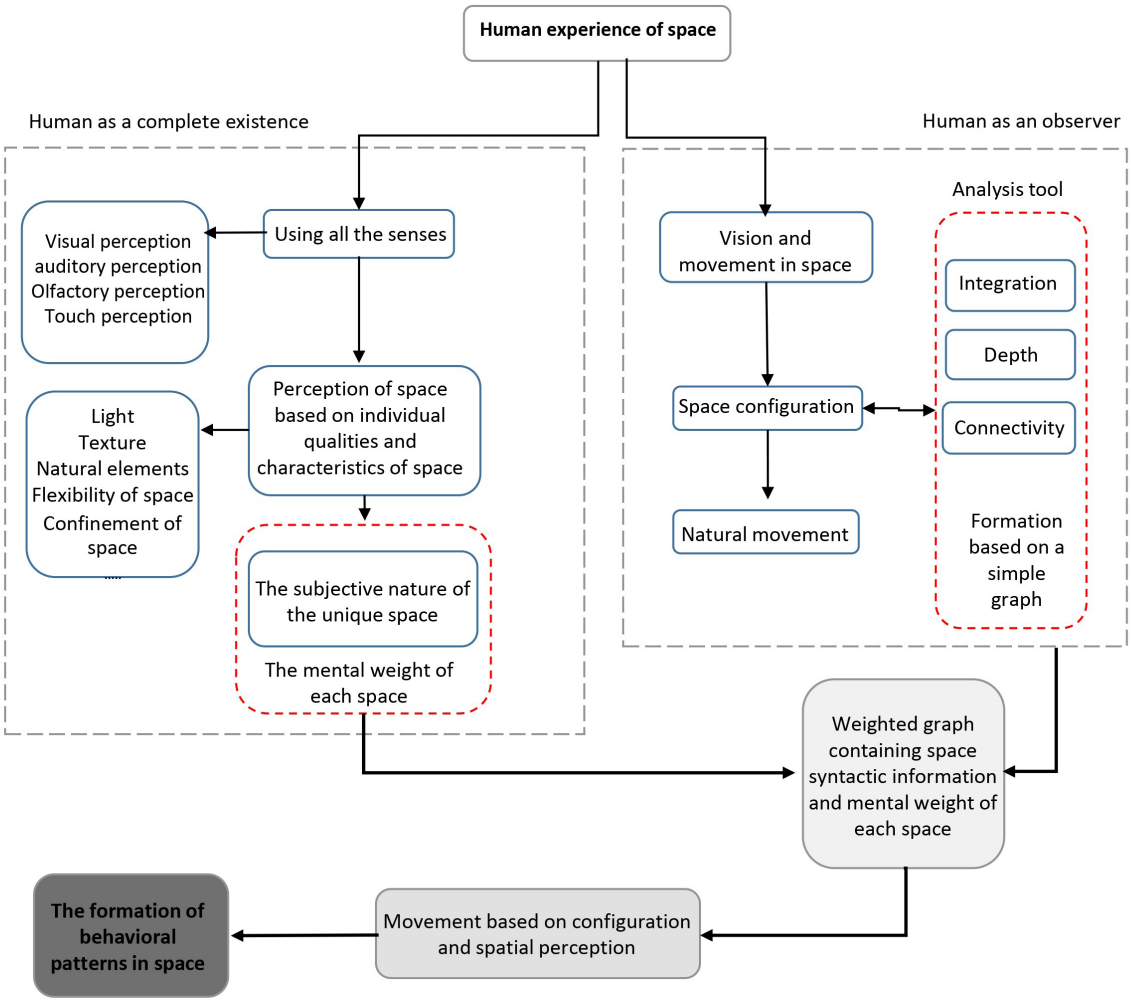

Fig. 1. The formation of the weighted graph and its impact on the formation of behavioral patterns. Source: Authors.

Configuration is a subject used in daily life. We can understand its concept through the way the parts or the whole are located relative to each other (Hillier, 2007). As "relationships that consider the other relationships," the configuration is defined in a complex network. Hence, the space syntax presents quantitative answers regarding the influence of the built environment and morphology on human behavior in space (Sabry Hegazi, Tahoon, Anwar Abdel-Fattah, Fathi El-Alfi, 2022). According to Hillier, regardless of their complexity, spatial sets can be defined in a structural framework of the spatial hierarchy formed based on the space permeability depending on the movement or attractiveness of the space and its use. Apart from being the rules and grammar of the space, the space configuration is a set of patterns that reveal the relationships between spaces and adds meaning to the space configuration (Dalton & Holscher, 2007, 3). The space configuration elucidates the place of each space in the whole, as well as its intrinsic characteristics. Differentiating a spatial combination and spatial configuration, Marshal believes that a combination refers to the geometric shape of the phenomenon or is depicted through the plan, location, length, area, and orientation, while configuration refers to its topological characteristics defined through their objective diagrams, lines and points, relative positions, vicinity, and relationship (Marshall, 2005, 35). The configuration may facilitate or restrict visual and physical bonds. However, humans seek to structure these bonds and make them controllable while using the built environment. There is no essentially direct relationship between spatial configuration and individual and collective behavior. Still, the spatial configuration creates a mental structure for the user based on the mental perception that affects the behavior. Thus, the relationship between spatial cognition and spatial configuration is bidirectional. The spatial configuration is effective in forming cognition. For periods of more than one, these are the cognitive structures that form the spatial configuration. In addition to being a force used for human activities in the architectural space and city, the configuration is the first thing that stimulates the spatial cognition of the human through movement in the space and determines the way it is formed (Jiang, 1998).

- **Natural movement**

The space syntax theory considers the "movement" as a major concept and a crucial mediator between spatial configuration and the formation of patterns of co-presence. Basically, the theory differentiates "spaces" and "routes" and ranks them from the most integrated ones to the separated ones: the more integrated a space, the easier access to it (Zaleckis, Chmielewski, Kamičaitytė, Grazuleviciute-Vileniske, Lipińska, 2022). The theory of natural movement describes the relationship between the movement and spatial configuration of the city. The space syntax theory believes that choosing mediating spaces to reach from the origin to the destination is directly related to the layout structure of the space (1993 ,Hillier, Pem, Hanson, Grajewski & Xu). Various observations have shown that most of the traffic in each space throughout a city is not due to the presence of the starting point or destination in the same space, but it occurs since the space is located in a part of the route from the starting point to the destination. It is worth noting that even a purposeful movement (from origin to destination) should pass through dependent lines. The natural movement theory deals with the effect of spatial configuration on leading the movement in the city and believes that spatial configuration is the most important factor in this regard, while factors like spatial attractions and land use are of lower importance (ibid.). The logic of the natural movement is based on the fact that configuration impacts the movement and spatial attractions while it is not affected by them. However, the movement and spatial attractions influence each other. When individuals cross a space more frequently due to its spatial configuration and characteristics, i.e., the

crossing density of the space is higher, uses suitable for such a population and crossing density would be located in such a space, which itself increases the crossing density. This condition is called "movement economy," which implies the "effect of crossing density on the performance of the adjacent uses" (Dorani Arab, Galenoie, Zamani & Moazzezi Mehr Tehran, 2016). While the performed studies confirm that the natural movement theory of Hillier properly predicts the movement of human crowds in the space in most cases, solely the configuration itself is unable to find the hidden aspects of a unique space, and the human factor is involved in it.

Space Syntax Tools

• Justified graph

The space configuration is mostly presented in the form of justified graphs. In a justified graph, the space of the starting point, which can be the input, has a depth of zero. Afterward, each space is laid out in its proportional depth according to the arrangement of spaces and their access to each other. As a result, the initial structure for space syntax calculations is formed. In a justified graph, a space that requires crossing more spaces to be reached is located at a greater depth.

Fig. 2 depicts a cell divided into two spaces, i.e., a and b, by a partition, along with a door that allows for penetration into the two spaces. As can be seen, the two spaces are symmetric to each other. By naming the external space C, defining it with a circle having the symbol inside it, and showing each space with a circle and the penetration of each space to another space with a line, the justified graph of the cell would be as follows. The relative depth of the set can be defined based on the formation of this graph. This is the most important factor in calculating the integration as the most important parameter of the space syntax.

• Integration

It may not be an exaggeration if this value is considered the most important value obtained from this method (Abbaszadegan, 2002). The integration of a point indicates its level of connection with the whole structure of the set or its subsets. A space that can be reached by crossing fewer spaces has higher integration and vice versa (Jafary Bahman & Khanian, 2013). Case studies reveal the direct relationship between integration and the presence of individuals in the space (Klarqvist, 2015).

• Agent-based analysis

This analysis is based on the simulation of the individual movement behavior in which the movement agents choose their movement orientation based on a visual field of view obtained from the analysis of the vision graph. The agent-based analysis allows the planner or simulator to simulate the probable behavior of the individual when moving through the environment. This analysis simulates the movements predicted inside the plan based on two major assumptions: the movement is purposeful, and the agents have good information about the environment. Herein, human behavior is planned based on standing, talking, looking, and gathering (Penn & Turner, 2003). The maps obtained from the analysis of the justified graph and users' movement determine the parts of the plan that are weak or strong in terms of circulation. Accordingly, the more successful points or those with lower effects can be detected and modified in the design stage.

• Case Study

The Iranian Artists' House was a reconstruction and land use change project allocated to the Gozineh Consulting Engineers Co. by the Ministry of Culture and Islamic Guidance in 2000. The project was designed and executed within a short time in the same year. The plan of the building, which was a part of an army garrison, is remarkably similar to the typical public building plans in different parts of Iran in the 40s and 50s. This type of plan has a great lobby with a wide staircase connected to two upper floors, along with one-sided corridors that receive light from one side and have access to large rooms of the building on the other side (Fig. 3)

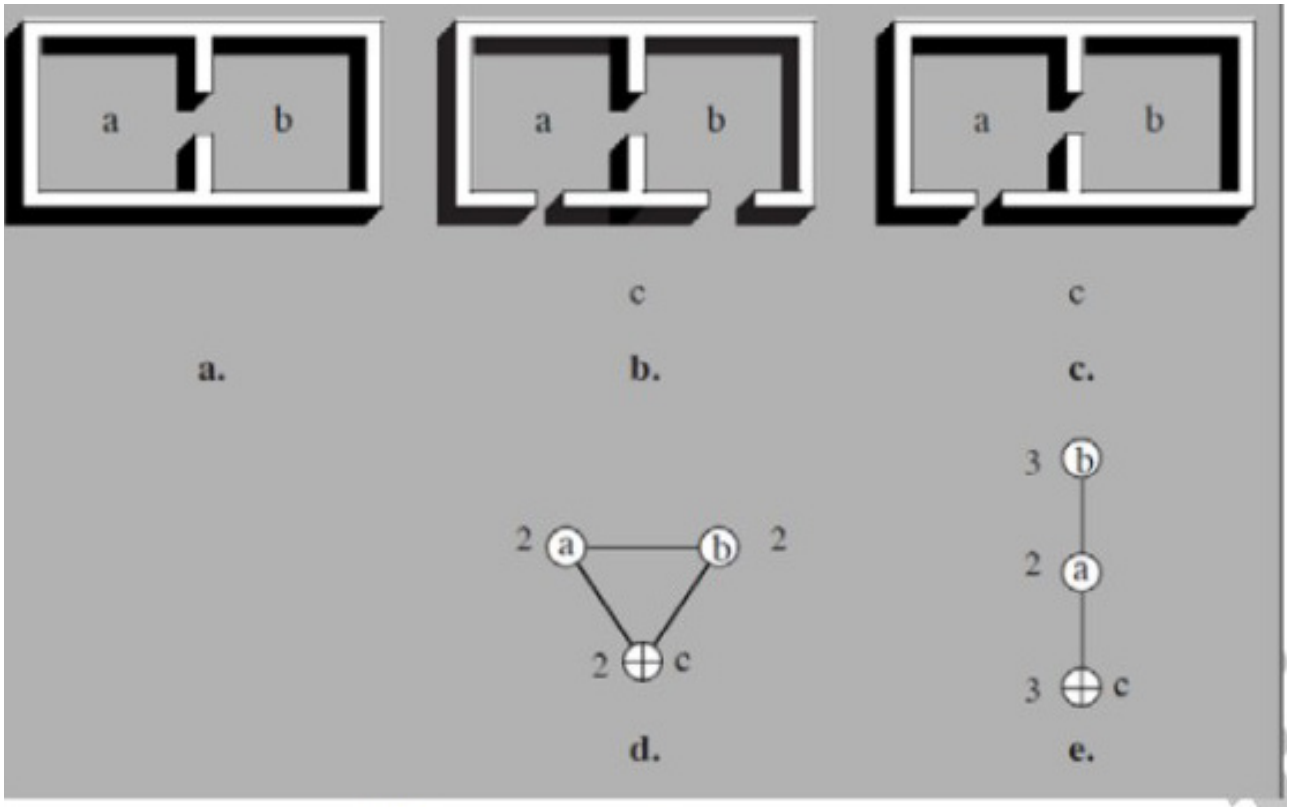

Fig. 2. The relationship between the plan and plotting method of the justified graph. Source: Hillier, 2007.

The vitality of the building having various and almost large users is among the most important reasons to choose it to evaluate the hypothesis. The goal is to assess the effect of mental components, along with configuration, as the agents leading to a natural movement. Accordingly, the nature of the complex allows the visitors to move, stop, encounter, and interact, and enables the researcher to track them. Accordingly, the total configuration of the building was plotted using the justified graph and Agraph software (Fig. 4). The integration of each space was calculated using the depthmap software, as listed in detail in Table 2.

In the next step, the movement behavior of the user was simulated using the agent-based analysis in the depthmap software (Fig. 5). The high movement density in the central lobby, the lateral corridors, and the main galleries of the Iranian Artists' House are obvious in this analysis. The red points experience the highest movement density, while the dark blue points experience the lowest movement density, according to the analysis. It is also found that the western corridor and gallery have a higher density of movement compared to the eastern part. Table 2 lists the maximum value of the gate count obtained for each space.

Findings of the Weighting Using the AHP Method

According to the article assumption, adding each mental criterion affects the space syntax results, and only the level of this effect would be different. Therefore, among the 14 criteria obtained, only five ones that had greater importance from the respondents' perspective were chosen as the basis to evaluate the hypothesis. At first, the weight ratios of the five criteria, i.e., permeability, readability, flexibility, light, and confinement, were compared using the questionnaire. The analysis performed in the Expert choice software revealed that flexibility (0.371) and light (0.052) had the highest and lowest weights, respectively (Table 3). Moreover,

the inconsistency rate was 0.02, indicating the acceptable consistency of the comparisons.

In the next step, the respondents were asked to determine the priority of each of the subspaces to the others, given their spatial perception of the space of the Iranian Artists' House based on the five criteria defined. The superiority of each space over the others was determined with a value from one to nine, indicating equality and maximum priority in the formation of the hierarchal analysis matrices, respectively. The weight obtained for each criterion in each subspace and the total weights of each space are respectively demonstrated in Figs. 6 & 7.

Findings Obtained from the Weighted Graph

In the next step, the relative weights of criteria were used to identify the movement patterns in the space. The new justified graph was designed not based on the common method, i.e., the simple graph, but using the weighted graph to measure the probable effects of these criteria on the natural movement (Fig. 8). In order to better understand the graph, the weight of each space is plotted in the form of a circle with a variable radius based on its effect on the user. Larger radii indicate the greater weights of the effect of mental components in each space.

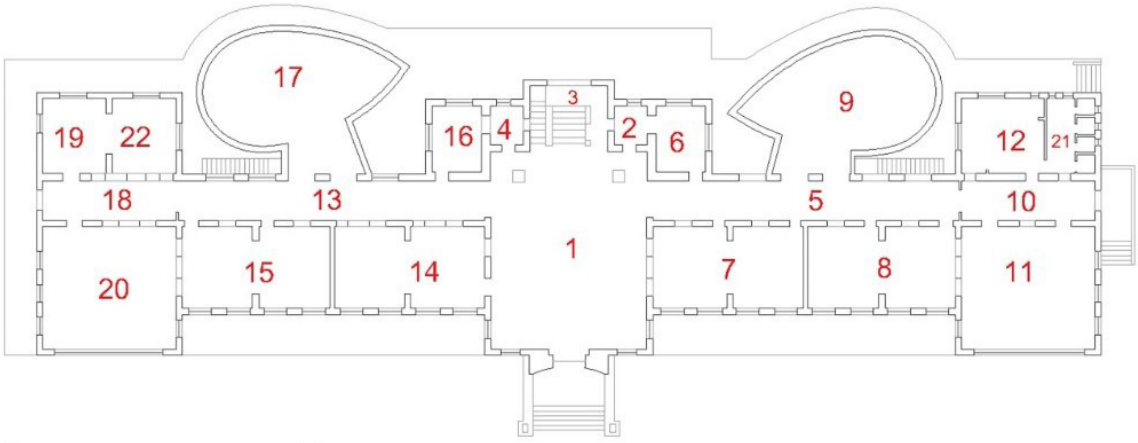

Fig. 3. Plan of the Iranian Artists' House. Source: www.caoi.ir.

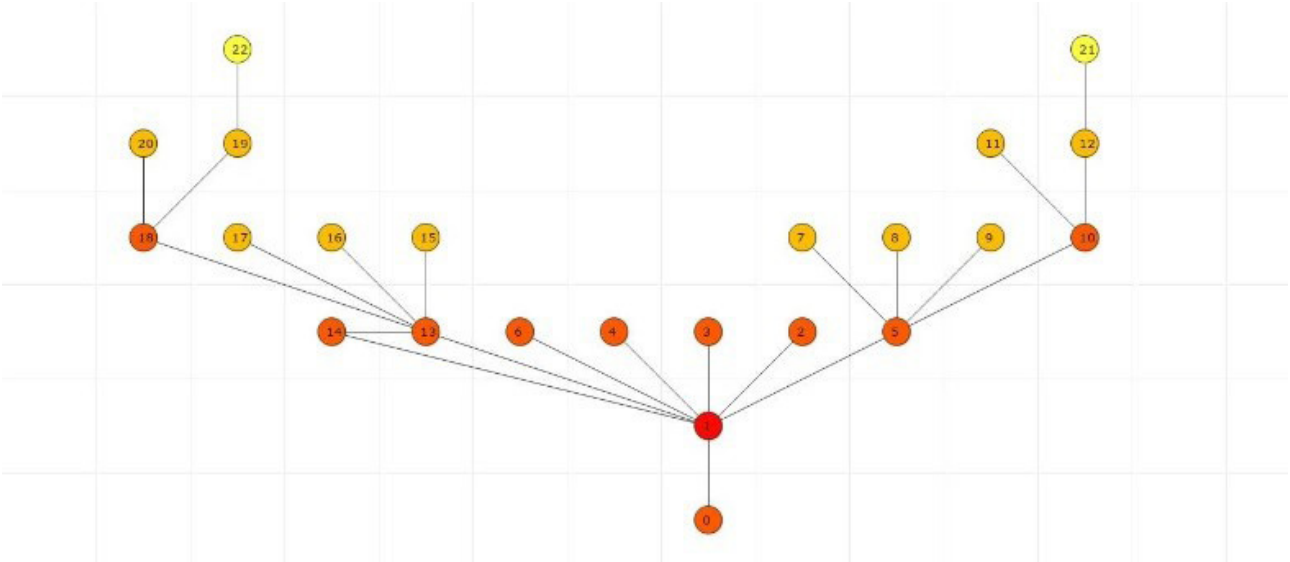

Fig. 4. The justified graph of the Iranian Artists' House. Source: Authors.

Table 2. The level of integration and the gate count obtained from the agent-based analysis of different spaces in the Iranian Artists' House. Source: Authors.

Space number	Space name	Level of integration	The maximum value of the gate count	Space number	Space name	Level of integration	The maximum value of the gate count
1	Entrance lobby	2.04	128	13	Western corridor	1.66	75
2	Service room	1.07	1	14	Store	1.32	41
3	Staircase	1.07	5	15	Gallery	0.95	27
4	Official	1.07	5	16	Official	0.95	6
5	Eastern corridor	1.60	70	17	Western gallery	0.95	119
6	Official	1.07	8	18	Western lobby	1.09	29
7	Gallery	0.93	19	19	Gallery	0.76	21
8	Gallery	0.93	25	20	Gallery	0.73	66
9	Eastern gallery	0.93	86	21	WC	0.56	7
10	Eastern entrance	1.07	28	22	Gallery	0.56	19
11	Cafe	0.72	57				
12	Services	0.75	22				

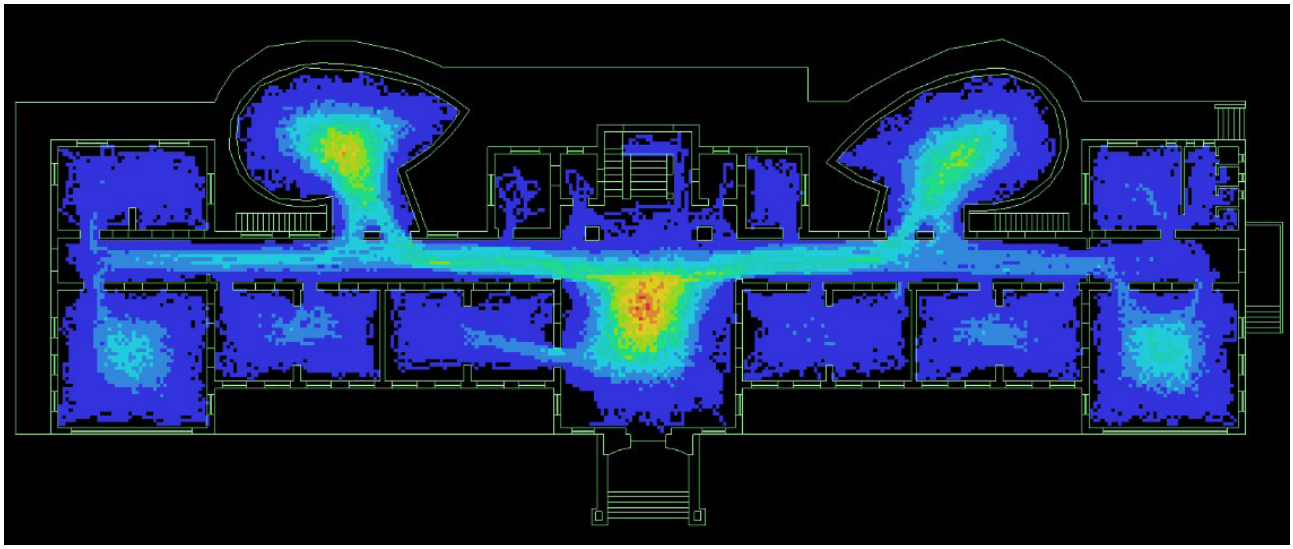

Fig. 5. The agent-based analysis in the depthmap software. Source: Authors.

It should be noted that the results obtained from the analysis based on the weighted graph cannot be compared one-to-one with the simple graph. For instance, space number 1, which is the lobby of the complex, has the highest integration in both graphs. Nevertheless, it cannot be interpreted that the numerical value of the integration in space number 1 in the calculations based on the weighted graph has increased compared to the simple graph. Instead, the ratios of integration between all spaces should be generally compared. In other words, by adding the graph weight to the justified graphs, the previous calculations are not valid anymore, and the ratio of the integration value in the new graph is used to analyze the space. The results of weighted graph calculations are presented in Table 4.

Table 3. The weights of the main criteria obtained from the Expert choice software. Source: Authors.

Criterion	Weight
Permeability	0.371
Confinement	0.153
Light	0.052
Flexibility	0.195
Readability	0.230

The outcomes of the new calculations reveal several hidden realities about the space of the Iranian Artists' House, which the simple graph could not show. While space number 1, the lobby, and space number 21, the WC, still have the highest and lowest integration, some changes are shown in other spaces. In previous calculations, after space number 1, the highest integration belonged to the corridor of the left side of the building (space 13), indicating that the western corridor is used more than the eastern one.

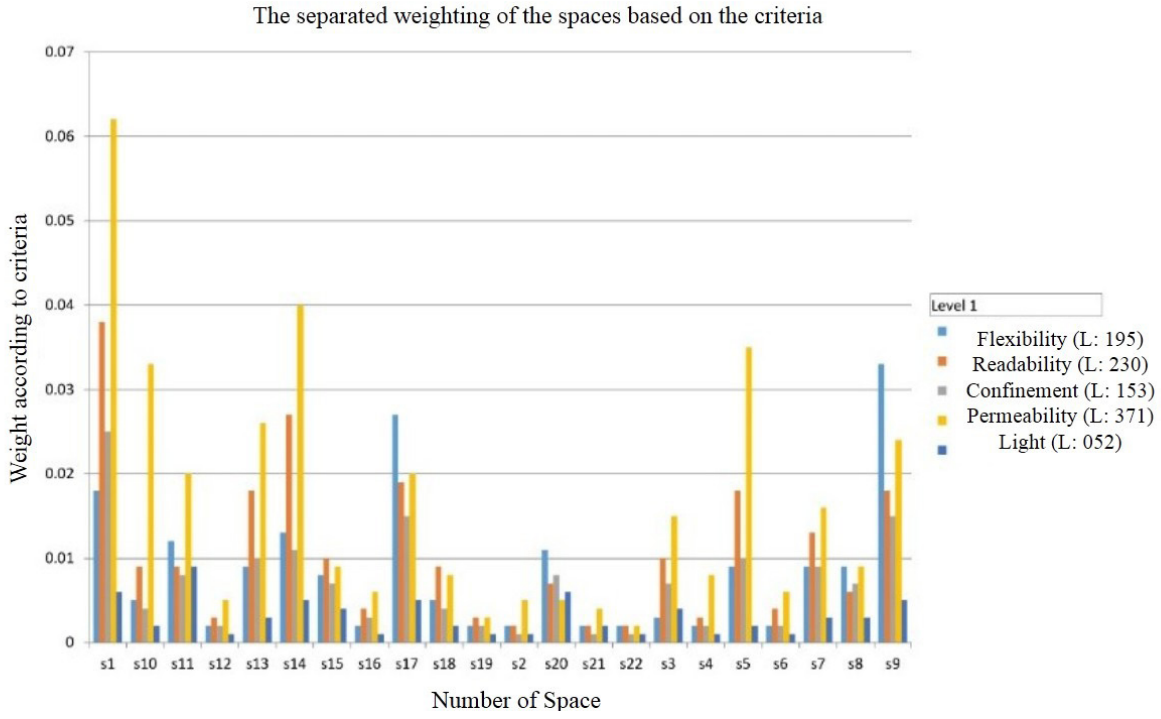

Fig. 6. The separated weighting of the spaces based on the criteria. Source: Authors.

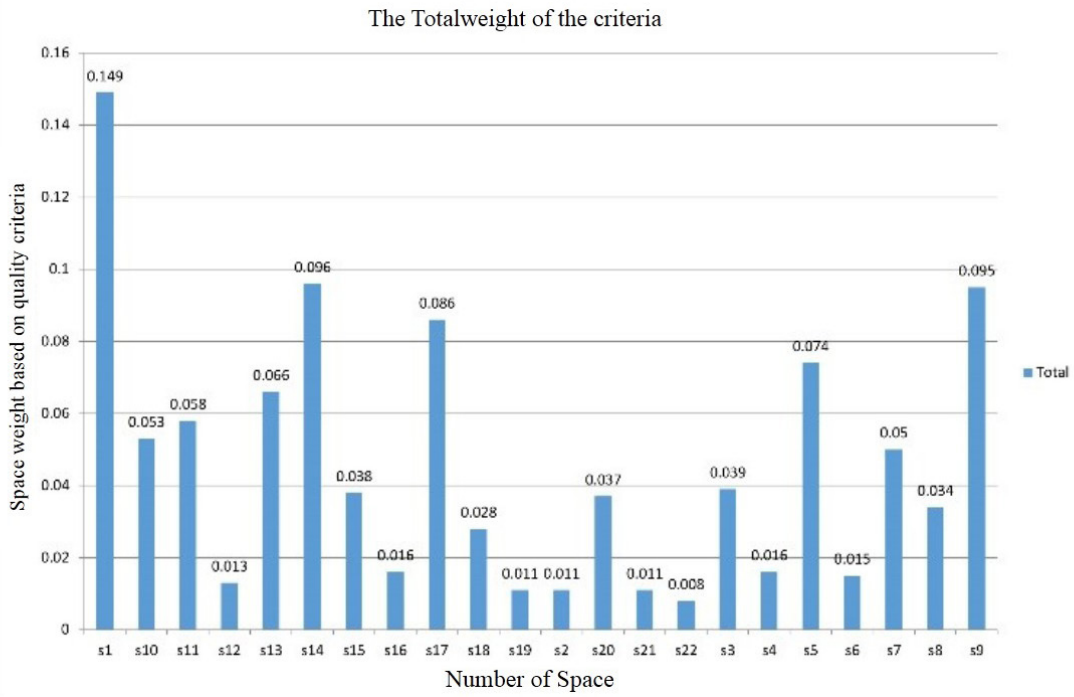

Fig. 7. The total weights of the criteria for each space. Source: Authors.

This was also shown by the agent-based analysis. However, in the new calculations, this is the eastern corridor (space number 5) that has a higher value. This change can be attributed to the presence of the entrance on the eastern side of the building. Indeed, a common drawback in the space syntax method is its inability to consider the simultaneous effects of different entrances of a building on the movement of pedestrians, which has been corrected in this method. The space of the store (number 14) has gained a higher spatial value. This can be detected from the difference in its numerical value with other spaces and in the agent-based analysis. This is evident that the effect of the use on the further use of a space results in more natural movements in it. Hillier states that this is the characteristic of the configuration that makes active uses like commercial use find their place in the spatial structure of a complex. Such uses are usually located in sections with more movement flows. The new analysis confirms the theory above and emphasizes the mental effects of active uses in the movement flow of pedestrians. In other words, the intrinsic feature of the configuration determines the active use

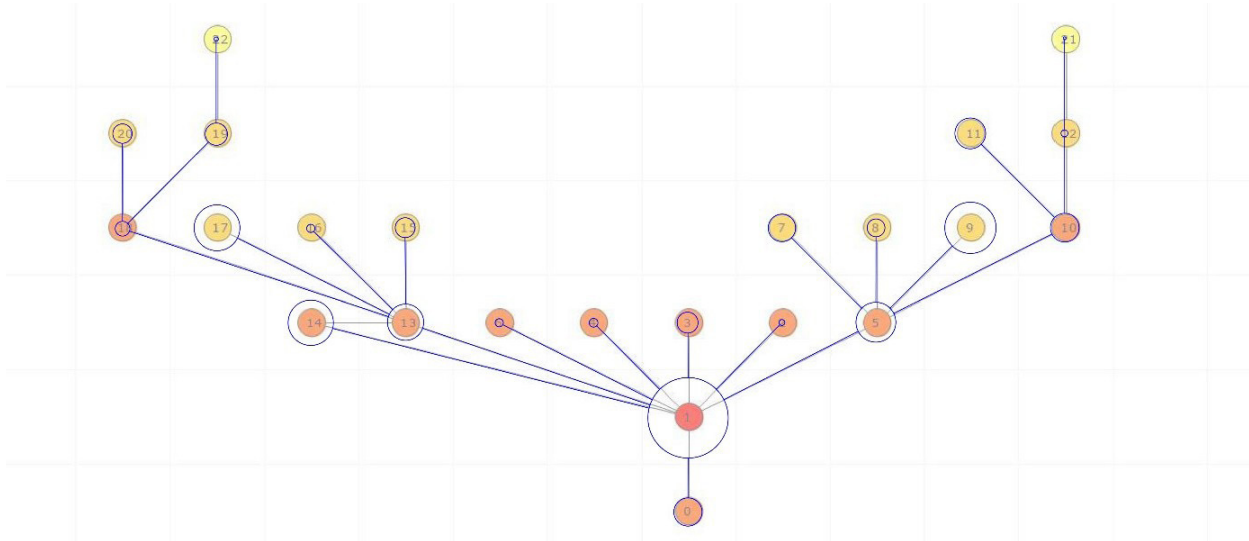

Fig. 8. The weighted graph based on the integration and weight of the mental component of each space. source: Authors.

Table 4. The integration level of spaces based on the weighted graph. Source: Authors.

Space number	Space name	Space weight based on the mental criteria	Integration level based on the weighted graph	Space number	Space name	Space weight based on the mental-imaginary criteria	Integration level based on the weighted graph
1	Entrance lobby	0.149	3.03	13	Western corridor	0.067	1.11
2	Service room	0.011	0.11	14	Store	0.084	1.1
3	Staircase	0.039	0.42	15	Gallery	0.037	0.35
4	Official	0.016	0.17	16	Official	0.015	0.14
5	Eastern corridor	0.074	1.18	17	Western gallery	0.085	0.8
6	Official	0.015	0.16	18	Western lobby	0.027	0.29
7	Gallery	0.051	0.47	19	Gallery	0.011	0.08
8	Gallery	0.033	0.3	20	Gallery	0.036	0.27
9	Eastern gallery	0.095	0.87	21	WC	0.010	0.05
10	Eastern entrance	0.053	0.55	22	Gallery	0.008	0.05
11	Cafe	0.057	0.41	-	-	-	-
12	Services	0.013	0.09	-	-	-	-

location, and then the mental components originated from an active use intensify the natural movement toward them. The presence of the entrance on the eastern side, besides the location of the active use like the cafe (space number 11), has generally made this section of the building have higher integration than its opposite symmetric side. The simple graph indicated that space like the western gallery (number 17) has slightly higher integration compared to the eastern gallery (number 9). Meanwhile, the weighted graph showed that the eastern gallery (0.87) has higher integration than the western one (0.8). Thus, it can be interpreted that due to the presence of different entrances and uses, the eastern side of the building has been able to experience a higher movement flow and is generally visited more.

The evaluation of the Iranian Artists' House based on the weighted graph reveals several points. The simultaneous effect of various physical and mental elements on the movement flow of the visitors is completely evident. Having many similarities in terms of their place in the spatial structure of the Iranian Artists' House, the eastern and western corridors have some internal differences that are ignored by the configuration. In the eastern corridor, the end of the path is clearer and more readable and can be perceived in a shorter time by the user. The end of the corridor, which leads to the eastern exit of the building, is a more certain destination, so the user chooses to move toward where they are more aware. This greater awareness in the corridor, which is the main element of the eastern side in terms of space configuration, has an evident impact on other spaces on this side. It can be said that when the main components in the configuration provide the user with more physical and mental stimulators due to any reason, they gain a higher weight, and this weight will affect other spaces related to this part of the space. The notable point in the Iranian Artists' House is the higher effectiveness of the individual components of the space in parts of it that are in the middle ranks in terms of spatial value. In other words, these components have had greater impacts in the lobby space, which has the highest integration, and smaller effects in the WCs, which have the lowest integration. This confirms the important impact of configuration on the formation of movements and behaviors. However, these individual characteristics of the space can yield different results in interstitial spaces.

Findings Obtained from the Gate Count test

In order to evaluate the movement flows in the Iranian Artists' House, 15 gates were considered, and the information was recorded on the last day of the week. Each gate was assessed in two five-minute intervals, and the number of movements that happened in each gate was recorded. Fig. 9 depicts the layout of the gates and the number of movements of the pedestrians.

Recording the number of movements revealed that the analysis performed based on the weighted graph is considerably reliable. The density of most movement flows has been higher in the eastern section of the building such that in the defined period, the eastern corridor had 38 movements, while the western one experienced 24 movements. The evaluation of other spaces also indicates a significant relationship between the integration of the weighted graph and natural movement in the building. Using linear regression, Figs. 10 & 11 demonstrate the significance of the relationship between the integration of the simple graph and the weighted graph with the number of movements recorded in the space.

The ultimate model of the linear regression indicates coefficients of determination (R2) of 0.734 and 0.903 for the integration relationship calculated based on the simple and weighted graphs, respectively, indicating the higher correlation of the integration calculated based on the weighted graph and natural movement of the pedestrians in the space.

Conclusions

As Hillier states, space configuration is the most important factor in the movement of pedestrians.

However, the ultimate and certain results of a movement and occurrence cannot be predicted solely based on the evaluation of the spatial configuration. Hillier starts his analyses based on the characteristic features of the space and then describes how events occur in the built space. Nevertheless, the space characteristics associated with the geometric location of spaces compared to each other cannot act comprehensively in providing an analysis regardless of the form and nature of the space. The techniques employed in this article were chosen based on the literature review. However, to achieve the research goals in the present study, the questionnaires were developed so that their results could be translated to numerical weight values using the AHP method, unlike the common procedure. As a result, they could be involved in the quantitative calculations of the space syntax. Given the research experience, a crucial finding can be mentioned in this study. Replacing the simple graph with the weighted one can provide the analyst with results that coincide more remarkably with the space's existence. The space syntax calculations using the weighted graph consider the general relationships of the space configuration and even add some things to it. Weighting using the Analytical Hierarchy Process (AHP) and combining it with the space syntax calculations did not harm the initial calculations. The movement flows recorded in the gate count test were also compared with the results obtained from the weighted graph using linear regression modeling. Accordingly, it was found that the made changes could have a significant and direct relationship with the existing spatial structure and remarkably improve the computation accuracy like in the common method. These changes help to move from space syntax toward place syntax and pay more attention to the role of senses in the encounter of humans and space. The results of this study, which included hypothesis testing through the gate count method, indicate that the movement and behavioral patterns identified by the space syntax are different from the reality of the built environment. However, the prediction accuracy of these patterns can be improved through environmental and supplementary studies and

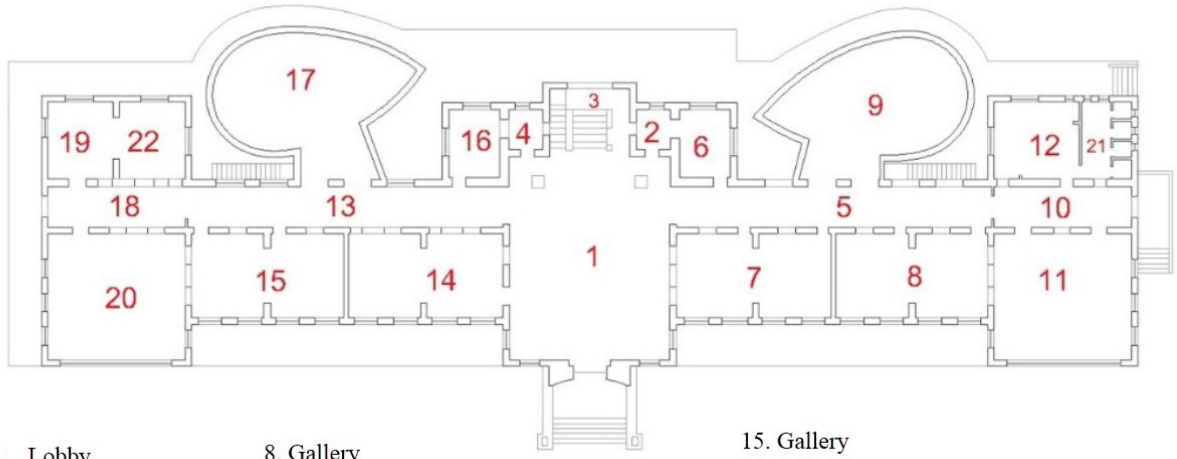

Fig. 9. The layout of the count gates and the number of crossings recorded in each of them. Source: Authors.

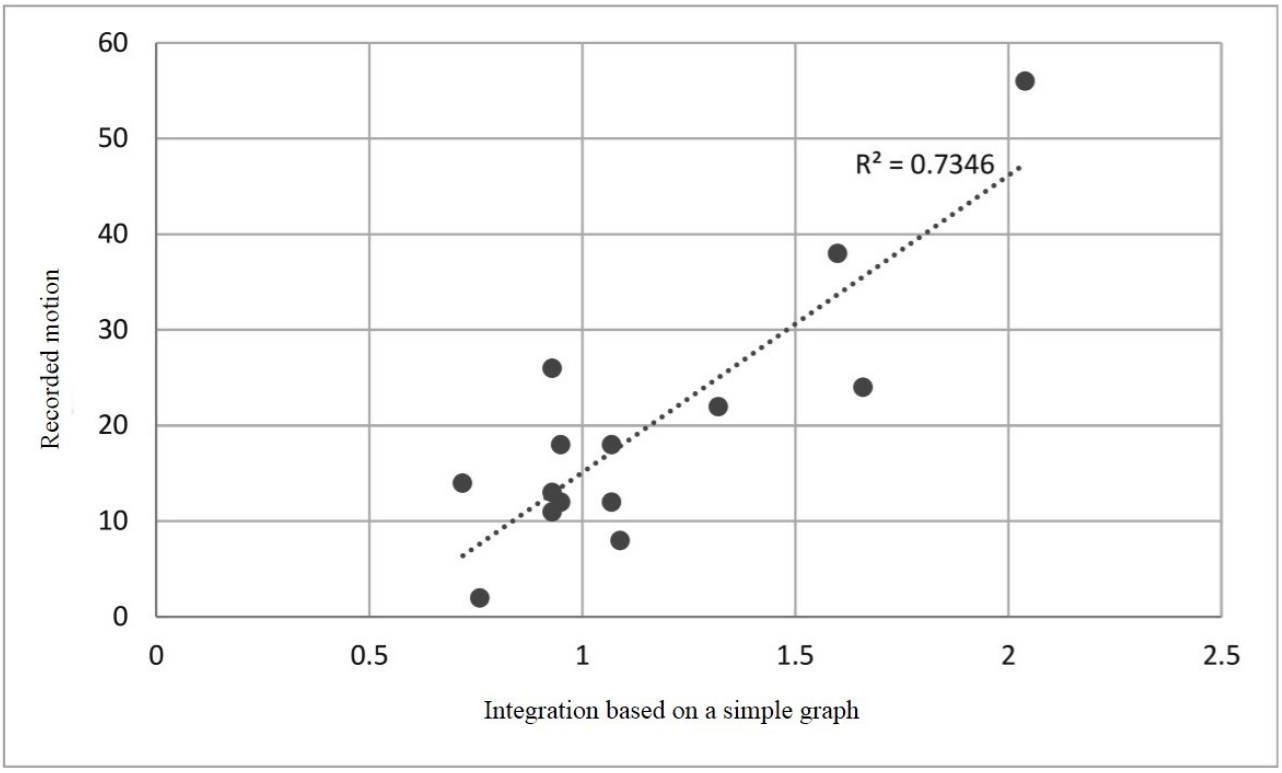

Fig. 10. The linear regression model based on the simple graph. Source: Authors.

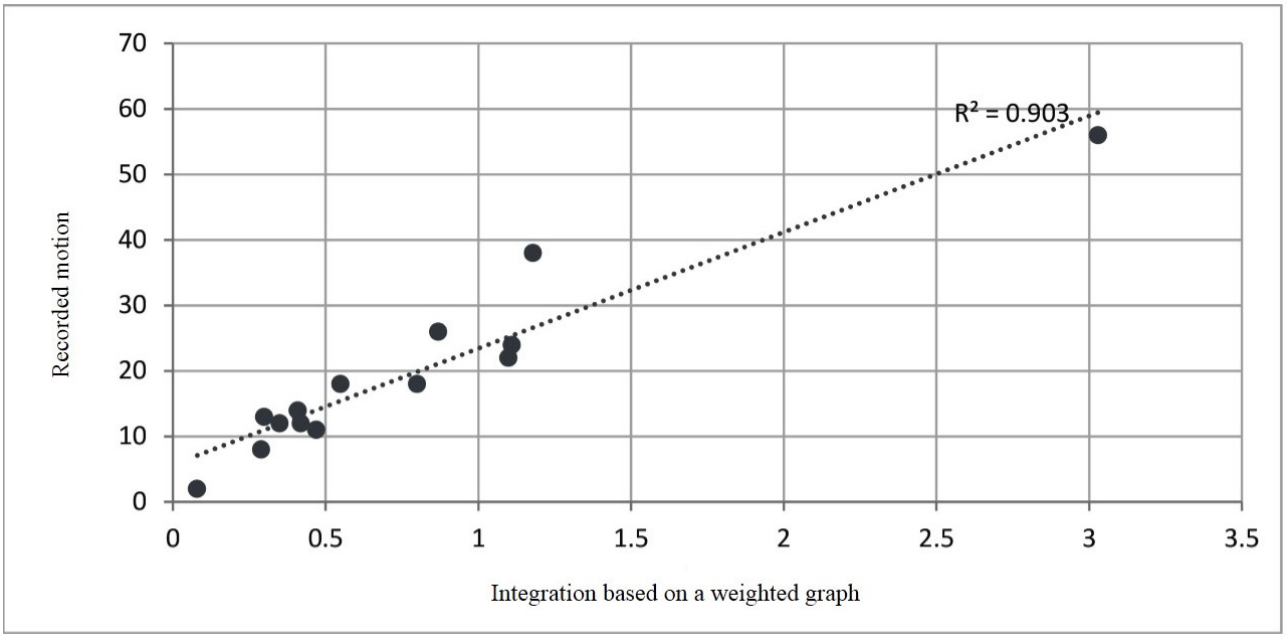

Fig. 11. The linear regression model based on the weighted graph. Source: Authors.

the integration of their results. Furthermore, it confirms that the subjectivity and objectivity of the space are not separable, and the movement, stop, and encounter of the human with the space and their individual and collective actions result from the effect of all characteristics of the built environment on the human senses. The minds of the user make them do activities, and the force of space configuration varies in different conditions. Table 5 makes a general comparison between the two analysis methods based on the simple and weighted graphs.

Although the results obtained from the calculation method based on the weighted graph were more reliable, this method is still in its beginning and has drawbacks, including human interventions in the analysis process. Although using the AHP method, this intervention improves efficiency and controls contradictory opinions to a great extent, the analysis procedure is lengthier. The other drawback is the analysis scale. This method can be properly evaluated on an architectural scale or in urban spaces on a small scale like neighborhoods. However, given the need for the one-on-one comparison of the spatial components on a large urban scale, it is very time-consuming. Nevertheless, they can be solely evaluated by identifying the main components of the spatial organization of a city and comparing them. As a result, a clearer perspective of the city can be obtained on a large scale. Explaining this subject is out of the scope of the present article but can be suggested for future studies.

Table 5. A comparison between the analytical features based on the simple and weighted graphs. Source: Authors.

Features of the analytical space syntax method	Calculations based on the simple graph	Calculations based on the weighted graph
Identification of the topological characteristics of the space.	✓	✓
Analysis of the natural movement of the human based on the spatial configuration.	✓	✓
The possibility for the analysis based on the geometry of the position.	✓	✓
The possibility for the analysis of the impact of the chosen activities.	×	✓
The possibility for the analysis of the simultaneous effect of several inputs.	×	✓
The possibility for the analysis of the physical characteristics of the space on the movement of the pedestrians	×	✓
Performing calculations using only a computer	✓	×

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