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Evaluation of the role of the yard in the spatial configuration of urban schools in order to improve functional efficiency (Case Studies: Chaharbagh, Marvi, Alborz, Firouz Bahram schools)¹

Farzaneh Narimani¹, Malihe Taghipour^{* 2}, Ali Akbar Heidari³

1 Ph.D. Student, Department of Architecture, Shiraz Branch, Islamic Azad University, Shiraz, Iran.

2 Associate Professor, Department of Architecture, Shiraz Branch, Islamic Azad University, Shiraz, Iran.

3 Assistant Professor, Department of Architecture, Technical Engineering University, Yasouj University, Yasouj, Iran

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ABSTRACT

The courtyard has a special place in the spatial structure of traditional Iranian architecture and in addition to climatic applications, it has also been very important from a functional point of view. In this way, by placing it in the center of the building and the arrangement of other spaces around it. This essential member of Iranian schools has been removed from the spatial structure of many schools due to the lack of land and due to the density of buildings, or its location has been changed in terms of configuration, and its role in changing the functional performance of the building is ignored. This has pushed the purpose of the current research to investigate the role of the courtyard on the functional efficiency of schools. Accordingly, factors such as the type of geometry of the courtyard in the configuration of the building, its location was considered as the desired indicators in the present research. Therefore, in general, the research method will be quantitative and qualitative and Based on that, four schools with traditional, contemporary, and modern designs were selected as case examples, and analyzes related to measuring functional efficiency were performed on them, using two methods of drawing graphs and using Depthmap software. Finally, the results the research showed that the presence of a courtyard with a central pattern and with a rectangular or square geometry creates the highest amount of functional efficiency in schools

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Email:*malihetaghipour65@gmail.com Phone: +987136230450* ORCID: https://orcid.org/0000-0003-1612-3673

1. INTRODUCTION

The yard is one of the main elements in schools, which has long played an important role in social and religious functions. The courtyard element has a special place in the spatial structure of the school, and in addition to climatic applications, it has also been very important from a functional point of view. This means that in the construction of the school, in cases where the intention of building a school with a courtyard was in the minds of the builders, at first the courtvard was located in a completely regular way in the configuration of the building, and then other elements such as cells, porches and were erected around it (Aminzadeh, 2017). The central courtyard is considered to be a sign of Muslims' feeling towards the space and especially the spiritual space, and later it has reached its peak in terms of functionality and symbolism in Islamic architectural culture. It is obvious that centrality in Islam is a symbol of unity and the basis of reflection is a quality in which unity is hidden. (Jaafari et al., 2015). Taking this into account, it seems that the central courtyard was considered not only in the geometrical and spatial structure of the school building, but also as a unifying factor and a place for the presence and interaction of people as a space. It is also considered a city, and this issue confirms its social and cultural importance (Heidari and others, 2015, 92). This means that when a space is placed in a specific configuration in such a way that the amount of penetration of unrelated activities in it is reduced and the possibility of providing services to adjacent spaces is increased, it can be better used by users, and in such a case, the space is efficient. It is considered to have a higher functional efficiency (Mostafa & Hassan, 2013). This is despite the fact that in today's schools due to the density of buildings and problems related to the land, in many schools the yard has been removed from the physical space or its location has been changed in terms of configuration. This means that in the construction of the school, what remains after the construction of the building is used as a courtyard (Heidari et al., 2015). Therefore, it is obvious that in such a situation, the courtyard no longer has its unifying nature and has become only a place to pass. Accordingly, the present research, while analyzing the courtyard in the past and contemporary architecture of schools, examines its role in the functional efficiency of the building. Analyzes and analyzes this important according to indicators such as its position in the configuration of the space as well as having a regular or irregular geometry. With this explanation, the research questions can be examined in the following form: As one of the main elements in the configuration of schools, how can the yard affect the improvement of its functional efficiency? Considering the necessity of the yard in improving the functional efficiency of schools, what is the most suitable geometric structure of the yard? How is the proper location of the yard in order to improve the functional efficiency of schools?

MATERIALS AND METHODS

The meaning of the yard:

In the culture of Dehkhoda, "yard" means an area and any walled place, a house and a house. Other words such as Sahat, Sahn, Mian Sera and Sahn Sera also have the same meaning (Mamarian, 1994). The central courtyard is a name that is usually used for various types of courtyards in which at least one side and above all, there is a built space on its four sides and it is the only or the most important and main space for providing light, ventilation, internal communication and some other functions. Occupying the spaces built around the courtyard, especially in the courtyards of large houses, and closing such courtyards on four sides with rooms or walls, has caused it to be called the central courtyard. In the old texts, it is called Mian Sara (Samarkandi, 1964). In this regard, he wrote: "Muslim houses get light and air from their inner courtvards, not from the street. Whenever you look at the map of Islamic cities, you will see that next to the main streets of the country, there are a series of dead ends and winding alleys, where there are many houses that come and go" (Mahdoinejad, 2011). Therefore, the courtyard is considered as an important space in the school because the life of the surrounding spaces is influenced by the functions of this open body. In this section, firstly, the role of the courtyard (with emphasis on its geometry and location) is examined, then according to the topic of the research, The point of view of space theorists in relation to the functional efficiency of space and the factors affecting it is examined and finally a theoretical framework is presented in this regard.

Types of yard patterns in school's configuration

Historical evidence shows that the yard at the school has been considered one of the main parts of the spatial configuration from the beginning, so that from the first schools of the modern era, the open space or in other words the yard has had a significant presence. Historically, it is understood that the yard at the school is more than a dividing space or just an architectural variety. From the perspective of Islam, some worships must be performed in the open space, including the prayers of Eid al-Fitr and Ourban, daily prayers. Arafa and other such cases mentioned (Qami, 1982). This issue confirms the necessity of having a courtyard in the configuration structure of the school. This is despite the fact that in the modern era, due to various reasons, many schools lacked courtvards. Or they consider a small part of the land that is not roofed as a yard. However, this space is used only for passing (Aminzadeh, 1999).

How to combine indoor spaces with open spaces is one of the important issues in the design and construction of different architectural spaces. In this connection, various factors and phenomena play a role in how open spaces are formed and how they are combined with closed spaces, among which we can mention the type of function in the structure of the building in question (Soltanzadeh, 2010). The yard in traditional schools is mostly built in a rectangular or square shape, which is enclosed in different patterns such as four sides (Meir & Etzion, 1995). This is despite the fact that with the passage of time and due to various factors, such as topographic restrictions, site, building direction, etc., new shapes such as T, L, U or even Y shape have also appeared in the geometric design of the yard (Ibrahim et al., 2013).

Introduction of patterns:

Yard patterns can be divided into two categories: geometric and non-geometric: Geometric Patterns: In this pattern, the geometry of the yard determines the geometry of the building. Even in lands with non-geometric boundaries, vard patterns have a great impact and shape the type of residence, movement, pause, rest, and spatial communication in the building. The most important features of geometric patterns are the pivoting of the yard, which causes a variety of spaces. Square and rectangle patterns are considered as the main patterns, and other geometric patterns such as trapezoids, polygons (octagons) and compound courtyards (combination and juxtaposition of two identical or different geometric patterns) are considered secondary patterns. (Mahdovinejad et al., 2013). Patterns without geometry: This category of patterns that used the geometry of the courtyard to cultivate other spaces are very limited in the ground floor and its use is seen more in the courtyard of the floors of these patterns than matching with the higher limit (moonlight). The patterns are created by matching the boundaries of the land and are separated from the alley and public spaces on one or two sides by a long wall. Since there is almost no centering of the geometric pattern in this type, some of the main living spaces, which used to be placed in the center of the sides (in line with the axis), are placed in the corners of the yard. Such spaces could be made less colorful and even the architectural type of these spaces have distanced themselves from the grandeur of geometric spaces and have become less valuable (Mahdoinejad et al., 2013).

Functional efficiency:

The concept of efficiency in the Persian dic-

tionary has been interpreted as efficiency, function, ability, etc. This word was first mentioned in the form of the concept of efficiency in the theories of Vitruvius. He considered the three factors of strength, efficiency and beauty to be the most basic and necessary According to this interpretation of the space, the designers should have designed and organized the environment in such a way that in addition to having the necessary strength and beauty, the ability to provide It also has the highest level of the needs of the users of the space. In this regard, one of the most important goals of human beings in order to improve individual and social life is to achieve proper and efficient performance of the building. A product when it has a specific purpose and meaning and If it is used in the right place, it will have a good performance, and one of the aspects of the capabilities of the space in line with its good performance is to have several potential functions instead of a fixed and actual function (Haidari et al., 2015, 93). One of the methods that evaluate the body of space from the perspective of its functional desirability is the technique of space syntax. This approach, above all, has the possibility to provide information to check the structure of the space arrangement, the level of efficiency of a building in its usability. It is introduced by the users. In this connection, indicators such as the location of the desired space in the overall structure of the building, the degree of its connection and connection to the adjacent spaces, the degree of access to the said space and other such factors affect the efficiency of the desired space. Research in the field of space syntax has provided quantitative methods for analyzing space that help to understand how space functions. These analyzes examine how spatial distribution, movement pattern and presence in space (Hillier & Hanson, 1984) (Bill Hillier in the book "Space is a Machine" defines functional efficiency as follows: "Efficiency means minimizing the influence of unrelated groups on each other and the proper organization of related spaces together in such a way that their efficiency in This type of spatial organization leads to the formation of efficient social relations. "Accordingly, with the help of some of its indicators such as depth, connection, interconnection, types of access, etc. It is possible to express some of the capabilities of space. This method provides researchers with information to describe the configuration of space and understand how spatial relationships are. Also, this technique is able to predict human behavior in the framework of man-made environment (Peponis, et.al, 1985). For example, the deepness of the spaces in some collective functions increases the criminality of the environment and the lack of possibility of its proper use. This is while the creation of depth and nested spaces, especially in traditional schools It causes the creation of a quality that, in case of its absence, the function of the space will be disturbed and as a result, a part of the space will become ineffective. According to the definition of the optimal efficiency of the space, which can be checked and proven with syntactic indicators, the optimal efficiency of the space is It means minimizing the influence of unrelated activities on each other and spatial organization of related activities together, so that their proper productivity depends on providing optimal services to each other. This type of spatial organization, along with Increasing functional efficiency also leads to the formation of efficient social relations (Hillier, 1993). It improves the performance of the whole space and organizes spatial circulation and daily activities.

Examining performance indicators:

As mentioned, in the space syntax technique, tools are used to measure functional efficiency, which are introduced below.

Depth: This index is checked by "depth stage" and "metric depth" in the software. According to the definition of functional efficiency, the lower the depth of the space, the less spatial separation and separation, and as a result, the space becomes more unified. This issue shows the value of higher integration and more accessible space, which ultimately facilitates the functioning of the space (Haq, 1985). When the number of syntactic or visual-kinetic stages increases between the existing spaces in the whole building, the communication A function between those spaces is weakened. This phenomenon is caused by the inverse relationship between separation and functional efficiency (Hanson & Hillier, 1984 & Hillier, 2007) Generally, this definition of the effect of depth on functional efficiency uses for spaces with collective and public uses. ; Because it reduces the length of the trip and the time spent (Khan, 2012).

Integration: Integration relates to the values of the depth of space. In this way, it is called a connected space when all the other spaces of the environment are located at a relatively low depth of it. In this way, to move from a space with a high correlation value to all other spaces in the system, less changes in direction are required (Penn, 1999). (Peponis et al., 1985) research results in this regard show that the location of the most interconnected spaces in the middle depth facilitates movement (Hillier, 2008). Therefore, the more interconnected a space is, the deeper it is. Decreased, and this causes greater integration of the space and an increase in its permeability. and as a result, increases the functional efficiency of the space. So, the more interconnected the space is, the more suitable it will be (Hillier, 2007, Peponis, 1985). The most connected spaces in the country's traditional schools have always been the courtyards (both internal and external). In these schools, the courtyards have played the role of distributing and providing services, because a space like the courtyard is also functional (increasing spatial efficiency) and for cultural and social reasons, it is considered one of the most interconnected spaces in Iranian schools.

Connection: Connection is defined as the number of places that are directly connected to other points (Klarqvist, 1993). The connection index means the relationship between spaces, which is of particular importance in collective uses. It means that the existence of communication between spaces means the ability to use it by different strata of people, and the higher the value of this index, the greater the usability of the desired space, the optimal spatial circulation, the appropriate level of permeability, and as a result, increasing its functional efficiency. (Penn et al., 1999, Hillier, 2007). In fact, all spaces are divided into four types, c, b, a, and d. In any two-dimensional diagram, space a is a space that is connected to only one other space in It is communication. In general, the presence of such spaces leads to an increase in depth and lack of proper access (decrease the desired integration level). Type b is said to be spaces that are connected with at least 2 other spaces. Research results show that creating spaces of the type b In educational buildings, it connects the public areas to private areas (Mustafa & et al, 2010). Type c spaces are spaces that are located in one ring, and typed spaces are spaces that are connected to at least two rings. As more spaces with d plan increase in the general plan of the building, it means increasing its usability and in such a case, the functional efficiency of the building also increases. The presence of typed and c spaces reduces the depth, ease of access and flexibility of the space. (Hillier, 1993)



Figure 1: Degree of specialty. (manum, 2009)

Convexity and concavity of space: Concavity and convexity of space are characteristics of space that are explained in relation to the type of geometry and the quality of visual accessibility of space. In this connection, convex space refers to a space where all its points can be seen from any point of it. This is despite the fact that the concave space, due to the change of the angle and the twist in its geometric plan, creates an obstacle, due to which, some points remain hidden from others (Hillier, 1985) each of these types of spaces (convex and concave), creates potential limitations and opportunities that by measuring the placement of each of the building elements of the space together, the best option can be chosen for the design. However, in collective uses, the spaces that are used for the presence and gathering of people should be more convex in terms of geometric shape, in addition to preventing the creation of cozy and unusable spaces, from a visual point of view, for the perception of the future. Be acceptable Therefore, according to this interpretation, the more convex the space is, the more its functional efficiency increases. In this research, this index can be measured using the Convex Map feature in the Depthmap software.

Axial space: Axial space or axial line represents the longest line of sight in a building, and this issue is significantly related to the direction of human movement in the environment (van Nes & Akkeles, 2011). In general applications, a space for presence and It is appropriate to carry out human activity in which the transparency is completely noticeable and the user can use the space without any problems. If a space does not have a direct axial view for any reason, there is a possibility of events happening in the invisible parts of the space that are not functionally expected to take place in that part of the space, and this ultimately leads to disturbances in the functioning of the space and as a result The presence of people in it will decrease. Based on this, it seems that in cumulative uses, in order to increase the productivity or in other words, the functional efficiency of the space, the existence of central spaces seems necessary. In this connection, in the Depthmap software, this issue is analyzed through the Isovist feature. According to the features of this part of the software, it is possible to evaluate the surface of the space seen in each stage and to identify clear and ambiguous surfaces in each part of the space.

Methodology

As mentioned in the introduction section, the main purpose of this research is to analyze and investigate the role of Hayat in improving the functional efficiency of traditional and contemporary schools in Iran. For this purpose, two variables "location" and "geometric design or vard position" was introduced into the spatial system of the school as an independent variable and the functional efficiency of the yard as a dependent variable. Based on this, first of all, a set of indicators should be extracted that affect the level of operational efficiency of an environment, especially educational environments. Therefore, in the first stage of this research, after various definitions of this concept, a set of factors that influence its promotion were introduced. This finally led to the extraction of the theoretical framework in which indicators were introduced, therefore, in order to check the indicators in this regard, the graphs related to each of the case samples were extracted from the analysis. The indexes of "connectivity" and "connection", "depth", "concavity and convexity of space" and "axial space" can be extracted using Depthmap software. Syntax of space is a theory and a tool for analysis in architecture and urban planning. The beginning of this attitude was founded by Stedman in the late 70s and early 80s in London. Spatial syntax is an attempt to determine how the spatial configuration situation expresses a social or cultural meaning (Hillier & Hanson, 1984). This description, the research method in the present study is of descriptive-analytical type as well as logical reasoning using comparative analogy, in this regard, two quantitative and qualitative strategies are used in order to extract and analyze the findings. The method of collecting information has also been done in the form of library studies and field observations. In this connection, in picture 2, the step-by-step research process is shown. The first stage of explaining the spatial structure using explanatory diagrams, graphs or explanatory diagrams, includes diagrams that are used to represent spaces and the way of communication between them. From the analysis of these diagrams, information such as the structure of the layout of the spaces, the depth of the spaces, their distribution and also the way of communication between them can be extracted. The results obtained in this step provide the necessary information to be used in the second step.

The second stage included the introduction of research case examples, in which four schools were selected from traditional and contemporary schools. In addition to being different from each other based on the number of courtyards, the selected samples also differed from the point of view of the location of the courtyard, so that out of these four cases, in two cases the courtyard is in the geometric center and in two cases of the courtyard (at least one of Yards) were located near the wall of the passage or the neighbor. In the continuation of the research process, in order to investigate the role of the yard on the functional efficiency of the building, four school samples, including two traditional samples and two contemporary samples, out of these four samples, two samples had a traditional design and two samples had an innovative design, as case examples. The research was selected. In this article, the most suitable examples of this type of architecture (four porches) of Chaharbagh School (1122) were selected. Chaharbagh school is located on Chaharbagh Street in terms of geographical location and was built during the reign of Shah Sultan Hossein Safavi. This building is also known as Soltani School, Mother Shah School and Imam Sadiq (AS) Theological School, which is currently known as Chaharbagh School among the people of Isfahan (Pirnia, 2001). Marvi School (Qajar) (1201) was chosen as an example of traditional Qajar schools to try to preserve the chronological sequence of the construction of schools. The spatial organization of modern schools (Tahersima, 2015), Alborz High School (1304 AH) was chosen because it clearly showed the changes in the architecture of new

schools and there are many schools with similar style, function and spatial composition in Different cities of Iran were built. Therefore, it can be considered as a "safe key to understand the change in the shape of contemporary schools in Iran" (Rajabi, 1355:66). Tehran is located in Jomohri Street, Mirza Kochakh Khan Street, and it is named Firouz Bahram in memory of Feroz Bahramji Bikaji. In addition to the number of vards, the selected samples differed from each other in terms of the location of the yard, so Out of these four cases, in two cases the yard was in the geometric center and in two cases the yard (at least one of the yards) was located near the wall of the passage or the neighbor (Sami Azar, 1997). In continuation of this stage, explanatory diagrams were drawn for each of the selected samples.

The criteria for selecting the aforementioned examples were the role of the courtyard in the configuration of the building, according to this explanation, two cases have a courtyard with a regular geometric design (rectangular in the center of the building), one case of a rectangular courtyard outside the central axis of the building, and finally in one case, the yard is placed around the building. In this connection, Chaharbagh and Marvi were selected as examples of the central courtyard; Firouz Bahram School was selected as a sample where the courtyard is located in the front and back of the building, and finally, Alborz School was selected as a case study as a school with a courtyard around it. Table 1 presents case samples and their location and geometric structure have been investigated.

The third stage: In this stage, spatial structure analysis is done using Depthmap software, which was previously introduced to evaluate each of the indicators, and the quantitative results obtained from each school were recorded in the relevant tables and compared with each other. The main goal of this theory is to analyze the composition of the existing spaces in a spatial structure. The method of space syntax is based on the concept of spatial configuration,



Table 1: Introduction of case examples and examination of the location and geometric structure of the yard with them

which is in the form of communication between the internal spaces of the architecture and emphasizing the communication between systems A social space has been formed. This method shows that social relations are not only effective in the formation of the desired interactions, but are also located in the heart of spatial systems. In the space syntax method, they describe the functions in the space (Haidari and others, 42, 2015). Therefore, the organization of space is related to a logical process because it must meet the minimum functional goals (Hillier, 2007).

Data analysis

In the first step, the graphs related to each school are drawn in relation to each of its inputs, which is presented in Table 2:

After drawing explanatory diagrams, in the sec-

ond step, in order to check the index of selection of spatial diagrams and to check the indicators of depth, location, convexity and concavity of space and axial space, Depthmap software was used, and the results of this section are also in the table 3 is provided. In this connection, the relationship and depth indicators are used to analyze the positioning of the yard, and the convexity and concavity and geometric space indicators are used to analyze the geometry of the yard. With reference to the results obtained from the above table, the analysis of the functional efficiency in the types of models under investigation is done. The functional efficiency of the building is examined. As mentioned, in the space syntax technique, tools are used to measure functional efficiency, which are introduced below.



Table 2: Explanatory charts related to sample mosques based on different inputs

Relationship

The variety of the level of communication in relation to the types of spaces in the school shows the way of creating cultural and social relations in the schools. In addition, from another point of view, it increases the integrity of the space and as a result, creates spaces that help in proper and optimal spatial circulation. Therefore, the existence of spaces, which have a large number of the shortest paths connecting to a space, helps the optimal functioning of the space. The yard is one of these spaces, the more it is in contact with other spaces in the configuration of the design, the spatial circulation improves and As a result, it leads to an increase in operational efficiency. In the body of traditional schools, the courtvard is the heart of the school, which sometimes has a rectangular shape along the north-south axis, inclined to the east. Many environmental aspects, such as topographic limitations, site, direction of building, etc., are the reasons for creating new forms of yard such as T, L, U, or Y. Also, in some cases, climate, geographical conditions, etc. It is effective in the location and geometry of the vard. However, in general, in the classification of vard space based on its location and number in this section, according to the research approach that "geometry" and "spatial" examination of the yard is optimal and according to the performance indicators (Heidari and others, 2015). In this method, 4 traditional and contemporary

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Table 3: Examining the pattern of courtyards in schools (depth indices, convex space, axial space)

schools were identified, collected, classified, and in some cases were drawn and modified. In the classification of schools in the present study, in some examples of these schools, the space of the yard(s) is located in the center of the school (in the form of a central yard), and in another example, the yard is located around the school, and in another, the yard is located in front and behind the building. According to the results of Tables 3 and 4, the maximum amount of space utilization in Chaharbagh school is at the highest level, therefore due to the high level of communication and as a result of spatial circulation and proper permeability, it is in a more favorable condition than other samples from the perspective of functional efficiency. After Chaharbagh school, Marvi, Alborz and Firoz Bahram respectively have the highest level of communication. It is also necessary to mention that in traditional schools, "spatial circulation" has a high level and due to the amount of spatial communication, the communication index is at a higher level even compared to contemporary courtyard examples. This is despite the fact that such a factor (wide spatial circulation) is not a priority in the design of contemporary spaces. On the other hand, the index of spatial communication that leads to the creation of wide spatial circles is more prominent in Chaharbagh school than other contemporary schools. The presence of the courtyard around the school has made their functional conditions significantly different from the traditional schools in the central courtyard, considering the impact of this issue on the usability of public spaces, it seems that this factor affects the functional efficiency of the mentioned schools compared to Two things have greatly reduced.

Schools	The name of the communication space and the level of the communication					
	index of each one					
	Yard	Corridor	Porch	Stair's space (close)		
Chahar- bagh	41	-	3	-		
Marvi	27	3	1	-		
Alborz	3	13	1	-		
Firouz Bahram	1	9	-	2		

 Table 4: Communicating spaces and the amount of communication index of each

According to the above table, based on the calculation of the "communication" index, the largest role of organizing access by the yard can be seen in Chaharbagh and then Marvi schools, and the lowest amount can be seen in modern schools such as Alborz and Firoz Bahram. Or comparing the communication index in the case of corridors. Alborz has the highest number and Firouz Bahram is in the next place. The highest index of communication regarding porches and semi-open spaces is related to Chahar Bagh and Marvi. According to the analysis made by the analysis software of space syntax, open and semi-open spaces in traditional schools have a greater degree of connection and communication than in contemporary schools. He knew it. In examining the relationship between the place of education and the open space and as a result of its flexibility, it was seen that the places of education in traditional schools are related to the open space and yard and are expandable and flexible, but the classes in contemporary schools have the least amount of communication. They are open space and do not have the possibility of expansion and flexibility. On the other hand, the division of courses in the modern education system and the teaching of each subject by its own teacher turned the school space into several rooms for teaching different courses. The spatial organization of the school affected and the role of the corridor was emphasized to connect the classes with each other, and the corridor, which was only a transit space without social interaction and educational role, acted to reduce the educational and social role of the school. We can clearly see the decrease in the importance and role of open and semi-open spaces in traditional and modern schools.

Depth

The depth of each space is the stage or order of that space in the overall structure of the building. The lower the depth of the space, the easier it is to access. Also, this ease of access to the space is determined by the presence or absence of paths in the space. The reason for the limited or fixed number of users is easily possible (like a school), we are allowed to "deepen" the collection of its internal spaces. However, by increasing the depth of the space, there are limitations from the perspective of ventilation and light considerations. Also, as the space becomes deeper, the distance traveled by the user will increase (Bustard, 1997). So, as the depth of the space becomes less, the level of functional efficiency will increase in relation to the depth index.

The depth index has been evaluated using the software and as it can be seen from the data in Table 3, in all the investigated schools, this index has been measured from the entrance of the schools. Blue and green colors indicate the lowest amount of depth and yellow and red colors mean the largest size of the depth step. The results obtained in this regard show that there is little spatial depth in Chaharbagh and Marvi

schools. Meanwhile, in Chaharbagh, Maravi, Alborz, and Feroz Bahram schools, respectively. the lowest to the highest level of spatial depth has been obtained, and this the subject shows a decrease in functional efficiency in the mentioned schools in the order mentioned. However, it seems that the location of the courtyard in relation to the entrance and classrooms in these schools and the effect of this on the formation of spatial hierarchy in them is the cause of this phenomenon; In this way, in schools where the vard is located in the center of the building, it is possible to access it through a vestibule and from there it is possible to reach the classes immediately. This is while in Alborz and Firoz Bahram schools, which do not have a central courtvard, due to the lack of distribution space, it is possible to access the classes in a linear way and by passing through different corridors, which is the linear geometry in the school plan. It has led to an increase in its depth and, as a result, a decrease in its functional efficiency. On the other hand, Chahar Bagh School has the lowest spatial depth level. This means that the yard in these houses has the least distance from the entrance and other spaces around it. On the other hand, according to the definition of the depth index in the study of functional efficiency. "the lower the spatial depth, the greater its integration (continuity and non-separation) with other adjacent spaces, and this increases its permeability to the adjacent spaces." This issue leads to It increases the functional and visual connection of the spaces around the yard. According to the definition of functional efficiency in relation to the interconnected component, the existence of service spaces as the most connected spaces facilitates the functional relationships of the spaces. According to this definition and the results From the software reviews, it is clear that the entrances of the spaces and the yard, as the main service space, are among the most interconnected spaces, because they are located at the minimum depth and have established a proper level of connection with other components.

The convexity and concavity of space

This index has also been checked using the software. As can be seen from the image analysis in Table 4, the highest amount of convex space has been formed in Chahar Bagh and Marvi schools. Among the selected samples, after Alborz School, Firoz Bahram School has the least amount of convex space (in other words, the most concave space). The reason for this is related to the geometric design of the courtyard of this school; This means that in this school, due to the rotation of the courtvard around the space, the space is out of convexity and visually there are many blind spots in it, and this is effective in reducing the functional efficiency in these schools. Reducing the convex space in Chaharbagh and Marvi schools increases legibility and, as a result, better navigation in space, while the use of convex space for the yard as a public gathering place prevents the creation of cozy corners out of public view. The set of these factors increases the usability of the space and as a result increases the functional efficiency in the space. Meanwhile, in Alborz and Bahram schools, despite the existence of the courtyard, due to its concave geometry, it is not possible for the user to understand the completeness of the space, and this issue, in addition to creating ambiguity, also hinders the access to the service spaces. Therefore, this has caused a decrease in the functional efficiency of the schools in terms of yard geometry. As a result, in addition to reducing the levels of space (spatial hierarchy), it has overshadowed the usability of spaces that are not located in convex and axial sections.

Axial space

In connection with the central space which was done using the software and according to the data of table number 4, it can be seen that in Chahar Bagh and Marvi school, due to the regular and rectangular geometry of the yard, the maximum amount of visibility around the space is from There is a courtyard area. In these schools, the yard is known as an independent part of the structure of the building, and with its placement in the central part of the building, it plays a significant role in spatial transparency (this situation is more clear for Chaharbagh school). In fact, in schools with a central courtyard structure, the role of the courtyard in increasing the clarity and transparency of the space is very prominent, which has a significant impact on its functional efficiency. In relation to Alborz and Firoz Bahram schools, there is no proper axial view due to the inappropriate geometry of the courtyard. And the yard itself, instead of creating spatial clarity and transparency, has become an ambiguous space due to the twist in its geometric design, so it seems that in these schools, the existence of the yard has not only helped to increase functional efficiency but because of its twisting geometry, it has created an opaque and illegible space in the configuration of the space.

Connection

As it was proposed before, the correlation index is evaluated using the mathematical relations of syntax and space, the results of which are given in the table. From the theoretical definition of the linkage index as well as the results of the table, it can be seen that Chaharbagh and Marvi schools, which are in the form of a central courtyard, have the highest degree of linkage in Maravi school (14.1) and Chahar Bagh school (7.2), which is in the schools where the court-

Plan	Connection Grade	Color	Space	School
	11/6	Light Blue	Porch	
The second s	6/1	Dark Blue	Corridor	Marvi
	14/1	Red	Yard	
	7/2	Red	Yard	Chaharbagh
	2/7	Light Blue	Porch	
	6/1	Dark Blue	Corridor	Albase
	14/1	Red	Yard	Alborz
	8/4	Red	Corridor	
	6/2	Light Blue	Stairs Space	Firouz Banram

Table 5: Examining the co-linking index and compiling the numerical specifications of the depth map software in relation to the co-linking index

yard space is The main one is in the depth of the building, the largest number of connections have been formed around that courtyard, which has increased the interconnectedness of all spaces. This will lead to greater integration of the entire complex and ultimately increase the spatial performance of the courtyard, as a result, it has the highest level of functional efficiency in relation to the index of interconnection among the mentioned schools. After that, Alborz and Firoz Bahram schools (due to the bad location of the vard for the proper connection with other components in the configuration of the plan, there is practically no proper connection between the spaces and this has led to a decrease in functional efficiency in these schools), in terms of the space index - The link is in the next ranks.

DISSCOUSION AND FINDINGS

Finally, the findings of the research about the various investigated indicators show that the best type of placement to achieve the maximum level of functional efficiency is the use of the central courtyard pattern (in the geometric center of the building) (Chaharbagh and Marvi schools), because in this case, the highest amount Communication and access with the indoor space is provided, and as a result, the maximum amount of spatial circulation in the whole complex is created. Therefore, placing it in the geometric center of the building brings the highest level of productivity and functional efficiency for the space.



Picture 3: Continuity of the central courtyard of Marvi (Qajar) and Chaharbagh (Safavid era) schools

The existence of a courtyard is necessary in line with the functional efficiency of schools, and schools such as Marvi and Chaharbagh, which have a courtyard with a regular geometry and micro-spaces in the structure of the school around it, have better functional efficiency. It was also observed in the model of these schools that the central courtyard with a geometric shape Rectangle has the least amount of concave space and the most amount of axial space. This issue increases readability and as a result better navigation in the space, while the use of convex space for the yard as a public gathering place prevents the creation of cozy corners out of public view, which the combination of these factors increases usability. from the space and as a result increase the functional efficiency in the space. At the same time, in Alborz and Firoz Bahram schools, despite the existence of the courtyard, due to its concave geometry, it is not possible for the user to understand the completeness of the space, and this issue, in addition to creating ambiguity, also hinders the access to the service spaces. Therefore, this has caused a decrease in the functional efficiency of the schools in question in terms of the geometry of the courtyard, and the courtyard has not only had a significant effect on the spatial communication between the open and closed space, but has actually turned into a space for passing from the outside to the inside, and as a result, in addition to reducing the space (spatial hierarchy) and accessibility in accordance with the function of the space has overshadowed the usability of the spaces that are not located in the convex and axial parts, and this has caused a decrease in the permeability of the building compared to the examples of the central courtyard and As a result, its functional efficiency has been reduced compared to the two mentioned examples. Therefore, it seems that the location of the courtyard in relation to the building and its geometry and the reduction of concave spaces and the increase of the axial space can be effective in increasing the legibility and functional efficiency of the building.

CONCLUSION AND RESULTS

The main goal of the current research is to examine the role of the courtyard in improving the functional efficiency of schools. To achieve this goal, explanatory diagrams and depthmap software were used. It was with the surrounding cells, it had created greater permeability to the school space and increased spatial integration, control and connection. This provided the grounds for more use of the courtvard as one of the main spaces of the school, as well as the possibility of spatial planning in the form of a hierarchical system, connection with the context of the neighborhood, which is effective in promoting urban interactions and raising the quality of interactions. and move the school from a purely educational space to the center of social developments, while in contemporary and modern schools, reducing the connection with the city and neighborhood, reducing the connection between open and closed space, reducing the importance and elimination of semiopen space, reducing the importance of open space and organization The open space and the organization of the interior space centered on the corridor, as well as their buildings, have gradually become more extroverted and more in visual relation with the body of the street, but in terms of social interactions, they are separate from the residents of the neighborhood and it is a sign of the reduction of the social role of schools. The spatial integration between the courtvard and the school space was severely reduced and the physical and (sometimes visual) spaces were completely limited to the courtyard. This caused the functional removal of the yard from the spatial system of the school and turning it into a mere transit space to reach the school space. This issue greatly reduced the functional efficiency of these schools. In the end, it is important to mention that the current research does not claim that the central courtyard type in traditional schools always creates the best values in relation to functional efficiency indicators such as cohesion, connection and depth, etc. This is despite the fact that apart from the location of the yard in the overall configuration of the building, there are other variables that affect the mentioned indicators and change their values; Moreover, among schools with a central courtyard (the establishment of a courtvard in the geometrical center of the building), there are always schools that, due to various factors, different values for the above indicators are formed in them, among these factors can be the number of cells around the



Picture 4: Alborz (contemporary) and Firuz Bahram (modern) schools

courtyard, He pointed out the number of openings from these spaces to the yard as well as the function of disreputability and accessibility in accordance with the function of the space, etc. From the values obtained from these indicators, it has been proven that traditional schools with a central courtyard (geometrical center of the building) compared to schools where the courtyard is located on one side and the body of space on the other side, from the perspective of functional efficiency indicators in They are in a better condition.

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