World Academy of Science, Engineering and Technology
International Journal of Architectural and Environmental Engineering
Vol:9, No:8, 2015

Comparative Spatial Analysis of a Re-arranged Hospital Building

Burak Köken, Hatice D. Arslan, Bilgehan Y. Çakmak

Open Science Index, Architectural and Environmental Engineering Vol:9, No:8, 2015 publications.waset.org/10002544/pdf

***Abstract*—**Analyzing the relation networks between the hospital buildings which have complex structure and distinctive spatial relationships is quite difficult. The hospital buildings which require specialty in spatial relationship solutions during design and self-innovation through the developing technology should survive and keep giving service even after the disasters such as earthquakes. In this study, a hospital building where the load-bearing system was strengthened because of the insufficient earthquake performance and the construction of an additional building was required to meet the increasing need for space was discussed and a comparative spatial evaluation of the hospital building was made with regard to its status before the change and after the change. For this reason, spatial organizations of the building before change and after the change were analyzed by means of Space Syntax method and the effects of the change on space organization parameters were searched by applying an analytical procedure. Using Depthmap UCL software, Connectivity, Visual Mean Depth, Beta and Visual Integration analyses were conducted. Based on the data obtained after the analyses, it was seen that the relationships between spaces of the building increased after the change and the building has become more explicit and understandable for the occupants. Furthermore, it was determined according to findings of the analysis that the increase in depth causes difficulty in perceiving the spaces and the changes considering this problem generally ease spatial use.

***Keywords*—**Architecture, hospital building, space syntax, strengthening.

I. Introduction

ANALYSING the relation networks between the hospital buildings which have complex structure and distinctive spatial relationships is quite difficult. Ensuring synergy of the necessary functions in the hospital buildings which generally consist of unlike blocks with different storey numbers is very important particularly for quick solutions and the visitors' ease of use. In addition to this, the necessity of designing the hospital buildings that require self-innovation due to increasing population and very rapidly-developing medical science and health technology, with a flexible planning concept is inevitable.

The hospital buildings which require speciality in spatial relationship solutions during design and self-innovation through the developing technology should survive and keep giving service even after the disasters such as earthquakes. Therefore the structures such as hospitals should be damaged at minimum after possible natural disasters, especially earthquakes. Most of the public buildings which were constructed serially to be able to meet the needs through limited means are insufficient with regard to earthquake performance because of various reasons. The tragic outcome of Marmara earthquake in 1999 is that majority of the public structures including hospitals were either damaged or completely demolished. For this reason, most of the hospital buildings in Turkey were evaluated in terms of the earthquake performance particularly within the last decade and most of them were strengthened or demolished while only a very small number of them could be used without change. In addition to improving load-bearing systems of some of the strengthened buildings, additional spaces were created by constructing additional buildings.

In particular, the manufacturing of additional reinforced concrete partitions and demolished or rebuilt bearing walls result in some changes in using the location. Considering the spaces of additional buildings which are added to main building, it is apparent that the relationships between spaces shall change in hospital buildings already having complex structures. The important thing is that such arrangements should be able to meet the need of the spatial relationship.

In literature, the social issues were discussed by using space syntax method as well as using the evaluation methods for increasing spatial satisfaction such as evaluating during usage and environment-behavior researches, and the studies about comprehension in space were initiated and a quite broad perspective was presented. Such studies which were conducted through measurable characteristics of the space's patterns, and represents indicated a strong relationship between both the users and the space in architectural environments [1]. Measurable characteristics of the pattern and organizational features of the space can be obtained numerically by means of Space syntax method which has become quite popular in evaluating complex structures. For example, spatial evaluations were made for museums [2], hospital structures [1], shopping centers [3], social evaluations of residences [4], and education buildings [5] by using this method. It is observed that space syntax method is not only used separately in studies, but also used comparatively together with the other methods such as questionnaire, cognition maps and visual simulation.

In this study, a public hospital in Sakarya province which is located on an active seismic belt, North East Anatolian Fault Line and Marmara region is discussed. Since the building is insufficient with regard to earthquake, its load-bearing system was modified. Such modifications led to several changes in use of the space. In addition to this reinforcement

B. Köken and H. D. Arslan are with the Architecture Department, Necmettin Erbakan University, Konya, Turkey (e-mail: bkoken@konya.edu.tr, deryaarslan@konya.edu.tr).

B. Y. Çakmak is with the Architecture Department, Selçuk University, Konya, Turkey (e-mail: cakmakbilgehan@gmail.com).

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manufacturing, the construction of an additional building was required to meet the increasing spatial needs. A comparative evaluation of the hospital building, architecture of which was changed because of above-mentioned reasons was made with regard to its status before the change and after the change. Spatial organizations of the building before the change and after the change were analysed through Space Syntax method and effects of the change on the parameters of the spatial organization were searched by applying an analytical procedure. Using Depthmap UCL software, Connectivity, Visual Mean Depth and Visual Integration analyses were conducted.

II. Space Syntax Methods

While evaluation of the architectural project is being scrutinized over the plan in the stage of design under the title of building planning, as for the assessment of the structure at the stage of usage is being carried out under the title of its process of use. Both methods are also an assessment method applied for the purpose of augmenting user satisfaction. Particularly in recent years, distinct analysis methods have been employed to be able to perform the building assessments more practically and fasted in a computer – aided medium. As for the most popular one of these methods is the space syntax method.

Syntax is defined as simple but basically different spatial arrangements required for the production of a set of rules. Space Syntax is a theory and method, used in order to define structural environments. The theoretical base of method has emerged with the thesis that "there is a relation between forms produced by external affects and numerical powers" [6].

A. Space Syntax in Architecture

Space Syntax contributes to a better understanding of interaction between design features, intended purpose of the formal possibilities and social contains. Space syntax is described as a whole of techniques to explain the spatial formation and classification of buildings and residential areas. Space Syntax reveals that must be understood the necessity of the rules and limitations to produce spatial forms. Method is also used to predict, evaluate and investigate the effects of various design alternatives. In recent years this method has been used to measure and define the readability through the eye of user and design styles. Space syntax tries to explain all the relations between the data of physical forms that observed by persons acting in space. These relations are between surface, edge and road data with each other and with whole system. In this study, for comparing layout scheme and spatial analysis of primary schools, Space Syntax method was used. Method is one of the analysis methods that included in morphological analysis techniques. Space syntax method can be called as a schematic presentation, which defines the changes in student behaviors, education methodology, user circulation and user differences [4].

Method is also used to investigate, predict, and evaluate the effects of various design alternatives. Nowadays, it is used to measure the intelligibility of the user or designer's perspective with the building's design styles [7]. The most important feature of Space Syntax is, being a numerical technique which has capable of analyzing the abstract characteristics of space as a concrete characteristic. These have a critical role in the formation of knowledge based on the experiences which can be named as a reflection of space in human mind. The general idea of this method is that, by separating the parts of place that these are "the starting point of human experience", and bringing these pieces into maps or graphs to allow them to make quantitative analysis [6].There are some specific concepts in space syntax methodology. Explanation of these concepts is important to interpret the results of analysis correctly and to understand the logic of the method.

Depthmap is a single software platform to perform a set of spatial network analyses designed to understand social processes within the built environment. It works at a variety of scales from building through small urban to whole cities or states. At each scale, the aim of the software is to produce a map of open space elements, connect them via some relationship (for example, indivisibility or overlap) and then perform graph analysis of the resulting network (Fig. 1).

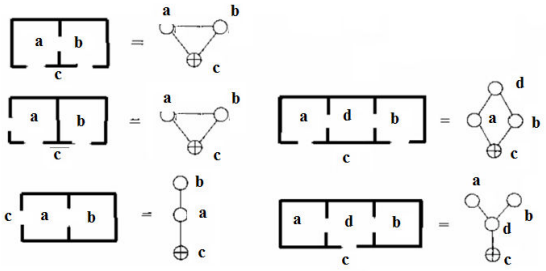


Fig. 1 Interior and external space connection in space organization and its expression with graphs [6]

The objective of the analysis is to derive variables which may have social or experiential significance 3 key concepts within the scope of the study will be considered for the interpretation of analyzes. These are connectivity value, visual integration value and visual mean depth [8]. Connectivity is measuring of the number of directly connected adjacent spaces. A local distance that measures the number of steps is away from each line [8]. This local criterion is the most basic knowledge about understanding space. The most important criterion to predict the movement of a movement along the line is the value of spatial integration (called as Visual Integration). Integration as a global benchmark is the average depth of the space to other spaces within the system. The relationship between the integration value and connectivity value is intelligibility or readability. If connected spaces are also integrated spaces, it means strong and intelligent spatial relation. In this case, all the components that make up the system itself are readable [7].

One of the most important relations in syntax method is the concept of spatial depth. Depth occurs when there is more than one crossing space to reach a space. If there is a low value to be reached in the deflection space, the depth is "shallow", if there is a high value; the depth is "deep". The important

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subject in this case is, showing as a value of the relation of each space with other spaces. This refers to the mean value of the whole, and allows for comparison with other systems [9].

III. Application of the Analysis-Sample Building

Entrance (ground floor) of Sakarya given in Fig. 2 Kaynarca Public Hospital determined as the research field was chosen as the sampling area.



Fig. 2 Sakarya province

Sakarya Kaynarca Public Hospital consisted of basement + ground floor + 2 storeys + garret storey and gave service with 15 bed-capacities. Load-bearing system of the building is a reinforced concrete system comprising of column, beam and floor. The building has 2 entrances as the emergency entrance and normal entrance. The general view of the hospital buildings given in Fig. 3, the layout plan given in Fig. 4, ground plan given in Fig. 5 and appearance of the building before change is given in Fig. 6.



Fig. 3 General view of selected hospital



Fig. 4 Layout plan and appearance of the building before change

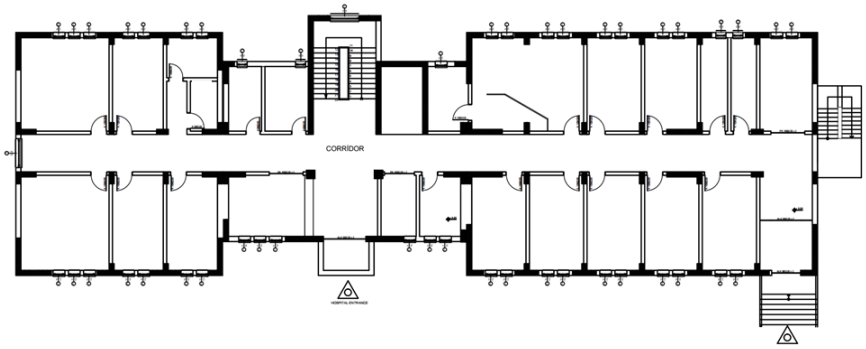


Fig. 5 Ground floor plan of the building before change



Fig. 6 Appearance of the building before change

Although the building did not have an apparent damage before change, significant insufficiencies were detected in its bearing system after the earthquake performance analyses. A reinforcement project was prepared to fill these gaps. In the reinforcement project, some of the reinforced concrete column sections making up the load-bearing system were expanded (jacketing), columns and partitions were added in spaces considered necessary and additional walls were included according to newly-designed plan scheme. Objective of the reinforcement study is increasing the resistance and earthquake performance of the building against both the earthquake and other loads.

Construction of an additional building was required in order to meet the increasing spatial needs of the building, load-bearing system of which was strengthened due to insufficient

earthquake performance. Thus, in addition to reinforcement project, an additional block was constructed for the emergency and surgery units that were insufficient before. Plan scheme of the building which was previously rectangular was converted into L-shape by adding blocks. Its former emergency entrance was cancelled and the new entrance would be moved to the additional building.

Bed capacity of the hospital increased from 15 to 20 and diagnose and treatment units increased spatially after strengthening the building and constructing the additional building.

- Using Space Syntax method, a comparative evaluation of modified hospital building was made with regard to its status before the change and after the change. Effects of the change on the organization of the space were observed by means of Depthmap UCL software. The analyses were made according to Connectivity, Visual Mean Depth, Visual Integration and Beta index.
- Beta index explains the type of the network numerically depending on the node and side relationships of the network which is shown with graphs. This value which is the ratio of the total number of sides to total number of nodes is regarded as tree, loop and complex circuit if $\beta<1$, $\beta=1$ and $\beta>1$, respectively [11].

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Fig. 7 Floor Plan after Strengthening the Load-Bearing System of the Building



Fig. 8 Ground Floor Plan of the Structure after the Additional Building

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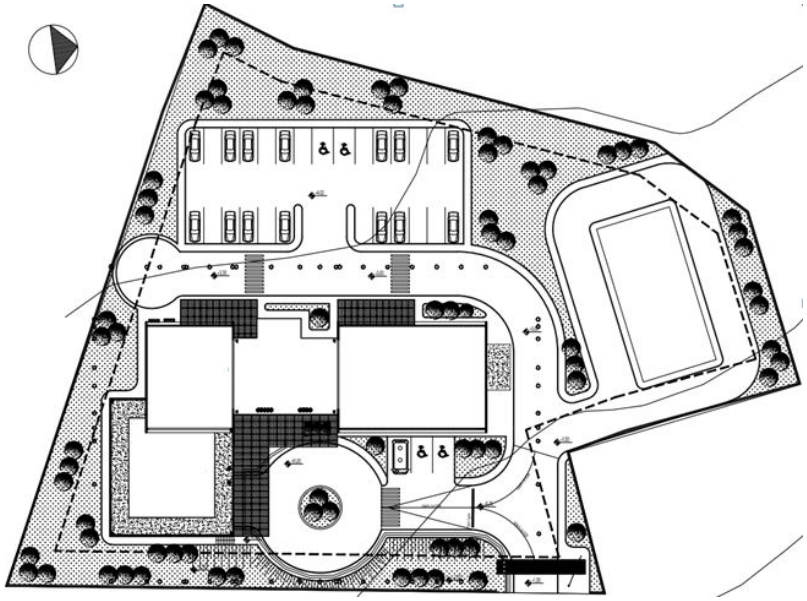


Fig. 9 Layout Plan of the Structure after the Additional Building

A. Parameters in Space Syntax

- Tree, loop or complex circuit describes that the total form of the building fits linear, cyclical or composite forms [10].
- Connectivity value is the measurement of the adjacent spaces which are directly related to the space. Every line refers to a local distance measuring the number of the lines one step ahead [7]. This local criterion gives the major information about comprehending the space.
- Integration value is the most important criterion to estimate the movement along a circulation line. In Space syntax method, spaces of a system can be ordered from the most integrated one to most disjoint one. As approaching the medium parts of the system, the number of the surrounding sections increases and it shows the integrity of the space.
- Mean Depth value is one of the most important relationships in Space syntax method. Depth emerges when we pass multiple intersecting spaces to reach another space.
- If the space to be reached has a low value with regard to changing direction, it is regarded as "shallow". If it has a high value, it is regarded as "deep". The important thing is being able to show the relationship of a space with the other remaining spaces as a value. Mean of these values refers to a total value and allows being compared with the other systems [6].

In the study, Beta index was calculated through graph scheme. Connectivity, Integration and Mean Depth values were calculated by using Depthmap software of Space Syntax method and basing on the average values.

IV. Analysis Results and Evaluation

A. Beta Index

When the functional network structure is analyzed according to Beta index, it is seen that the building has a loop structure before and after the reinforcement, since beta index value of the structure equals 1 before and after the reinforcement. Loop structure of the functional network demonstrates that the movement can be controlled and read both within the spatial structure and in relationship of the building with the outer space. Same results show that the functional structure of the building shall not change. (β before change =1), (β after change =1) given in Figs. 10 and 11, respectively.

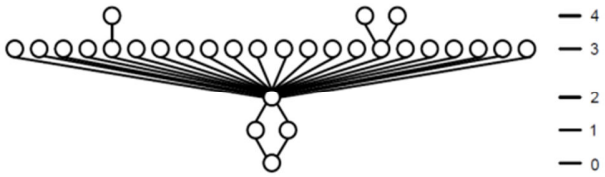


Fig. 10 Graph Scheme before change (B=1)

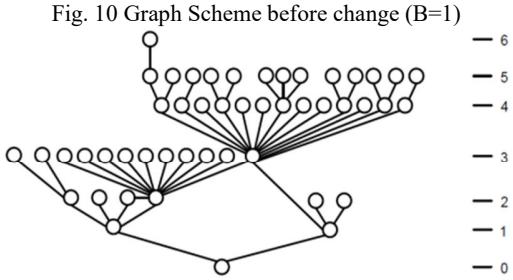


Fig. 11 Graph Scheme after change (B=1)

B. Connectivity Value

The number of the adjacent spaces connected with the space increased (Connectivity before change =1800), (Connectivity

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after change=2066) given in Figs. 12 and 13. This means the strong relationship between the spaces and the frequent and dense passes between the spaces. There are disconnections in interrelationships of the spaces located on a linear line, because traffic of each space occurs on the same corridor. Adding a perpendicular circulation in the reinforcement, the entrances closed up, different reach points emerged and alternative connections were created between the spaces.

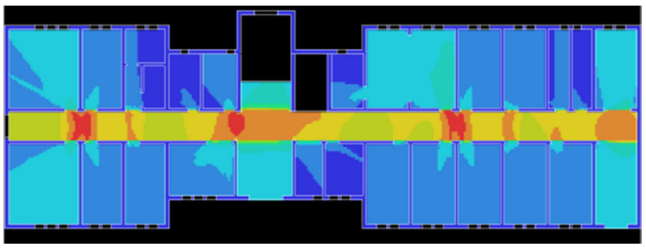


Fig. 12 Connectivity values before change (1800)

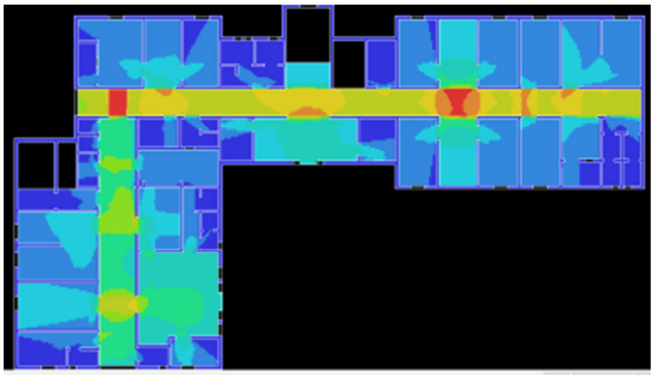


Fig. 13 Connectivity values before change (2066)

C. Integration Value

With regard to integration value, mobility in the current status and density in space use were observed before. However the system was relieved with the additional building and circulation line after the reinforcement and the spatial mobility decreased. The spatial density and mobility observed in the entrances and gathering areas decreased and the system became more explicit and understandable. (Integration before change =9,115), (Integration after change =6,761) given in Figs. 14 and 15.

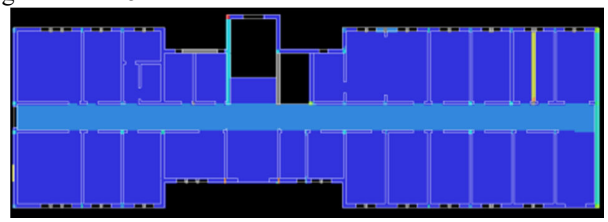


Fig. 14 Integration values before change (9115)

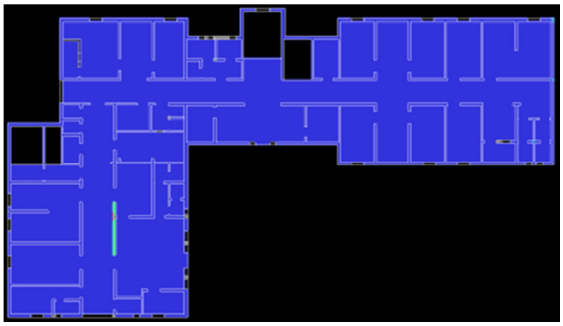


Fig. 15 Integration values after change (6761)

D. Mean Depth Value

With regard to mean depth value, it is seen that from Figs. 16 and 17 the building had a higher depth value than the current value after the reinforcement. Its most significant reason is creating new spaces within several spaces because of the needs of the building. Increase in the depth value shows that the nested spaces increase and all spaces are perceived more difficultly when looked from the main entrance or main corridor.

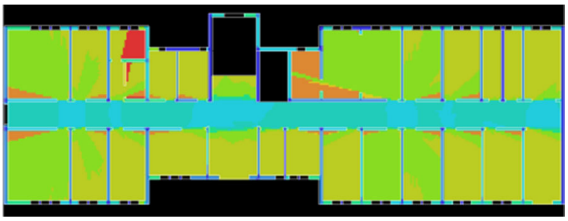


Fig. 16 Mean Depth values before change (2393)

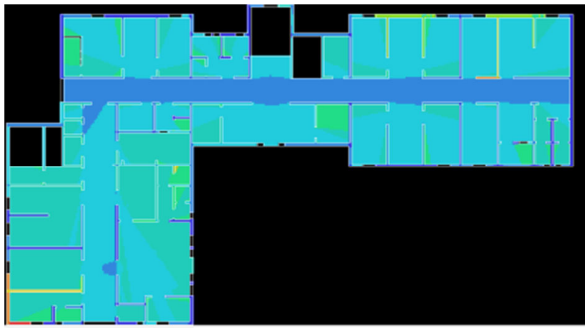


Fig. 17 Mean Depth values after change (2970)

V. Results

In this study, the comparative evaluation of a hospital building which was taken as example and modified due to various reasons (strengthening against the earthquake and increasing capacity) was made with regard to its status before the change and after the change. The following results can be considered according to the findings of the study;

- It was seen that the relationship between spaces of the building increased, building became more explicit and understandable.
- It was determined that increase in the depth values of the spaces leads to difficulties in perceiving the spaces, but the changes generally ease the spatial use.

- Additional new building and modified indoor solutions increased the relationship between the spaces and different connections between the spaces emerged due to alternative entrance, the dense and frequent circulation was relieved and the system became more explicit and understandable. It shows that the additional building is on the right point and new indoor solution is a proper decision relieving the system.
- Even though increase in the depth value leads to difficulties in perceiving the spaces, this condition required for the function of the hospital does not cause any trouble. Moreover, separating some of the nested functions was a solution to relieve spatial use.
- In addition to the fact that reinforcement process concerns many technical and structural factors, it also concerns the spatial organization and plan scheme change because of its intervention in the plan scheme and space use. Hence Space syntax method was used to test how space use was changed, the right point of the additional building and accuracy of the results of the additional space sections which were built for strengthening.
- It is seen that the method used in this study can be easily used to scrutinize the consistency of the revision projects of especially the hospital buildings. In Turkey, there are also various hospital buildings which shall be used through reinforcement instead of the ones that were decided to be demolished because of the earthquake risk in the last decade. More comprehensive reinforcement manufacturing is performed particularly in the ground floors and lower floors. In this study, the spatial relationships between the method used and reinforcement, and the effects on the building with regard to spatial depth and spatial integration can be analyzed. The analyses can be performed not only inside the floor (horizontally) but also by connecting the floors (vertically).
- Besides, it is important to test the model in projects by the architectures, since it is possible to test the model of a new design before applying it.

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