Analysis of the spatial structure of the city based on theoretical configuration models

Olena Oliynyk

1 Department of Architecture of the National Academy of Fine Arts and Architecture, Kyiv, Ukraine

Abstract. The article examines spatial and architectural structure of the city. System analysis and spatial syntax were used as a scientifically based approach in the study, which allows to investigate the relationships between spatial planning and a number of social, economic and environmental phenomena. It was established that the spatial planning organization of the city center is a complete system consisting of two subsystems - spatial planning and volume spatial. Spatial Syntax applies the concept of configuration in urban spaces to reveal social and behavioral patterns. It was established that the configuration of public spaces determines the nature of activities and potential directions of people's movement, and therefore, the use of public space, types of activities, directions of conservation and methods of environmental design. The author identified two types of theoretical configurational models of public space: a) centric; b) linear-axial; which, according to the principle of isomorphism, determine the pattern and relationships of public spaces in most cities. The legality of using space syntax and spatial analysis for the analysis of the architectural environment is confirmed.

1 Introduction

It was determined that the organic integrity of the planning structure of the city, the high degree of interrelationship of the constituent elements allows it to be classified as a system object. The model of the urban planning system "population - environment - activity" (according to M.M. Dyomin [1]), which, in turn, is a subsystem of the general urban planning system, can be taken as the basis for building a model of urban public space and researching its components. It was established that the spatial planning organization of the city center is a complete system consisting of two subsystems - spatial planning and volume spatial. In the spatial planning system, it is proposed to distinguish zones that are relatively homogeneous in terms of spatial characteristics and the pattern of open spaces. Based on previous studies, the author identified three theories of analysis of the spatial planning structure of the city: (1) figure-background theory; (2) the theory of connections; and (3) place theory [2]. The theory of figure-background, which originates from Gestalt psychology, allows us to single out the structure of open spaces, which is defined as a system of connected voids between the masses of buildings. The author proposed a method of spatial analysis based on the improvement of the "figure-background" theory to determine the...
compositional structure and ratio of transit and stationary spaces. This method makes it possible to formalize the complex multi-level pattern of the urban fabric of the city, highlighting only the compositional and spatial aspects of the structure of urban spaces. Two types of public space are proposed: the space of stay (stationary) - the one where residents stay, sit, rest, and the space of movement (transit) - the one in which they move.

Spatial Syntax applies the concept of configuration in urban spaces to reveal social and behavioral patterns. It was established that the configuration of public spaces determines the nature of activities and potential directions of people's movement, and therefore, the use of public space, types of activities, directions of conservation and methods of environmental design.

The author proposes to combine syntactic analysis with spatial analysis based on the “figure-background” theory. Spatial formations are first presented as a drawing of positive spaces covering the plan (or some combination of them), and then an analysis of the configurational relations between each spatial element and all or some others is carried out.

2 Materials and Methods

When studying the spatial structure of the architectural environment, we used a spatial analysis and spatial syntax, as a scientifically based approach that explores the relationships between spatial planning and a range of social, economic and environmental phenomena. The movement of a person in space consists of many phenomena that in one way or another affect the perception of the environment, and are partially described by the theory of spatial syntax, which is based on the relationship between space and society.

B. Hillier and O.Oliynyk proposed a method of analyzing spatial configurations that can be used for different fragments of the urban structure. They noted that architectural environments from the point of view of spatial and formal organization can be considered as configurational entities. It is through the spatial configuration that social goals are expressed. Configuration is a defining component of architectural and urban planning, because it takes into account all possible relationships and the simultaneous influence of a complex of entities on each other through this relationship.

The model of spatial integration in spatial planning correlates to a certain extent with the traffic scheme. The main strategy of the syntactic method is the analysis of the configurational properties of the spaces that make up the plan, and with the help of this - the identification of the key structural features of the plan.

To determine the compositional structure and the ratio of transit and stationary spaces, a method of spatial analysis based on the improvement of the “figure-background” theory is proposed. Using the method of spatial syntax, the structures of public spaces of historical cities were investigated and it was found that the degree and nature of movement along the street will be determined by how the street is embedded in global and local networks. Similarly, the functioning of public squares is determined not only by how their space is limited by surrounding buildings, but also by how it is spatially embedded in a larger system of space. That is, not only the configuration of public spaces affects their functional use and directions of movement, but also the relationships between neighboring spaces that form a network. Thus, what happens in any individual space - a room, a corridor, a street or a public space - is fundamentally influenced by the relationship between this space and the network of spaces with which it is connected.

3 Results
The author identified two types of theoretical configurational models of public space: a) centric; b) linear-axial. According to the principle of isomorphism, these models determine the pattern and relationships of public spaces in most cities.

The first model demonstrates the presence of a central, distributive space connected to the surrounding spaces—either directly or through intermediate linear spaces in the field of vision. Using linguistic or biological terms, we can call this method of connections "agglutination" (N. M. Dyomin’s term [1]), i.e., gluing, sticking together spaces into a single system with a common center. Such a model, as the historical review showed, was characteristic of extroverted, democratic societies, involving a constant return to the distributive core, communication, and meetings. (fig. 1a, b).

It was established that the possibility of returning to a certain meeting place creates conditions for the so-called "serendipity" effect—a happy unexpected event, and therefore improves the social content of the space. These re-encounters appear to be random events, but are actually a predictable effect of planning. Plans with "returns" tend to be perceived as more socially engaging than those that exclude them due to excessive consistency.

Fig. 1. Centric configuration model of public space: a) model; b) San Marco Square, Venice. Source: author.
The centric model can have a free, open space of the central core, or include an additional object in its center. In addition, this model has a variety-centric-branched, in which a return from the side spaces to the main one is provided. (Fig. 2, 3, 4).

Fig. 2. Centric model with integrated core. Source: author

Fig. 3. Centric-branched configuration model. Source: author

Fig. 4. Centric configuration model with a monument in a center. Source: author

The second, linear-axial model, demonstrates movement in a clearly fixed direction. This is a model characteristic of introverted societies, it does not involve communication and interaction. It directs, determines and controls the behavior of people (Fig. 5).

Adding a linear-axial configuration model with elements of the composition, we will get a scheme of the composition of the urban space (Fig. 5b).
It was established that in modern configurations there is a tendency to combine both models with increased integration of spaces. An alternative is to design the space in such a way that sequences are localized and interconnected, allowing tourists and city dwellers to choose different paths and construct their own model of experience. However, the urban territory is organized in a much more complex way: it can have several districts, each of which has squares, public centers and many blocks, and therefore several space compositions can exist in parallel in the city.

The linear-axial configuration model of public space, in this case, will have a variety—linear-biaxial, or even branched axial, in which there is a great freedom of choice of individual movement and its determinism is reduced, but there is no possibility of social contacts and joint activities—this is more existential, individual model (fig. 6 a, b).

The analysis of two types of theoretical models—a centric model with an integrated core and a linear-axial model—at two levels: local (area and fragments of cities) and at the level of a district or city—made it possible to make a typology of urban public spaces. Thus, the centric type at the local level includes such spaces that were a manifestation of the democratic structure of cities, such as Piazza Campidolio and Piazza Navona in Rome, San Marco in Venice, and others.

*Fig. 5.* Linear-axial configurational model of public space: a) model; b) The structure of the composition of the urban space. 
*Source:* author

*Fig. 6.* Varieties of the linear-axial model: a) linear-biaxial; b) branched axial. 
*Source:* author

*Fig. 7.* Linear-axial configurational model of public space: a) model; b) The structure of the composition of the urban space. 
*Source:* author
The spaces of eastern, imperial and post-Soviet cities with their deterministic, controlled, totalitarian structure belong to the linear-axial type—such as Nezalezhnosti Avenue in Minsk, St. Marschalkowska in Warsaw, Tiananmen in Beijing, Tuileries in Paris; or with a specially controlled function, like St. Peter Square in Rome.

The spatial planning structures of such cities as Bologna, Krakow, Lviv (actually all cities with regular market squares) author classifies as centric type. All of them are found to be highly integrated spaces connected to many adjacent public spaces.

The linear, axial type includes such cities as New York, Washington, Zaporozhye; natural linear types are characteristic of ancient Russian cities (Suzdal, Lutsk, Vitebsk); as well as Samarkand, cities of Morocco and others. In most cities, the structure of public spaces is a combined type—several axial (Le Havre, The Hague), multi-center ring (Paris) or multi-center axial (Prague).

At the same time, the spatial-planning structure of the historic city center can have the form of either a linear sequence, where “turns” and “meetings” occur only at the first level of integration (New York), or a circular structure connected to the public transport system, which combines local “rings” and eventually returns visitors to the starting point (Venice, Paris, London). Spatial-planning organization of the historical center can have several return rings strung on a linear or branched structure (Rome, Prague) (fig. 7.8,9).

Fig. 7. Examples of public spaces in linear-axial configuration. Source: author

Fig. 8. The linear biaxial model. Source: author

Fig. 9. The branch-axial model. Source: author
Note that linear-axial and centric configurational models of public space, as well as their varieties involve temporary departures from the main line of movement, its interruption, departures to side spaces and return to the central core or to the main route.

In addition, the constant possibility to return to a certain meeting place creates the conditions for so-called "serendipity" - a happy unexpected event. The centric, deeply integrated structure of the plan with the distribution core inside gives people the possibility of a certain freedom of choice: they can enter the adjacent spaces and return to the central core, and in any sequence. However, returning to the central core, people will "accidentally" meet the same visitors, which will be perceived as a happy accident, "serendipity" [3]. The Oxford dictionary defines serendipity as "the occurrence and development of events by chance in a happy or beneficial way".

Serendipity is a component of happiness; it is what enhances social experience and life in general. Increasing the feeling of happiness is a problem that hundreds of sociologists are currently working on, and it turns out that it lies in the topology and configuration of urban space. Integrating space enhances its intuitiveness, and architects and designers become wizards using this tool [5].

So, basic theoretical models helped in the analysis of the configurational structure of spaces, as they describe the hidden mechanisms of building objects. Models are built according to the following conditions: formal spatial units are selected as objects - types of spaces corresponding to specific spatial objects (rooms, corridors, fragments of streets, squares, etc.); defined limits of variation of selected types; defined connections between spatial elements and their configurations characterizing the type of spatial interaction; the rules of the transition from the formal model, which describes the structural characteristics of the object, to its object implementation (use and preservation strategies) are defined. This kind of rules define a "code" (or algorithm) in its totality, in which the individual characteristics of an architectural object are concentrated, reflecting the properties of its geometric dismemberment and spatial connection of elements.

The practical significance of the study of the configuration (structure of interrelationships) lies in the determination of variations in the availability and use of spaces and their corresponding transformation, which involve various types of activities, directions of preservation, methods of interpenetration of spaces, environmental design, placement of amenities, information, etc. The configuration of spaces chooses the nature of the activity and the directions of movement of people, and therefore the use of the spatial form.

These models were developed by the author for both outdoor public spaces and interior spaces.

4 Discussion

---

E3S Web of Conferences 452, 05024 (2023)  
IPFA 2023  
https://doi.org/10.1051/e3sconf/202345205024
5 Conclusions

Sustainable development of the city at the current stage includes the preservation of cultural values, such as open public spaces and architectural monuments. The Global Report on Culture for Sustainable Urban Development, prepared by UNESCO states that culture is inextricably linked to public spaces which reflect the history and cultural diversity of a society, while creating a higher level of social diversity. Open space is an important part of the urban heritage, a strong element of the architectural and aesthetic form of the city. To achieve the goals of sustainable development, UNESCO proposes to include in this concept the preservation of cultural values, such as the image of the city and its architectural monuments.

Open public spaces, connected by pedestrian streets in a continuous network, create the image of the city and its recognition. And the tool for studying the structure of urban spaces is spatial analysis and syntax. In the process of movement, the perception of the city depends in a certain way on the configuration of open spaces. It was established that in modern configurations there is a tendency to combine both models with increased integration of spaces. An alternative is to design the space in such a way that sequences are localized and interconnected, allowing tourists and city dwellers to choose different paths and construct their own model of experience. This reduces the impression of the didactic potential of the space and actually gives the visitor a certain degree of intellectual control. The script of the movement goes from "show" to "conversation", from classification to narration. Such multi-functional relationships between context, content, space and visitors, 'choreographed' through architecture, can be extended to the analysis of both outdoor and indoor public spaces. These models were developed by the author for both outdoor public spaces and interior spaces.

Our further research will be related to the definition of urban planning elements, architectural objects, which are reference points of spatial syntax on the historical, semantic and content levels, the action of which forces a person to change his movement and thus affects the social effect of the environment.

References

4. B. Hillier, Space is the Machine. A configurational theory of architecture. London E1 5LN, United Kingdom discovery.ucl.ac.uk/3881/1/SITM.pdf (Last accessed 16.08.2020)
Issues of the organization of systems of pedestrian zones in the historical center of Kyiv.

Transportation Research Procedia, 63, 1681-1689 (2022)
https://doi.org/10.1016/j.trpro.2022.06.182

O. P. Oliynyk, Peculiarities of spatial and syntactic analysis of museum and cultural complexes. Collection of scientific works Urban planning and territorial planning, KNUBA, K., 81, 274-286 (2022)
doi:10.32347/2076-815x.2022.81.274-286

Agenda for Sustainable Development, Resolution 70/1 (2015)

Council of Europe Recommendation No. R (86) 11 of the Committee of Ministers to Member States on Urban Open Space, Strasbourg: Council of Europe (1986)

council.coe.int/09000016805101ab (Last accessed 16.09.2023)

N. M. Mossin, S. Stilling, T. Bøjstrup, H. Chevalier, An Architecture Guide to the UN 17 Sustainable Development Goals, Publisher: KADK, Copenhagen, Denmark, 2 (2020)


https://doi.org/10.1051/e3sconf/202345205024