

# Designing lightspace in contemporary architecture

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**Abstract.** Daylight has a significant impact on the perception of the building space. The term “lightspace” is introduced to determine phenomena of sensorial perception of architectural object’s indoor space and four different components of lightspace, such as functional, architectural and artistic, light-technical and visual, are considered. Further, three groups of architectural and artistic design techniques were estimated: based on space modeling (organisation of lightspace in the building structure, organization of multi-light spaces, plasticity organization of lightspace, methods of natural light penetration through the shell of the building), light modeling (the distribution of light in space and its spectral composition), and time modeling (light dynamic, transformation of the building parts, movement of people in the place). Attention is drawn to relationship between diverse lightspace design techniques and architectural practice.

## 1 Introduction

Natural light in contemporary architecture occupies a unique position in which it appears simultaneously in two forms. It exists in the world of physical phenomena and the metaphysical world of meanings, metaphors and ideas.

On the one hand, light is a universal physical constant. It allows us to see, to understand where we are and what exists around us, to interact with the world and to perceive it. Light affects our physiological condition and various parameters of our habitat. On the other hand, abstracting from the utilitarian understanding of the role of light leads us to the light as an important cultural concept based on sensually perceived phenomena. At this point, light becomes a powerful tool for the emotional impact on the viewer, acting as a catalyst for the perception of the architectural image.

The history of the architect’s relationship with natural light shows a large semantic capacity of light and infinite variety of its orchestration. Despite this, natural lighting in architectural theory is usually studied from a utilitarian point of view. Great attention is paid to the functional and material aspects of the light design, while the relationship between the physical and metaphysical aspects of the natural light design and their influence on the sensual perception of the architecture remains understudied.

The purpose of present study is to develop an integrated model illustrating the role of natural light in contemporary architecture.

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## **2 Materials and methods**

The research method is based on the complex scientific study of the problems of usage of natural light in architecture, on the application of evolutionary and system analysis, on the study of the illustrative and graphic documents and video materials, on the natural study of architectural objects, on the classification and systematisation of materials, on the comparative analysis, on creation of schemes and models.

## **3 Results**

The term "lightspace" was invented by N. Shchepetkov and has been used to describe artificial light [1]. During the research, this term was used as a working hypothesis to describe also the inner space lit up by day light. In what follows, we shall understand "lightspace" as the light-spatial environment of architectural objects as a sensually perceived phenomenon and a phenomenon of the complex modelling of light, space, time, movement, material properties and sense. For the research of the features revealing the meaning of the term "lightspace" of an architectural object and the content of the project problems and of the design methodology, the following main components were identified [2]: the functional, the architectural and artistic, the light-technical and visual.

### **3.1 Functional component**

The functional component contents the utility functions of the natural light. Three groups of functions were defined: informative, morphofunctional and indirect. Light as an integral condition of the comprehensibility of the world provides humans with information about the environment creating visual forms. Ultraviolet, visual and infrared radiation has an impact on the hormonal background of humans and their psycho-emotional state. The indirect influence of light on the environment and its chemical, physical and biological parameters defines the habitat comfort and improve its hygienic parameters.

### **3.2 Light-technical component**

The light-technical component is regarded as a controllable subsystem, which is influenced by technological progress and development of the lighting technology as a science and includes the basics of modelling of lightspace. The light-technical simulation of the environment can be divided into two methods: experimental and computational. The experimental method involves the construction of planar and three-dimensional models of the projected object in order to identify the states of lightspace. The calculation method includes computer simulation, mathematical models and formulae for definition of the lighting parameters in order to define the lighting parameters.

### **3.3 Visual component**

The visual component is manifested itself in two aspects – in the design of lightspace of buildings by the architect, and the perception of the designed space by humans. In the first case, the author defines the idea of the architectural and spatial organisation of the object and the concept of formation of its light environment as well as develops a scenario of its perception by humans. In the second case, the subjective image of space is shaped by the psychophysiological peculiarities and the way of the lightspace perception of an individual

whose behaviour within it cannot be fully determined by the architect's scenario and depends on the individual's free choice.

### **3.4 Architectural and artistic component**

The architectural and artistic component of lightspace represents a complex of the design of space by the architect, of natural light and temporal flow. It is it that defines the image of the interior and affects the state of atmosphere inside the object. Let us consider methods of forming of the architectural-artistic image of the internal space of buildings by means of natural light.

#### **3.4.1 Techniques based on space modelling**

Consideration of the static basis of the architectural and artistic component of lightspace allowed us to identify a group of techniques based on the interaction of natural light with the architectural form – the shell of the building, its volume, mass and plasticity of its surfaces.

The functional purpose of a building, its plasticity solution and shape can imply different form of organisation of light spaces in the building structure. Lightspace of architectural objects can have a floor organisation and multi-light, in case of inclusion of multi-light spaces in the form of atriums and passages in building structure. Based on the type of multi-light spaces, the following combinations can be identified. The first type is the lightspace inside the shell, through which natural light penetrates. The second type is the multi-light space inside the building and is surrounded by the multi-storey mass of the building. Light penetrates into the atrium from above. The third type is the light space in the form of a passage which is squeezed between the two sides of the high-tiered blocks of the building. The fourth type is the multi-light space of the gallery type adjoins the multi-storey mass of the building. In this case, the light illuminates the multi-light space on four sides. The fifth type is the inner lightspace, which is a combination of several multi-light courtyards dispersed in the multi-storey body of the building. And the sixth type is an open space, decorated with a frame or other material elements which surrounds a closed volume or system of closed volumes. In this case, the closed volumes are illuminated from the outside.

The revealed types of organization of multi-light spaces are subordinated to four principal types of volumetric-spatial compositions. Horizontal type of composition of lightspace has a predominant horizontal structure and can develop in one or several directions. Vertical solution of the light-spatial composition has a pronounced vertical structure. Volumetric composition of lightspace is characterized by close relations of height, depth and width and has proportions close to the cube. The deep-spatial type of composition differs in the dispersed interaction of separate light spaces.

Each of these types of composition can be represented as a certain type of plasticity organization of lightspace: orthogonal, multi-axis, curved, folded, and parametric.

Different methods of natural light penetration through the shell of the building have been identified. Light can penetrate into the building through openings, through channels, through light-transmitting membranes, be reflected from planes with different geometries, "sifted" through perforated surfaces. Six types of interior lighting by natural light have been identified: flowing (through large stained-glass windows or overhead lights), dispersed (through a system of openings), directed (through individual windows or openings), concealed (through channels in wall constructions), diffuse (passing through surfaces covering the light openings) and combined lighting.

Diaphragming of natural light allows the direction of light flow to be adjusted and affects its quantitative characteristics. Depending on the orientation of the light opening, the aperture of the same size can create completely different states of space. The size, the amount of the

openings and their orientation not only affect the light amount but also play an important role in determining the nature of interaction between internal and external space. The size of the aperture determines the field of view and, accordingly, controls the amount of information about the outside world entering the room, allowing you to control the relationship with the environment and determine the relationship of the building with the context.

It is important to note that the active use of light openings in the architectural and artistic formation of light space is one of the most notable differences between modern architecture and classical. If before the beginning of the twentieth century, the use of enclosing walls as a supporting structure significantly limited the size of the window and the possibility of its placement, the emergence of rolled metal and reinforced concrete frame allowed architects to use the glazing freely [3].

### *3.4.2 Techniques based on the simulation of natural light*

A group of techniques based on the simulation of the light itself includes various ways of transformation of the characteristics of the light flow. Modelling of properties of natural light, as a rule, occurs as a result of interaction of sun rays with any material. Thus, the characteristics of natural light become directly depended on the ability of the material to reflect, to transmit or to absorb sun rays.

The reflection coefficient ( $\rho$ ) indicates the ability of the material to reflect light. There are three types of reflection: mirror, diffuse and mixed. The reflected light has a set of unique properties: reflections are able to create an illusion of lightness of shapes, adjust the illumination, multiply and expand the boundaries of space.

The transmission coefficient ( $\tau$ ) indicates the ability of the material to transmit light. There are three types of transmission: transparent, diffuse and mixed. The absorption coefficient ( $\alpha$ ) indicates the ability of the material to reduce the intensity of light by converting it into other forms of energy. Water in various aggregate states, matt, coloured or curved glass, fabric, polymeric materials or stone can act as a “filter” that partially absorbs natural light. For example, John Pawson, reconstructing the Church of St. Maurice, replaces stained-glass windows with onyx sheets. Thus, the architect creates a fog of diffuse luminescence in which absolutely smooth texture of vaults of church obviously appears.

The analysis of the role of simulation of natural light in the formation of an architectural object is reduced to the consideration of modelling the qualitative characteristics of lighting: the distribution of light in space and its spectral composition.

Four main groups of techniques based on the light and shade contrast have been identified: revealing the shape and plasticity, creating a counter-journey effect, creating a light and shade pattern, revealing the texture of the material.

Thus, the light and shade contrast reveals the spatial solution in the project of the residential house Apartment building on Fosterstrasse, designed by Christian Kerez. The architect forms the living space with the help of massive partitions. By illuminating them with natural light through continuous glazing, he obtains complex perspectives from planes of varying degrees of light.

Light, entering the space through an opening that is many times as long as its width, creates a counter-journey effect. The contrast between the bright light bar and the dark space around it creates a sense of closure and security, increasing the value of light. Architect Louis Kahn, talking about the properties of natural light, says: “Even the room which should be dark needs at least a slot of light to determine how dark it is” [4]. The Spanish bureau RCR uses a similar technique at the Bell-lloc winery. The divergent bands of light penetrating into the inner space through complex shaped lanterns “cut” the darkness of the dungeon. The contrast created by the narrow and bright “plates” of light and darkness, together with the rough texture of the walls, creates an atmosphere of tranquillity.

The direction of light flows has a significant influence on the image of the interior. The directional light creates sharp light and shadow contrasts and makes the outlines clear. Diffuse lighting, on the other hand, causes objects to lose their volume, while shadows and outlines to become smoother. Six main types of light space based on the directions of light flows are formulated: directed contrast, directed, selectively directed, variable, reflected, diffuse.

The use of light filters that change the spectral composition of the light flow opens up a wide range of possibilities for the architect. The use of chromatic light – a technique that has been widely used in Gothic cathedral stained-glass windows – has an incredibly powerful effect on human emotions. Mark Chagall, speaking about the power of the impression made by stained-glass window, calls it “a transparent partition between his heart and the heart of the universe” [5].

A striking example of lightspace, which is based on a change in the spectral composition of light – the “Seashore chapel”, built by Vector Architects. Natural light penetrates the space through a narrow opening between two roof planes. Passing through coloured sheets of glass, the sun rays create a pattern on the white rough surface of the chapel wall, giving birth to a light and spiritually filled atmosphere of divine involvement.

### *3.4.3 Techniques based on modelling the temporal flow*

Consideration of the dynamic basis of architectural and artistic component of lightspace allowed us to identify a number of techniques based on the modelling of temporal flow.

In this regard, the most obvious is the transformation of the qualities of lightspace, associated with the dynamics of the most natural light: architecture becomes a “stage” on which natural light creates deep and emotionally filled states. The image of space can be based on changes in the characteristics of natural light (its intensity and spectral composition), depending on the time of day and weather conditions.

For example, in the Asencio House project created by Alberto Campo Baeza, the smooth white walls facing west become a screen on which nature draws successive paintings during the day. The uniform grey surface of the wall in the afternoon is replaced by a sharp contrast of the white surface with intense sharp cold shadows; the airy and elegant silhouettes of the tree trunks are replaced at sunset by a saturated shade of dusk. Henry Plummer, conveying his impressions of the effect, writes: “The shadows from the trees gaining depth of depth are superimposed over the clouds, combining the impression of the earth and the sky in moments, depicted in the Hopper’s paintings” [6].

The Cistercian Monastery in Bohemia, by architect John Pawson, is a striking example of the sensitively designed atmosphere of space, built using the dynamics of natural light. Of particular interest is the gallery around the perimeter of the courtyard. Banded glazing is a kind of boundary between the spirit world, where there is no time, and the earthly world, where nature exists at its own pace. Monks, whose lives are directly subordinated to the rhythm of the sun, being in a pure ascetic space, where time is immovable, contemplate, as against the background of white architecture, some states of light and nature are replaced by others.

The transformation of lightspace over time is influenced by the dynamics of the elements that make up the space with which the light interacts. Innovations in the field of technical systems for the regulation of lighting parameters of the light field, allow architects to determine the quantity and quality of natural light entering the building and thus regulate the light and atmosphere of the space.

The picture of the dynamic component of lightspace is complemented by the movement of people in space. In this case, it is not a question of light, which moves, gives the same

space with different states, but about a person who moves through different spaces, observing the successive changes in the states of light in them.

The movement of the viewer can be defined by the perception scenario laid by the architect during the design stage, or flow freely from one act of perception to another.

The most striking example in this regard is the *Thermes in Vals* by Peter Zumthor. The architect plunges visitors into the darkness of a giant cave, the darkness of which is dissected by the planes created by light that form a slow flow of complex perspectives. The inner space is permeated by the streams of light from the apertures located at a considerable distance. The light pulls the space out of the darkness, taking visitors with it. The trajectory of their movement flows freely through the space from one state to another. “The meander, as we call it, is a designed negative space between the blocks, a space that connects everything as it flows throughout the entire building, creating a peacefully pulsating rhythm. Moving around this space means making discoveries. You are walking as if in the woods. Everyone there is looking for a path of their own”, describes Zumthor his idea [7].

### **3 Discussion**

During the modern history, the term "space" has become a central category of architectural thinking. It defines the direction of architects' creative searches since the beginning of the twentieth century, while design questions, in essence, are reduced to space organization issues. At the same time, space itself is traditionally understood as a three-dimensional void, an abstraction that exists apart from the temporal flux. In this case, the question of space organization is essentially one of the creations of a shell containing air, and the space itself is a derivative of the architectural form. This classic interpretation of the architectural space – as containing no content – is one-sided. It is incapable to uncover the rich spectrum of aspects that modern architects put into the concept of the atmosphere and spirit of the place.

Introduction of the term "lightspace", by which we mean the interior space of an architectural object illuminated by natural light, allows us to take a fresh look at the building design and the creation of the atmosphere. In the same way that the space was the main material for the architect throughout the twentieth century, nowadays we can define lightspace as a new material architect can work with.

The development of various aspects of lightspace modeling changes the traditional methods and approaches to architectural design and involves the aspects of the sensorial perception of architectural objects (or “object” if singular and not plural) into the this process. Natural light creates an emotionally filled artistic atmosphere of the interior space enriching it with subtle nuances, transforming the architectural form and revealing its features. An abstract emptiness of the space has been replaced by the lightspace enriched with different qualities and states. Thus, to two inviolable categories of space and time, the third one – natural light – is added.

### **4 Conclusion**

The study of the light design foundations in contemporary architecture has revealed the reasonability of introducing the term "lightspace", understood as the interior space of an architectural object illuminated by natural light. The theoretical concept revealing the subject matter of the term "lightspace" buildings was developed. Four different components of lightspace such as functional, architectural-artistic, light-technical and visual are considered.

It should be noted that the questions of interaction of natural light and architectural space raised at the present study have not been exhausted. Issues regarding the ecology of light, as well as the impact of natural light on human health and hormonal activity require further

study. Investigation of the effect of light on impression and behavior, along with the research of the relationship between the emotional state of a person and the atmosphere of the architectural space, seem to be perspective research directions. Systematization and management of knowledge on tools used to achieve the certain quality of light in the space is a current topic of further development. Inter-influence of natural and artificial lighting, their interference in the historical perspective and their ability to transform, complement and duplicate the each other's properties requires further examination.

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