Investigating the Effects of Light on Forming Architectural Spaces and Strategies of Using it

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ABSTRACT
Architecture and light or light and architecture are concepts which have depended on each other during the history, so; certainly a relationship happens between these two so as to say that light is a form of architecture. On the other side, different methods of structuring can be attributed to interference of light in configuration of architectural space and controlling daylight in configuration of architectural space is necessary as a determining factor in creating, more stable and more humane, convenience and better space. Descriptive-analytic method is used in the present study considering the previous studies to represent proper and useful solutions to configure architectural space using daylight. First the relationship between light and architecture is considered and then the results are extracted and finally some principles to use light are presented.

INTRODUCTION
Architecture is among the arts and sciences where the role of light can be referred to specifying a detailed issue on the trend of using natural light. In architecture, light is one of the concepts propounded beside other elements and concepts such as structure, spatial discipline, materials and color also it should play its role as a distinct element in designing. One of the most outstanding features of natural light is its sequence and change during the day causing the movement and alteration in different hours [1].

Kahn said “light causes the presence of everything. The objects are derived from light or in other words whenever light is consumed, the object is resulted. Objects are those that create shadow and shadow belongs to light. Light moves toward the object and object moves toward light and this reciprocal movement creates environment and atmosphere of construction. The form says to itself: I should make something” [6].

light is reflected in architectural space which is among the important factors in forming and configuring these spaces. Not only can light reveal the real identity and architecture elements but also it can consider a kind of change and transformation or in other words, a kind of metamorphosis displaying different games of a space with an element [11].

Light is an architectural instrument that influences other architectural instruments. The scenario considered by the architect for proper light of the building has a role in general aura of the structure and these general goals form the first step in reaching to spiritual skeleton of the structure.

Light and architecture are indispensable. Light is not though about just for architecture but architecture usually searches a kind of organization to use the light in the best possible way. Light has an important role in rating architecture elements and gives dependence to them. Perhaps it can be said that light emphasizes a separated object so that it can be recognized in its ratio in the context. At the end it can be said that light is one of the important and determining factor in configuring spaces.

Research questions:
One of the forgotten issues in our daily life is the existence of light. So the following questions can be raised about light:
Asking the main question that light presence especially the natural light in architectural space can have a meaning beyond lighting is necessary.

Secondary questions:
- Can light make space significant so that it can be recognized independently from other spaces?
- Does perception of architectural space have a direct relationship with light?

Purpose of the study:
Today’s architectural space has less comfort and sense of belonging to location. So spacing methods in architecture can be done through lighting where residence location will have proper life quality in residential space.

Research hypotheses:
- Light can increase spatial efficiency.
- The effect of light spacing is not less than the effect of architectural forms.
- Light can increase the sensory perception of space.

Research purpose:
- The general purpose of current study is emphasizing on mental and ethical balance and physical health, growth and prosperity, creativity and quality of human life caused by light.
- Light can be effective as an architectural form causing spacing in architecture.

Literature review:
The following cases can be mentioned about the use of natural light:
- The main idea of gothic style which was creating a part of sky on the ground needs a non-material space. Two factors help solving this problem including transferring the loading structure of the building outside and proper lighting. The aspects of structural elements were lessened inside as far as possible and huge windows were used in freed surfaces. The light shining from top of intermediate carrier walls is so extreme that not any dark part is remained in this section and the observer really thinks that the intermediate upper roof is hanging. Inversely the lower part of intermediate carrier remained semi-darkened. Two side by side carriers having the needed aspects for structural elements in the lower section prevents the possibility of such lighting. in this part man thinks that he is standing on a earthly semi-darkened space and when looking up, he sees a bright light sky that is divine place [4].
- Another case is the use of natural light by Louis Kahn. Due to his sensitivity to light value in designing the buildings, Louis Kahn is called the poet of lighting and his designing of Kimble museum shows the proper designs with daylight (location: forth worth, Texas, America). This building should be placed among the classics of all the times. lighting of art Museums has been accompanied with lots of doubts from the past because the ultraviolet ray in daylight can have destructive effects especially on paintings. This museum was made of a set of round concrete arches 30 meters long and 7 meters wide with a transparent ceiling skylight along with the ridge of every arch. The daylight is returned and refined through natural light fixture under the ceiling skylight. Daylight fixture includes a frame being connected by a metal plate having small holes that allows penetration of some daylight to balance any intense contrast between underneath parts of fixtures and around them [6].

Research methodology:
Regarding the identity of the research, the used method is descriptive-analytic based on an interpretative approach.

Data collection:
Regarding the identity of the research, library-document method have been used for data collection.

Light and space:
Light especially the natural light is an unstable factor changing based on diurnal time and annual time and weather conditions. With light changing, the perception of environment and a building is changed [10].

Light is recognition tool of our environment and depending on how it is used, the perception of man from spatial context can be changed, making space pleasant, dreary or mysterious, perception of enlarging a space or making it smaller or concentrate on special aspects of the space, making some parts observable and above all makes the space more pleasant, more residential and more convenient. The architects should know that good light gives worth to the space and bad light lowers the space’s value. The best light in space is the one making a good feeling when entering the space but is not seen [9].
So there are two important factors for the light we feel including the light intensity or the amount of light shining on an object and the reflective power of the object. It should be noted that the amount of light we perceive does not only have a direct relationship with light intensity. There are two ways for changing the amount of light in lighting an architectural space, one is changing the light intensity and influencing reflectivity power and the other is selecting the appropriate materials proportionate with proper reflectivity power. therefore, light intensity and the surface material of the objects can influence the amount of lighting [14].

So there is a direct relationship between lighting and complexity of an architectural style. the more the system of style is complicated, the more the importance of lighting will be. In other words, the effect of lighting in showing an architectural idea is more [7].

The methods of accessibility of systems to daylight:

Glass and some other elements are components of daylight system helping the control of natural light in a room. Usable daylight presentation can be done in more depth through window’s wall with common designs. Increasing the usable daylight for weather condition with mostly cloud-covered sky is appropriate but for extremely sunny weather where direct control of sun is needed increases the usable daylight for windows which should be obstructed by external barriers. Daylight system divided in two classes: [5].

- Moving daylight systems: it divides to two mechanisms including manual and automatic control which can regulate the qualitative and quantitative optimization of natural light. Auto Daylight system includes a sensor of penetration intensity rating and a system of practice control based on the signal’s sensor
- Fixed daylight systems: designing a fixed light system appropriate for all conditions of daylight is hard since the intensity, color and distribution of brightness of daylight changes continuously with the change of height angle of sun but it reduces the electricity costs [5].

Lighting systems can be useful in following conditions:

- When around the building is surrounded by big barriers, a system to collect light from barrier free parts of the sky can be designed.
- When the space is very deep and the normal windows can’t provide a stable light.
- In sunny regions, this system can be used for limiting the penetration of direct shining and deviating it to deeper parts of the building.
- When there is a need to an exact design to guide the light, for example in museums or offices where computer screens are used, these systems can be used to reduce the daze and inconveniences related to direct shining of light.

Lighting building’s exterior spaces using natural light:

Light is a part of building material making a skeleton with mass, body and facet of the building. Every element complements the other. To show the height of a mass more extended with making thin and long ridges that makes vertical and long shadows to show the facet more extended. Also to display landmarks like entries, the wanted parts can be specified with shadow through making holes on the mass. So, light in architecture art is an element which is propounded beside other elements and concepts and plays its role as a significant element.

Lighting building’s interior spaces using natural light:

The most simple method to use too much daylight in interior space is embedding big windows with bright glass, ceiling skylight or Claire Stori with appropriate controllers [3].

Direct shining of light is exciting in architecture and changing penumbra which it makes on objects and interior space creates a pleasant feeling toward time and place. In using direct sunlight, cautions should be considered to prevent inappropriate vision or making excessive temperature in interior space [3].

It can be said that the need for light in interior space is different based on the kind of its use. Using extreme lightness and darkness in architectural space cause exhaustion of visual mechanism. So, the lighter the space, the more pleasant the environment will be but going beyond the light intensity, the light can be unpleasant [7].

Distribution of natural light in interior spaces:

Using design and simple implementable tools, the distribution method of light in interior spaces can be corrected and reach to proper light. For example, ceiling can act as a light reflector and breaker helping more uniform distribution of light in the space. The penetration of natural light in a space increases in proportion with windows location height. The useful depth in space where its lighting is provided naturally increases the penetration of light through increasing height of roof and placing the windows in greater height and terminal part of the room possess more daylight.
The effect of natural lighting on building’s form:

Regarding the limitation of the penetration of light to interior spaces, selecting a proper form and direction for building is effective in distribution of optimized light. In buildings having a square or circle plan, light and temperature penetrates hardly in intermediate space. In buildings with free or extended plan, light and temperature can be received in all parts. In climates where the plan should as far as possible be condensed with the least contact with exterior air, using central yard, patio or atrium is one of the solutions. Making such holes in building is significant regarding natural lighting and ventilation providing the arrival light and fresh air into the building. The amount of light penetrated in these holes depends on numerous factors such as brightness of roof, reflection ratio of walls and geometry of their space [13].

Sun shadow as a solution for configuring architecture space:

This issue is searched by experts. There are different configurations for sun shadow having their own advantages and disadvantages. When determining the identity of the needed shadows, the architect should be certain to consider some criteria that is a kind of desirable regulation or not? The followings are the reasons for shadow requirement:

- Reducing the effect of sun heat increase
- Reducing the dazzling shine of sun through windows
- Presenting a private territory which is normally not needed
- Reducing the sun heat increase: in some times or seasons this issue can have great importance but consistent reduction of temperature increase won’t be needed and for some special times of year, temperature increase may be needed. The biggest problem is lighting the south part.
- Reducing the sensitivity to sunlight: dazzling direct sunshine can be caused by some external sources like lighting of the opposite building which is toward north or by reflection of some objects inside the building like a business machine or a computer. Unlike heat, dazzling shine can be easily controlled from inside the building.
- Presenting a private territory: if lace curtain is needed in all cases, the break of interior picture can be seen from outside.

During the day where interior light is more than exterior light, it is less important and there is no weakness to insert penetrable materials in windows. Generally sun shadow solutions can be divided to three groups:

- Exterior shadow
- Interior shadow
- Alternative glass [8].

Advanced solutions of natural lighting in buildings:

However windows have usually been the main source of light providing inside the buildings, but naturally the ability of changing the light direction is transferred or can’t be reached to the end of the rooms. To reach this goal, the windows of the buildings should be equipped with ancillary lighting tools. Mixing ancillary tools with windows, a system of lighting with daylight is created. Lighting systems can be divided to three main groups.

1. Reflexive components
   In this system, reflective plates installed inside or outside the building is used for natural lighting.

2. Components mixed with windows
   These systems are usually created by stacking or repetition of the number of small optic tools in a two-dimensional plate and are installed in a parallel frame with window frame in some millimeters distance behind it or between the layers of the window. Mixing these components with windows causes their use easier.

3. Light guiding components
   These systems are used to get the light to deep parts of a building and parts having limited or impossible access to building shell. These systems are usually formed by an external collecting tool like a heliostat and a duct. Light collector tool, guides sunlight into the duct.

Daylighting is a moving target, one that shifts from moment to moment, morning to evening, and season to season:

Daylighting provides powerful incentives to strive for more. Daylighting is the simple concept that seeks to control natural light in a space and reduce or eliminate electric lighting. Economic benefits come principally from energy savings (kW and kWh) due to reduced electrical lighting and cooling loads. Because sunlight has less heat per unit of light than electrical lighting, cooling loads will be smaller if windows are appropriately sized and oriented, and electric lights are automatically switched off. Smaller cooling loads mean smaller and less costly HVAC systems. Of course, energy usage is also affected by other variables, including geographic location, climatic zones, glazing, and wall properties. In terms of the environment, energy efficiency is the most Cost-effective means of reducing greenhouse gas emissions though reduced generation of electricity. Daylighting substitutes a clean, plentiful resource (the sun) for an expensive, limited resource (electricity).

1. Linking to Other Sustainable Strategies
There are four ways to achieve LEED for New Construction daylighting credits:

- **Simulation:** Demonstrate daylighting performance through computer modeling of light levels. This is typically the most expensive approach to document credit compliance, but it is also the lowest risk, especially for projects with complex floorplans.
- **Prescriptive:** Meet credit requirements through a simple calculation involving geometry, glass size, and transmittance. This is a very cost-effective approach to achieving the credits, but it can be difficult to achieve due to its reductive nature. There is also a risk that the prescriptive approach will provide too much daylight if not used with caution.
- **Measurement:** Record indoor light measurements in the space after construction is complete. This is the most accurate calculation of a space’s daylighting performance, but it has inherent risk as a post-occupancy strategy for verification.
- **Use a combination of the strategies above.** In contrast to LEED for New Construction’s two points for Daylighting and Views, it’s important to consider all of the elements that affect daylight penetration. Consider them in order of importance: first, a building’s context (climate, site, orientation, and neighboring obstructions); second, the active measures (lighting, lighting controls, and HVAC sizing); and finally, the passive measures (window-to-wall ratios, glass types, materials, and surfaces). projects can execute all of the daylighting details to perfection yet fail to consider the orientation of the building. As a result, blinds remain closed to prevent glare and heat gain, the lights remain on, and the views inaccessible to the occupants. On other projects, orientation and active controls can be perfect, but the interiors contain dark, light-absorbing materials that result in low light levels, negating the benefits of the lighting controls.

![Fig. 1: It combines both passive and active daylighting features: exterior and interior light shelves, high-performance glass for both vision and clerestory lites, and automatic shades and lighting controls.](image)

2. **Assessing Existing Spaces for Daylighting Potential:**

   It is more difficult to adapt an existing space to daylight access than to design one from scratch, but there are still a number of opportunities for upgrading to a more daylit space. One unique advantage of retrofitting an existing space is having a solid baseline from which to work.

   **Begin by assessing the nearby obstructions (or opportunities):** other buildings, trees, views, or parking lots. Western exposures are typically bad due to glare and heat gains from the low afternoon sun. Even, indirect northern light is usually the best quality, but remember to balance the potential for heat loss in colder climates.

   **Assess the interior space layout to determine the daylit zone.** For example, in a typical office floorplan, executive suites are located along the window wall and have access to the best views and natural light. Placing the open office at the perimeter of the building and moving individual offices to the core increase the daylit zone by removing full-height obstructions. Lastly, address lighting controls. Typically, controls are the most challenging element of a daylighting plan. They are costly and difficult to calibrate and maintain; however, they provide the foundation for energy savings. Automated shading should also be considered, especially for buildings where orientation is not optimal. Not surprisingly, most historic buildings built before the turn of the century have highly tuned daylighting designs. They have smaller floor plates so that daylight can penetrate deeper into the core of the building. The floor-to-ceiling heights are typically higher (12 feet or more) than newer designs, as are the corresponding window head heights, which also facilitate light penetration.

**Conclusion:**

Mental need of human to natural light and direct relationship with nature has changed the use of daylight to one of the main needs of designing. Designing the windows as light entries to buildings can have determining roles in the ways of light entering and the rate of the light of interior space. Mixing ancillary components with
window, we can make a complete lighting system or daylight. Simultaneous with primary design, the architect designers consider and study the issues of lighting of building or interior environment from the very beginning. Environmental lighting, regarding its wonderful capabilities, has proved its place in new art and technologies of construction. As it was mentioned, light not only have important effect on rating architectural elements but also it is one of important and determining elements of space.

The followings should be considered in day lighting:
- Using raised and recessed textures
- Using the reflections that sun makes on bright and mirror-like materials
- Installation of skylights in proper places
- Using colors and geometries that light and shadow make pleasant sights in them

Regarding that sequence and change are among the most important features of natural light during the day causing the movement and state change during different hours, this light change can enliven the space. Lighting through daylight can give movement and dynamism to space. Light can be used through different titles to induce a concept or goal, for example, by making an aperture or guiding the light to a subject we can focus on it or by using the soft and mild movement of light, we can give a spiritual sense to space to feel veneration when entering such space and find ourselves in front of an endless grandeur.

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This article is extracted from the thesis.

REFERENCES