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Comparative Study on New lighting Technologies and Buildings Plans for High-performance Architecture

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Abstract

Daylighting has always been the central focus of designers. Today, due to economic, health, and environmental concerns, daylighting has taken on paramount importance. However, due to location and architectural restrictions, the use of natural light in all interior spaces is a challenge facing architects. Today, although the development of modern lighting systems has contributed to a solution to this problem, the provision of necessary conditions for more efficient daylighting necessitates a thorough understanding of all types of lighting systems and plans. This study aimed to further link technology and architecture to take the required steps to solve the shortage of interior daylight by comparing and selecting appropriate daylighting systems and plans. To this end, we first studied various modern lighting systems and analyzed their characteristics to prioritize and select their most efficient elements and factors. In this regard, the FGD method was used to identify criteria and sub-criteria. Then ANP was used to analyze and compared to identify the most optimal ones. In the next step, we studied different types of office plans to prioritize them based on the aforementioned elements. It is worth noting that to validate the results, we surveyed experts in the field. In the last step, we studied compared the compatibility of different plans and systems to achieve the most compatible ones.

Keywords: Daylight, Natural lighting, Innovation Daylight systems, Office plan, Architecture

1. INTRODUCTION

Development of indigenous fossil fuel resources, conservation programs, improvements in energy conversion, and efforts to utilize renewable sources have been introduced in response to the energy crisis[1], [2]. Renewable energy will be the undeniable future of mankind, where using fuel needs is concerned [3], [4]. Solar energy has always been considered as the main source of renewable energy[5], [6]. The biological importance of sunlight to humans has led to the sober usage of natural daylight to illuminate the interior of the building[7]–[9]. Daylighting is considered one of the fundamental design features of energy-efficient buildings[10]. In line with the industrial revolution at the end of the 18th century, the advent of artificial light provided a uniform illumination during the daytime and marginalized natural daylight. As a result, the buildings gradually reconciled themselves to new conditions and artificial lights diverted the attention away from the impact of building orientation [7]. This negligence resulted in a health crisis, shortage of energy resources, and environmental pollution, highlighting the importance of renewable energies[10]–[12].

One of the influential factors to energetic and environmental is Buildings' energy consumption[13]. The architectural design has great potential to solve this problem[7]. In using daylight in a building for the visual comfort and well-being of its residents, several factors should be considered, including the composition of the light spectrum and view to the outside. Negligence in using daylight not only reduces the quality of interior spaces but also is associated with economic, health, and environmental issues as real challenges facing architects [8], [14]. The substitution of daylight for artificial lighting can also cut the utility bill[15], [16].

In recent years, special attention has been given to daylight to reduce dependence on artificial light, delivering energy consumption efficiency[6], [16], [17]. Regarding that, 90% of all daily activities are now in closed spaces [18], [19]. The quality and quantity of

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lighting are very important factors. According to studies, the use of natural light in all interior spaces of an office building increased the productivity of employees of about 15% [20], [21].

Economic analyses of energy consumption have shown that lighting accounts for approximately 30 % of electric energy consumption[22]. Although Tehran is a city with an average of 300 days of sunlight per year, a high percentage of buildings suffer from daylight deprivation. The country has total average electricity consumption of 2000 kW per year, which is considerably higher than in other countries [23].

Today, there are several reasons for poor daylighting in urban buildings including high-density urban sites, uneven building layouts, poorly designed spaces, inefficient windows and openings, and spaces designed with low daylighting quality and quantity[22]. The changing demands for new building forms by new users have resulted in the construction of high-rise, deep-plan, and compact buildings[16]. Consequently, the high surface area to volume (S/V) ratio, which allows for daylight to reach most building spaces, is no longer an important factor [24]. Generally, the percentage of electricity used by buildings for lighting is rising [25].

Therefore, alternative energy sources, such as renewable energy resources, should be considered to generate electricity for lighting[26]. Artificial lighting energy use can be reduced by expanding indoor daylight availability, thereby maintaining the human circadian rhythms[7]. The development and utilization of solar energy, as a clean energy resource, have attracted much attention around the world. The mechanisms for admitting daylight into space are becoming more and more popular [27]. Daylighting systems allow for redirecting daylight to the rooms away from solar radiation and provide a more reliable source of natural light to indoor areas. Any effort to distribute daylight to deep spaces is beneficial. The minimum level of 300 lux is recommended for building cores and rooms without windows to feel the actual daylight presence [28].

2. RESEARCH METHOD

The article focuses on a range of daylighting systems to adopting a method to evaluate the compatibility of daylighting technologies with generic office plans, which can redirect and admit daylight into spaces as alternatives to daylight penetration through façade systems, where floor plans are deep, or parts of floor areas are disconnected from an external facade. For this purpose, some articles, which related to the analysis of different types of systems separately, have been reviewed. Also, it suggested a decision-making analysis method. To this end, we tried to prioritize daylighting systems by examining their most important properties. In this regard, the FGD (focus group discussion) was used to identify and obtain important criteria and sub-criteria to rate daylighting systems. Then, we evaluated different types of office-building plans based on important design factors with this method. In the end, with the use of the ANP method and experts' opinions, the strengths of each system and plan were analyzed, assessed, and compared to identify the most optimal ones.

It was envisioned that using this method/data in the early design phase could contribute to improving daylighting performance outcomes for office buildings, which could, in turn, reduce energy consumption and operating costs.

2.1. OVERVIEW OF OUR APPROACH

Therefore, this study was conducted to address the importance of energy crisis for lighting, as the primary concern of the present study, and to fill the research gap in Iran. This study was generally comprised of three steps (Fig 1):

- First, finding appropriate solutions to deal with the energy crisis and developing new daylighting systems.

To this end, writers studied a different kind of daylighting systems and then obtained criteria and sub-criteria, which are important factors to rate these systems, based on results from the FGD method and surveying the experts' opinions.

- Second, studying existing office building plans and analyzing their characteristics.

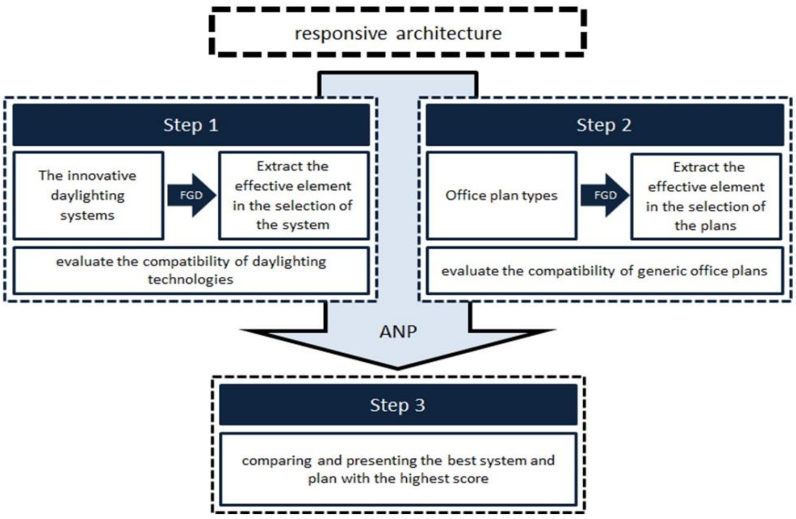

Fig 1 Liner Diagram of the present research structure and its three steps

To this end, writers investigated and evaluated existing office building plans and their specific characteristics.

- Third, the ANP method was used to prioritize criteria and sub-criteria for compatibility of the tools with the buildings. Then the strengths of each system and plan are analyzed and compared to identify the most optimal ones.

To this end, writers investigated the results from previous steps and compared all scorers with each other.

2.2. STEP 1
Innovative Daylight Systems (IDS)

Considering the potentials of IDS, we first needed to examine the challenges in selecting the appropriate daylighting elements. The literature review resulted in four categories [23].

The first category concentrated on innovative assessment techniques [29]. The second category focused on efficiency improvement. The third category was based on adopting an appropriate scheme [30]. The fourth category included controlled studies into the adaptation of daylighting systems to specific physical characteristics of a building [31]. The results from the literature review showed that adaptability is one of the most essential characteristics of the system. Therefore, a quantitative estimation of the system performance does not necessarily draw a firm conclusion [32].

This step showed that other parameters are also involved in the interaction of IDS [33]. Based on the significance of integrated design for architects, an in-depth analysis of daylighting technology and its elements can show the factors affecting the selection of an appropriate building system [34].

A comprehensive classification is required due to great variations in the DGS. They can be classified based on the work function of their components. Each system consists

Table 1 Types of innovative daylight systems, their three components and their performance

		System type	advantages	disadvantages
Light collection - collector	Concentrating collectors	• Anidolic concentrators	• Increase the optical efficiency by up to 5 times in cloudy skies • Thermal control • Glare control • high reflection coefficient • Suitable for high density • Ability to combine with canopies • Low light absorption	• Functional interference with technical systems • Reduce the internal height • Suitable for indirect light • Suitable for cloudy climates
		• Light concentration system	• Focus light • Reduce light carrier space	• High cost • Need expert force to build and install
		• Luminescent solar concentrators	• independence on the angle, direction, and height of the sun • performance of collector and distributor • Reduce the dimensions of the light tube	• Fluorescent carcinogenicity • Proper performance up to a depth of 10 meters • Low efficiency Inadequate Color Rendering *Index*
		• Laser-cut panel	• Inactive system • Input light control • Heat control • No need for specialists	• Functional constraints • independence on the angle, direction, and height of the sun
	Light redirecting collector	• Light redirection system	• high efficiency • Proper penetration depth	• High construction and maintenance costs • large scale • Occupy a lot of space for the transmission of light • Active system
		Heliobus	• high efficiency • Proper penetration depth	• High construction and maintenance costs • large scale • Occupy a lot of space for the transmission of light • Active system
Light transport systems		• Lens system	• Easy installation • Not occupy a lot of space	• Need to clean the lens • Need to adjust the lens • Need parallel lights
		• Mirrored light pipes	• Cheap and affordable • Integration of natural and artificial light • Integration with the ventilation system • Efficient in cloudy weather • Easy maintenance • Simple structure	• limitation of Dimensions and diameters • Depth limitation • Lack of flexibility in installation • Low efficiency • The maximum transfer depth is 30m
	Hollow prismatic pipes	• Natural light	• performance of transport and distributor • Horizontal and vertical performance • High efficiency • Appropriate visual quality	• Low flexibility • Possibility of light leakage
		• artificial	• Ability to integrate with artificial light • Ability to work at night	
		• Solid core systems(fiber optics)	• flexible • High efficiency • Easy installation • Minimal changes in the building • High volume light transmission	• Need a complex collector • Possibility of light leakage • Inefficiency in cloudy weather • High repair cost • The maximum depth of light transmission is 30m
Light distribution		• Light extraction	• Management of light output Distribution uniformity	
	Light emission	• Combined transport & emission	• Continuous light output along the pipe • Synchronous process of transmission and distribution	• Not controlling each section separately
		• Discrete emitters	• Ability to distribute light separately	
		• Other emitters	• Uniform distribution of light in space • Inactive system	

of three essential components, namely solar collector, transporter, and emitter [6][35][36]. Each component has different types, the combination of which produces different systems [8], [9], [12], [16], [23], [35], [37].

For this purpose, in the following, a table of different types of innovative daylighting systems has been analyzed, in which the advantages and disadvantages of each system have been described separately(Table 1).

Regarding what was mentioned earlier and constituent parts of the IDMs (collectors, transporters, and emitters), there are other effective factors and components, except effective factors of quantitative estimation of the tools, which play an effective role in higher compatibility of the tools with the buildings. Method FGD has been used to obtain effective criteria for selecting and adapting systems.

Focus Group Discussion (FGD)

The Focus Group Discussion is used as a systematic way to understanding problems and finding intervention strategies by asking specific questions with formal and informal orientations[38][39]

Focus group discussion is one of the useful and acceptable methods in the field of problematic[40]. Most researchers use this method to get ideas, opinions, and issues related to the purpose of their researches[41]. FGD helps researchers to evaluate their needs before design and also after implementation in the long run. In this method, interviews and meetings with target groups are conducted according to research expectations. To obtain data in this method, a purposely group of individuals is selected. there are no critical evaluations of the application of the technique [38].

One application of FGD is system development. In this technique, different methods can be evaluated. Also, the needs of designers and users can be understood. by this method, the researcher can be obtained the way of thinking, priorities, specific points, and other unique characteristics of groups[42]. Finally, this method can be considered as organized discussions with selected and specific groups to know their views and experiences about a specific topic.

Often FGD is used as synonymous with interviews ("group interviews" and "one-to-one")[39]. But, the role of the researcher and also the communication with the participants is a fundamental diversity of opinions between the two methods [43]. Interviews involve a qualitative, in-depth, and one-to-one discussion. In this method, the researcher is similar to "investigator it means that the researcher conversation with a certain individual and asks some questions so he controls the discussion's dynamics at a time. But, the researcher is in the role of a "moderator" or "facilitator" in a concentrated group discussion. In this method, a group discussion between participants is facilitated or moderated by the researcher [44][45][46].

By examining features of daylighting systems and using the FGD method, the following conceptual model was suggested as efficient factors of system compatibility with building, providing a new framework for understanding the interactions between these tools and the building. Further, all components were analyzed and prioritized to select the most compatible light transmission tool. In this step, a conceptual model was created as a new framework to determine the integration components of the IDS: lighting performance, utilization, building compatibility, and social area (Fig 2).

Lighting performance

The lighting performance of IDS refers to the proportion of light collected from the source and transmitted into the building [47]. It is an essential aspect of the quality and quantity of light with their unique criteria. The quantity of light is one of the most common assessment criteria.

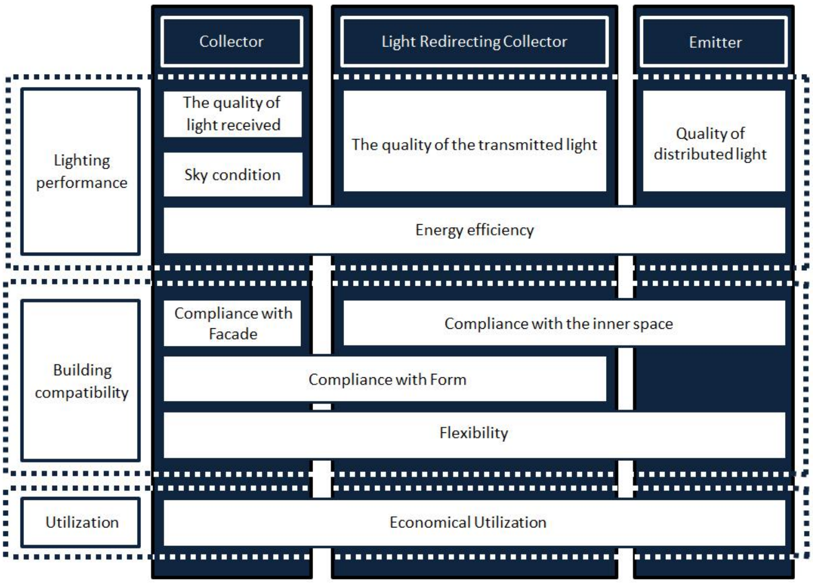

Fig 2 Classification of Effective Components in the selection of the appropriate

In IDS, the quantity of light quantity is measured with the following three criteria: the amount of collected light, the amount of directed light, and the amount of emitted light. Based on the component technology, these systems differ in the level of efficiency [48].

There are few clear definitions for the indices of light as a physical phenomenon including architectural space, space perception, and visual, physical, and mental effects. Among the quality components of light are maintaining daylight color and ultraviolet ray resistance.

Building compatibility

In this area, the main focus is on the relationship between modern systems of light and building for higher system efficiency. It includes such indices as compliance with form, façade, and internal space, and flexibility. Each of these indices has a different significance and coefficient.

Compliance with Form

This criterion shows the physical relationship and compliance of systems with the building, which depend on a system's mechanism. Due to the physical interference of systems with the collection, transportation, and emission processes, it can be assessed based on the required space and dimensions. According to aforementioned criteria, it is needed to determine the required degree of change in a building to make it compatible with a given system and to examine whether the building has required physical potential for the installment of the system[49]–[56].

Another aspect of interaction with the building is the compatibility of a system's form with a building, which the other hand, some tools will not be capable of integration with the interior space and require redesign considerations inside space [24], [49]

Compliance with the facade

Facade compatibility refers to the visual effect of the system on the facade. The effect of optical collectors on the cityscape changes the skyline and the roof view, as significant factors in the urban scale[32], [49].

Areas of Utilization

This study proposed a new technique based on the system's design. The original cost involves all production and shipping expenses.

The criteria in energy

This criterion in energy systems is among the most important factors for efficiency assessment. Regarding the use of different technologies and/or the replacement of costly attachments, it tries to reduce its role in selecting an appropriate system[47], [57]–[59].

The cost of setting up

This criterion includes all of the fees, government energy incentives, and costs of the system operating. The

Table 2 Properties and performance indicator of Light Redirecting Collector with the significance of them

	Properties	Total importance coefficient	Assessment indicator	Importance of indicators
Collector	The quality of light received	7	Maintaining daylight color	10
			UV resistance	9
			uniform light	8
			Excessive focus and fire creation	7
			Understanding light in all directions and angles	6
			The density of light	5
			IR resistance	4
	Economic exploitation	6	The proper initial cost	8
			Ease of installation - not requiring expert force	7
			Ease of maintenance	6
			not requiring special cases	5
	Energy efficiency	5	The received light is equal to the light	6
			Lack of dependence on the dimensions and properties of the system	5
			Not attracted much of the incoming light	4
	Adaptability to the facade	4	Facade compatibility	6
			Facade shape compatibility	5
			Opening Arrangement	4
			Lack of sight and view	3
			Compliance the proportions of the building facades	2
	Building shape Compatibility	3	Lack of high space occupation	5
			the lack of need to change the physical	4
			Uniform distribution of light	3
			Compliance with the form of a building	2
			Compliance the proportions of the building components	1
	Flexibility	2	High - level technical harmony with the building	3
			Possible to change the size and size according to the constraints of the plan	2
			Possible to connect with different types of light redirecting collector	1
	Sky condition	1	The orientation of the sun and the maximum light.	3
			The right efficiency in the favorable weather conditions	2
			The possibility of using a cloudy climate	1
			No use in overcast weather	0.5

can be applied to a range of additional elements. The above aspect explained the conformity with the internal space and façade of the building.

Compliance with the internal space of the building

It refers to a set of visual effects of the system on the interior space of the building. Optical interference is created within the interior space according to visual quality. It affects the visual quality of the internal space and thus is a challenge facing the architects and interior designers. Some of the light transmission and distribution tools can be used as interior elements and provide favorable feedback to be integrative and adaptable to the internal space without causing the visual obstruction. On

cost of setting up has a lower priority than the initial cost [58]. The cost of maintenance of the system includes the cleaning and replacement of parts of the system, which varies depending on the static nature of the system [47], [60].

According to the above description and the role of active components in selecting an appropriate system for all three parts of the system (collector, light transporter, and distributor), first, writers should determine the effectiveness of active components then prioritize each system based on their critical features.

therefore, writers used the method to measure the important coefficients of each indicator and prioritized

Table 3 Properties and performance indicator of Light Redirecting light transporter with the significance

	Properties	Total importance coefficient	Assessment indicator	Importance of indicators
Light Transporter	The quality of the transmitted light	6	Flat light transfer	9
			Maintaining daylight color	8
			The combination of natural light and artificial light	7
			UV resistance	6
			IR resistance	5
			the possibility of using the light on the path	4
			Glare Prevention	3
	Economic exploitation	5	The proper initial cost	6
			Ease of installation - not requiring expert force	5
			Ease of maintenance	4
			not requiring special cases	3
	Compliance with the inner space	4	Compliance with the form of the internal space of the building.	6
			Non - occupation of the interior	5
			Flexibility with internal space	4
			The aesthetic of Interior Space	3
			The absence of need for isolated internal space	2
	Flexibility	3	High - level technical harmony with the building	4
			Possible to change the size and size according to the constraints of the plan.	3
			Possible to connect with different types of light redirecting collector	2
	Energy efficiency	2	The received light is equal to the light	4
			Lack of dependence on the dimensions and properties of the system	3
			Not attracted much of the incoming light	2
			Lack of impact of transmission length with productivity	1
	Building shape Compatibility	1	Possible vertical and vertical transmission of light	4
			Compliance with the form of a building	3
			Lack of high space occupation	2
			Lack of limitations on the scale	1

Table 4 Properties and performance indicator of Light Redirecting distributor with the significance

	Properties	Total importance coefficient	Assessment indicator	Importance of indicators
distributor	Quality of the output light	5	Uniform distribution of light	7
			Having natural light properties	6
			Glare Prevention	5
			Create shadow and light	4
			The control of the light and the aristocracy	3
	Compliance with the inner space	4	The aesthetic of Interior Space	6
			Lack of visibility outside the urban landscape	5
			Opening Arrangement	4
			Compliance with the form of the internal space	3
			Flexibility in dimensions with respect to the interior space.	2
			Compliance with the proportions of the interior components	1
	Energy efficiency	3	The received light is equal to the light	4
			Lack of dependence on the dimensions and properties of the system	3
			Not attracted much of the incoming light	2
	Economic exploitation	2	The proper initial cost	3
			Ease of installation - not requiring expert force	2
			Ease of maintenance	1
			not requiring special cases	0.5
	Flexibility	1	Possible to connect with different types of light redirecting collector	2
			High - level technical harmony with the building	1
			Possible to connect with different types of light redirecting collector	0.5

components based on the opinions of the experts, which had been obtained by the FGD method (Table 2, 3, 4).

2.3. STEP 2

The office patterns

Several factors affect the applicability of a building. These factors are divided into two categories related to the outside environment or associated with the building itself [61].

Different approaches have been used to design typologies of office space. In general, there are two key approaches in designing office buildings: inside-out and outside-in [62].

Different programs have been proposed for designing office buildings with a primary focus on the surrounding landscape, geographical directions, the ability to receive light from each direction, and the ability to reduce the influence of daylight penetration in the building. According to the primary approach of this study, the components related to the index of organizational space typologies will be considered to be general and permanent. Therefore, the variables and main components of the research are related to the shape and spatial arrangement of the inner space.

The patterns of the floor of the building/shape of the plan

The shape of the building floor or the plan is one of the essential features of an office building in terms of daylighting efficiency. In a study conducted in the research center and building of Iran on office building typologies, the overall building plan was considered. These types of office buildings are classified based on the Krum's capabilities.

A study published in “The Design Code of Administrative Buildings”[61] showed that the majority of four general, linear, radial, radial, and central squares models present 10 major generating typologies and 15 optimal shape typologies in general. In another study, the prevailing typologies of the office building plan were analyzed in terms of total energy consumption [61], [64]–

[66]. In some cases, geometric criteria for describing typologies are presented. Moreover, some studies are, typologies focused on the geometrical features of the plan. In some other studies, the typologies concentrated on the common factors influencing the formation of office buildings. As a result, regarding different distinguishable capabilities of plan typologies, such typologies as L, T, U, H, and cross-like (Y) were analyzed[67].

By adjusting the typologies given in previous studies, seven typologies of L, T, Crusades, O, and Y, and three arms were selected as the typologies studied in this paper (Fig 3).

It is worth noting that the typologies of the office plans used for the analysis were extracted previous studies on the office plan typologies[64], [65].

As the first step, an appropriate criterion was selected for the assessment of the components and features. To this end, we extracted five major factors for the selection and design of a plan and their vital role in the following table. In the second step, these factors were discussed one-by-one.

Effective Components in Plan Selection

The depth of plan: the most crucial element about the collection of daylight the depth of the plan. The focal length of the building, or the non-front to the outer wall or atrium, is defined as the depth of the plan. Duffy has divided the depth of office typologies into shallow, medium-depth, deep, and very deep [68].In all typologies, according to the results of this thesis, the optimal depth of plan is maximally 12 meters. It is because of the higher angle and lower depth result in better view quality in the workspace. According to the results[67], the maximum daylight is used when the mean depth of the plan is less than the sidewalls.

The ability to use daylight: It is necessary to change architectural design considerations as a fundamental and essential source. A sound system provides the proper distribution of light from one or more directions, providing sufficient light surfaces for daily activities[69]. Researchers found many design factors of daylight in office spaces. Electric energy consumption level is an internal lighting factor, which depends on the form of the building. Studies have shown that the efficient use of daylighting is achieved when it provides light to 75% of the interior space [70].

*Interior flexibility***:** The internal composition of spaces is among other active plan elements. To design office spaces with higher performance, some studies classified them into cell offices, shared-room offices, and open-plan offices. Some previous studies have analyzed different types of workspace in terms of employees' satisfaction with natural lighting. In terms of daylight visibility, the flex offices performed better than open-plan offices [71].

*Proportions***:** The component proportion depends on the ratio of plan kurtosis, width, and overhang. In this study, the results from a doctoral thesis by Morteza Malek were applied. By change the aforementioned components, we achieved optimal performance of each plan based on the experts' optimal scoring schemes.

*The compression or circular ratio***:** this criterion is calculated based on the length of the circumference of the reference plan to that of the desired plan. For the relationship between the relative compression ratio and energy consumption, we found that the energy consumption factor increased with reducing energy consumption, and Energy dissipation increases and its management gets more difficult with reducing the compression ratio to lower than 0.55[67].

According to the aforementioned explanations about useful elements in the design and selection of the appropriate plan, we drew the following table to represents the important coefficients of each indicator and prioritize the components based on the experts' opinions (Table 5).

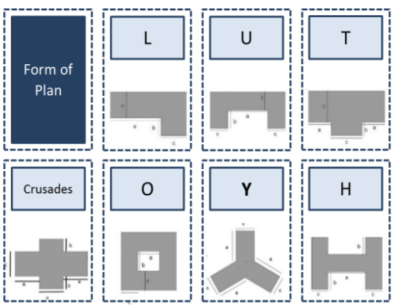

Fig 3 The patterns of the office patterns investigated in the

Table 5 The properties and indicators of the plan evaluation and their importance

	Properties	Total importance coefficient	Assessment indicator	Importance of indicators
Plan	Depth of plan	5	Keep the quality and quantity of light in the depth of the plan.	6
			desired, from the furthest away distance	5
			Optimal depth = 12m	4
	The ability to use the light of day	4	Make maximum use of daylight due to weather conditions and conditions	6
			Uniform distribution of light day	5
			Ability to save electricity (artificial lighting)>75%	4
			Understanding the brightness of daylight in space>75%	3
			Ability to receive light in all directions	2
			A dazzled state of light from the direct light of the day.	1
	interior Flexibility	3	effectiveness different types of internal space (Cell - Open – Combined)	4
			variable of the location of spaces with respect to view and light	3
			Possible to change the interior spaces	2
	proportions	2	a defined relation between kurtosis, width, and ledge	3
			balance in plan	2
			Modula	1
			The aesthetic of Plan	0.5
	Compression ratio	1	The optimum ratio of the shaft to the level of the whole space.	2
			The absence of non - rational proportions	1
			The compression ratio of the compression ratio is 0.55 = optimal compaction.	0.5

2.3. STEP3

This step aims to identify the most compatible tools and office plans. For this purpose, the results of previous steps were used to analyze.

The related tables (table2, 3, 4, 5), which were drawn based on the literature results and experts' opinions, were used to analyze and compared all scores to identify the most optimal one.

In Fig 4,5,6,7, the scores of different types of systems were displayed separately in 3 parts (collector, Carrier, and distribution). It should be noted that the final score is the sum of the total score, which was obtained considering the system's components and the effectiveness of these active components. The following results were extracted from these tables:

Collectors *(Fig 4):*

- Sundolier system has the highest scores in the quality of light.
- Parabolic linear system has the highest score and the most economical system, followed by the laser cut panels system.
- Linear Anidolic collector systems and Sundolier systems with a score of 50 have the highest energy efficiency score among.
- SunCentral systems have the highest score and the Linear Anidolic collector systems have the lowest scoring in terms of compliance with the facade and the body.
- Solar canopy system has the highest flexibility score.
- Solar canopy system has the highest scores and Helibus and Heliostat systems had the lowest scores regarding weather conditions

Carrier *(Transporter) (Fig 5):*

- Mirrored light pipes system has the highest score and the Prismatic light pipes system has the lowest scores in quality of the transmission light.
- Light duct system has the highest score in economic efficiency.
- Solid core systems and Fiber optics have the highest harmony with the interior space, and the Light ducts system has minimal harmony.
- Solid core system has the highest score flexibility.
- Fiber optics system luminescent system has the highest and lowest scores in the optical efficiency, respectively.
- Solid core systems and fiber optics systems have the highest score in physical compliance

Distributors *(Fig 6):*

- Paran systems have the highest score in the quality of the output light.
- Fiber optics system has the highest score in compliance with the inner space.
- Fiber optics systems and Parans have the highest score in energy efficiency.
- Prismatic light pipes system has the highest score in economic efficiency.
- Conductivity system has the highest score in flexibility.

In conclusion, the Sundolier system, followed by SunCentral and Paran systems had the highest total score in light collection efficiency. The HIMAWARI solar lighting system had the lowest score. The Fiber-optic systems, followed by the Solid core systems and the Luminescent system had the lowest total score in light transportation. The fiber optic system has the highest total score in the distribution of light.

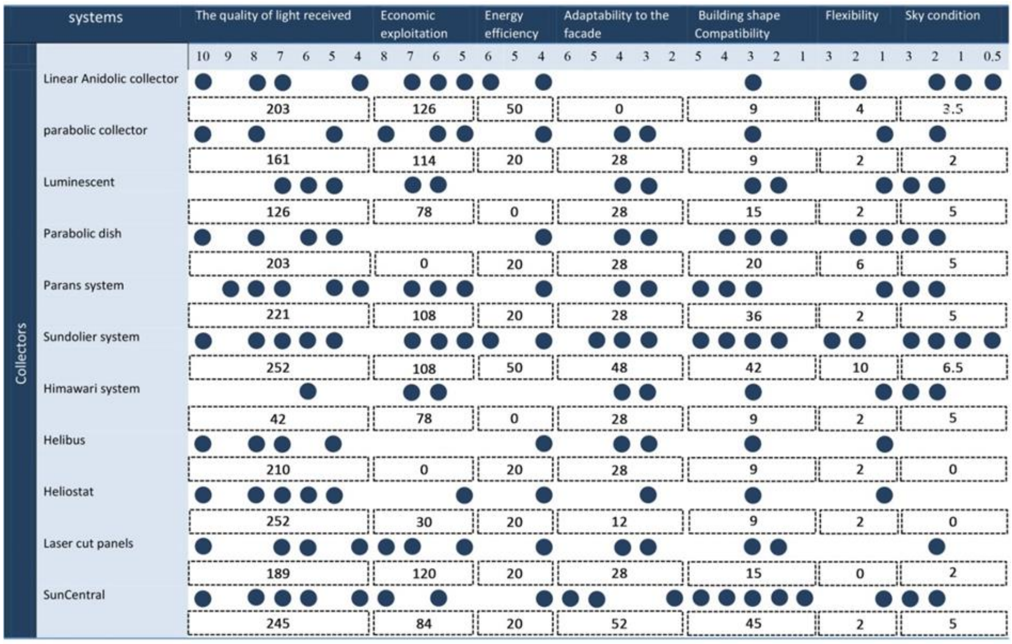

Fig 4 The prioritized list and scoring for each indicator in the collector variety

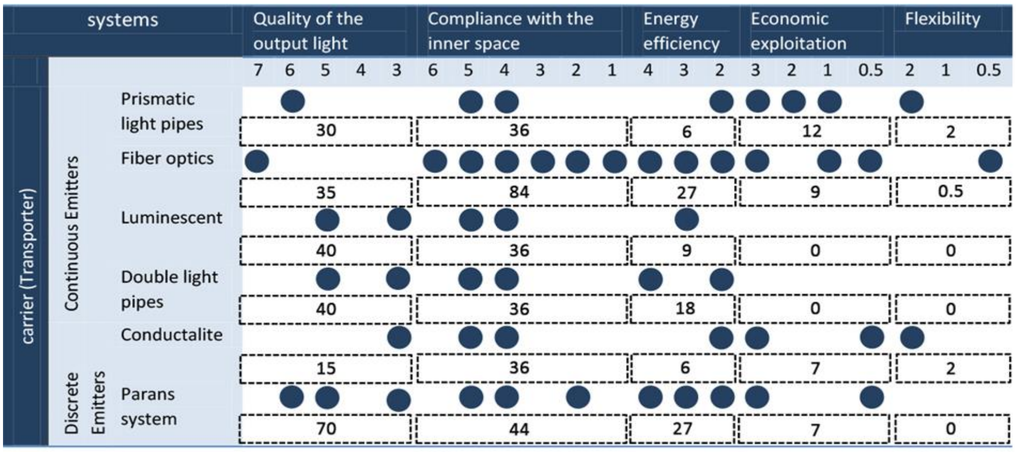

Fig 5 the priority table and the scoring for each indicator in the distributors

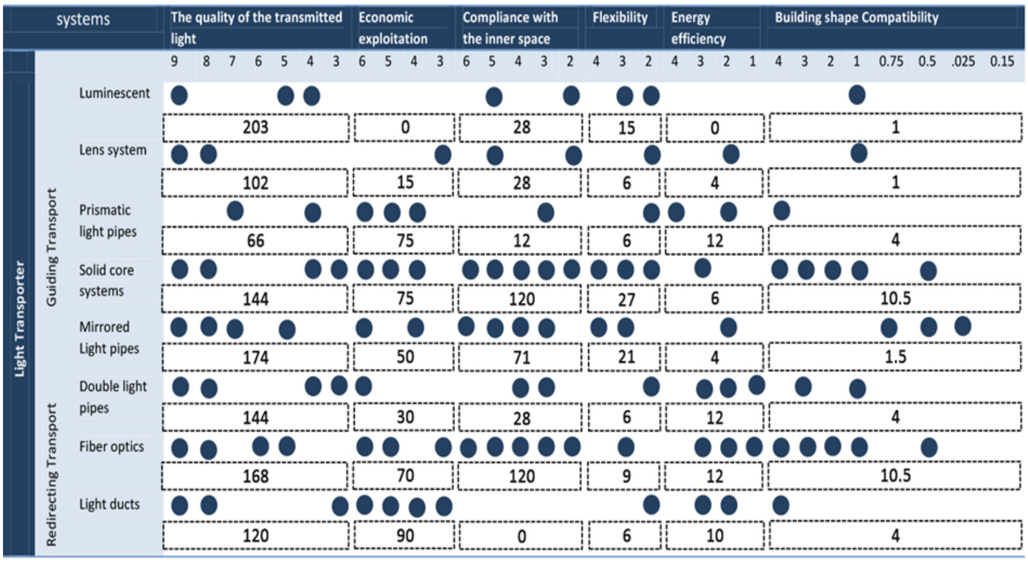

Fig 6 the prioritized list and scoring for each indicator in the Light Transporter variety

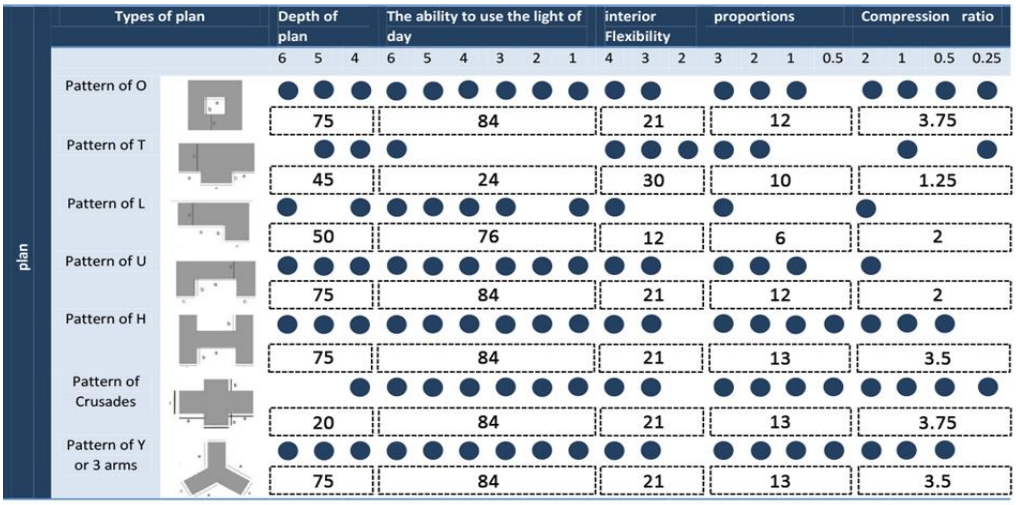

Fig 7. The prioritized list and scoring for each indicator in the plans variety

***Plan** (Fig 7):*

- The following results can be obtained from the corresponding table with respect to plans:
- Typologies O, U, and H have equal points in the depth of the plan and the usability of the daylight.
- Typology Crusade has the lowest score in the depth of the plan
- Typology L has the bottommost score in flexibility.
- Typologies Y, H, and Crusade have the highest scores in proportions, and the typology L has the lowest score in this criterion.
- Typologies Crusade and O have the highest scores and typologies L, U have the lowest scores in compression ratio
- It can be concluded that typologies H, Y have the highest total score and typology T has the lowest scoring.
- The following tables represent the comparison results between the scores of typology in each area. These tables also present the comparison results between the scores of each typology in each area (lighting performance, building compatibility, and utilization).

3. RESULT

This section presents the experimental design, datasets, assessment strategies, and results in detail. Due to the high diversity of daylighting systems, the components of each system (collector, carrier, and distributor) were assessed separately for better system analysis and assessment. Tables 2, 3, 4, and 5 present the assessment criteria for each part of the lighting systems and office-building plans. These tables were assessed by interviewing experts in this field using the FGD method.

As a result, the significance of the effectiveness of these active components was determined using the FGD method and ANP method. The different parts of each system were scored based on the information obtained about its characteristics.

Each attribute has a specific coefficient shown in the table derived from the FGD method. After completing the ratings for each section, the following diagrams were drawn for better system analysis (Fig 8, 9, 10). As was mentioned in step 3, the following results were obtained:

- Soundolier system had the highest score in the collector section
- Optical fibers had the highest score in the carrier and distributor sections

In addition to the daylighting systems, the office-building plans were examined and prioritized. Fig 3 presents these office-building plans. As the first research step, the properties of each model were studied to determine the most effective criteria for the compatibility of office-building plans with daylighting systems. Then, the priorities in each plan were examined to obtain the

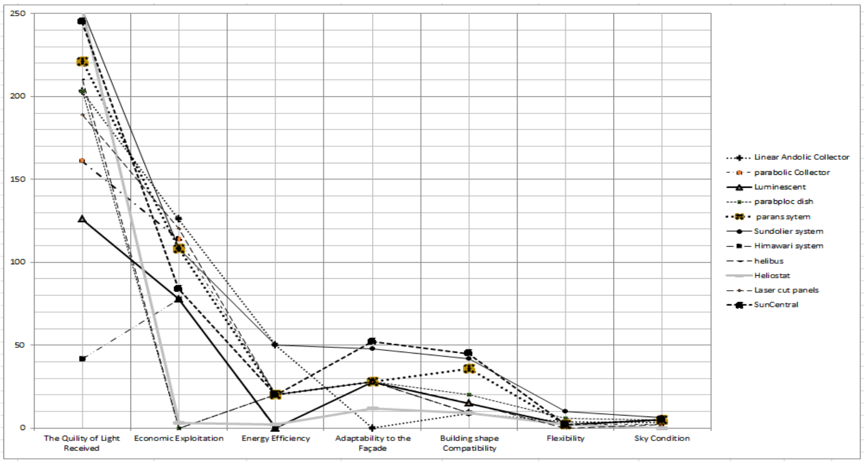

Fig 8. System Evaluation Results in the Collector Section

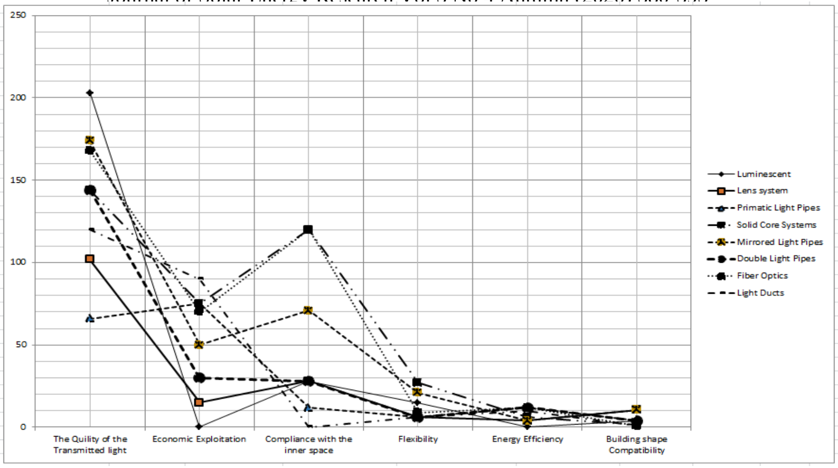

Fig 9. System Evaluation Results in the Distributors Section

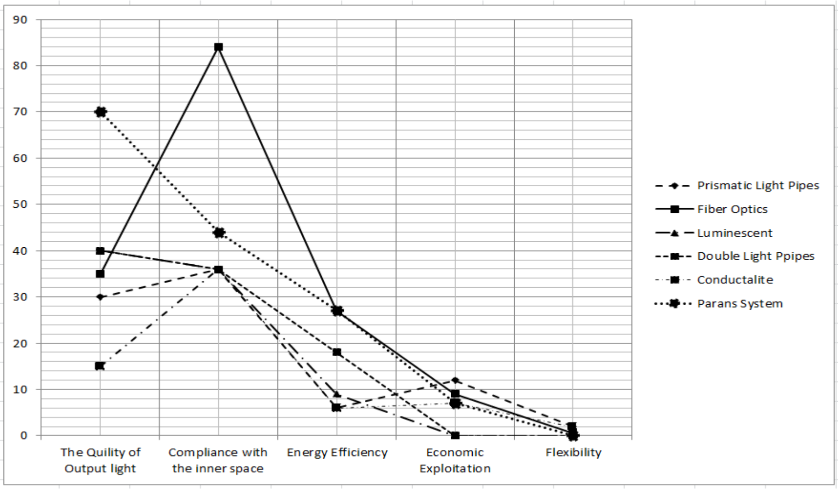

Fig 10. System Evaluation Results in the Carrier Section

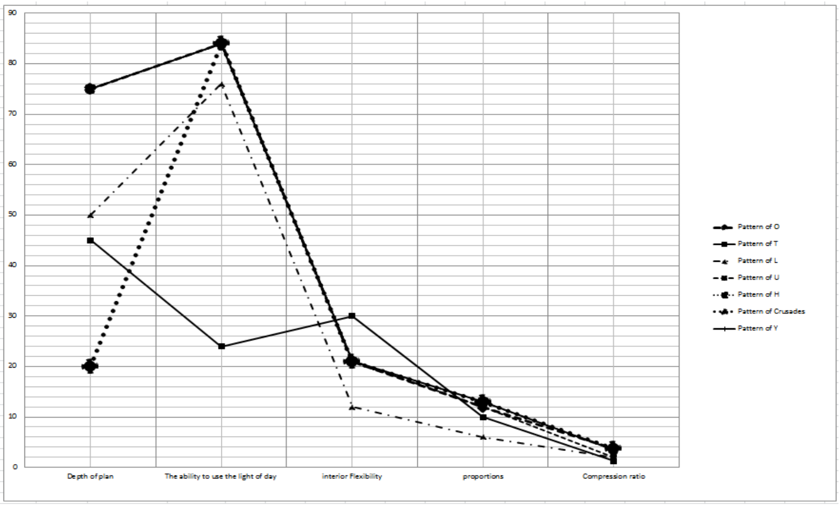

Fig 11. System Evaluation Results in the plan Section

coefficient of the significance of each criterion using the FGD method.

Then, the characteristics of plans were examined to prioritize them according to their significance factor, to make some better comparisons. Concerning the merits of each plan, Plans H and Y had the highest score in terms of compatibility with daylighting systems (Fig 11).

4. DISCUSSION

The maximum use of renewable energy, including sunlight, should not be neglected due to daylighting problems. The excessive lighting near the porch and insufficient light in the back room were among the challenges facing us in using daylighting. One solution is to use modern daylighting systems which can direct daylight into the end of the room. Using modern daylighting systems is a solution to this problem. The use of light transmission systems in the building reduces the energy consumption for artificial lighting, thereby reducing the heating and electrical loads as it transmits natural light to the building's depth and provides the necessary light to the room's endpoints. Using modern daylight systems allows the better use of daylight. We need to think more about how these systems fit into the construction to make better use of these technologies.

This research adopted an established qualitative Analytic Network Process method to comparatively evaluate existing proprietary daylighting systems in relation to spatial characteristics of generic office plan typologies.

It is envisioned that using this method/data in the early design phase could contribute to improving daylighting performance outcomes for office buildings, which could in turn reduce energy consumption and operating costs. This paper aimed to explore the factors influencing the selection of new light transmission technologies and their effects, as well as the variables influencing the design of office building plans to maximize the compatibility of these two fields and to increase the system efficiency. To promote these objectives, we first examined all light transmission systems and each feature of them, as was mentioned earlier. In selecting these systems, we investigated the effective factors and prioritized the components and determined the coefficient of significance using the FGD method.

The next step was to prioritize and assess the schemes based on each component's coefficient. Different kinds of office plans were studied in conjunction with these steps and the efficient components for developing an optimal plan were extracted. To prioritize the plans with these coefficients, the FGD method was used as a first step to determine the important factors of plans. The outcomes of each step were assessed in the final step and priority was given to lighting systems in each plan. This can be applied to multiple plans. Knowing each structure and plan's characteristics and advantages, architects can have a better option to use to make the best use of sunlight in the plan. With the help of these results, architects can know that how many scores each daylight system or plan has, and it is easy to compare them together.

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