Daylightinging effects on Living Standards in Iran

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Abstract

Daylighting has special role in human well-being due to the fact that it can reduce the rate of asthma and increase human performance. Living standards depend on everything that affects human well-being thus Daylighting can affect living standards.

In this paper, by using different questionnaires and simulations, relation of Daylighting and living standards and human well-being in Iran will be investigated. The main aim of this paper is to allow designer to provide appropriate amount of Daylighting for buildings which can improve human performance and occupant's satisfaction.

Key words: Daylighting, Living Standards, Human Well-being, Human Performance, Occupant's Satisfaction

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1. Introduction

The presence of natural light in commercial buildings with its fluctuations, the variations in its spectral composition, and the provision for external views-is of great importance for the comfort and well-being of occupants, potentially resulting in enhanced productivity.

If carefully designed, a daylight strategy can also bring tangible energy savings, as long as it minimises energy use for artificial lighting, manages to balance heat gains and losses and prevents visual discomfort (e.g. glare). The specification of daylighting solutions can however be a very complex task, whereas many factors and variables can diverge from each other making design choices extremely difficult. The main task for the designer generally consists in selecting the most appropriate daylighting systems and strategies that foster trade-offs between conflicting requirements of transmission and protection, and optimise quantitative physical measures such as illuminance, luminance, colour rendering and daylight factor to provide sufficient luminous levels and always guarantee visual comfort. Nevertheless, if energy-conscious buildings are designed to be also conducive to human health and well-being, these variables have inevitably to be related with qualitative and behavioural factors such as time/duration of exposure, directionality and spectral composition of radiation, psychological stimulation and user preference. In this context, photobiology is a new stream in daylighting research revealing the complex interactions between biological functions and external stimuli. Recent research has indeed proved that daylight, other than providing vision for tasks, has also an important nonvisual effect on biological processes, synchronizing the circadian clock, stimulating circulation, controlling the level of hormones, etc. In addition, further studies suggest that visual performance and comfort can be influenced by perceptive cues (such as an interesting view) other than merely by physical parameters. According to these findings, the routes by which daylight can affect the ocular performance and the well-being of occupants seem to involve not only visual but also circadian and perceptual factors which take over once the luminous image has been processed by the eye. Lighting recommendations have thus to consider awareness of many more factors than those currently suggested in standards, involving, other than visual and energy criteria, also non-visual attributes conducive for human health and physio-psychological well-being.

The use of daylight in buildings, with its variations, its spectral composition, and the provision for external views, is of great importance for the comfort and well-being of occupants. In a workplace, for example, daylight can positively influence the health of office personnel, improving efficiency, reducing unnecessary sick leave and resulting in greater benefits for enhanced productivity. If carefully designed, a daylight strategy can also bring tangible energy savings, as long as it minimises energy use for artificial lighting and prevents glare and other visual discomfort (such as contrast, adaptation problems and internal reflections). However, the overall energy efficiency of windows depends also on thermal effects (e.g. solar gains and heat losses through glass) and their balance against heat production of artificial lighting systems. The importance of daylight has been reflected for centuries in building legislation worldwide.

findings actually suggest that visual performance and comfort can be strongly influenced by perceptive cues (such as an interesting view) other than merely by physical parameters. According to these results, it follows that psycho-physiological characters could increase the tolerance to extreme daylighting conditions beyond what is stated in international standards, thus potentially reducing the need to install and operate shading devices that could deprive internal environments of beneficial amounts of daylight and also act to the detriment of users' physiological and perceptive well-being. In 'light' of these new findings, the aim of this study consists in defining a framework to implement existing daylighting practices basing not solely on photopic requirements for visual tasks but also containing awareness of the demands for psychological and photobiological stimulation, so as to positively influence the health and attitude of building occupants whilst also enhancing energy savings.

2.DAYLIGHTING AND WELL-BEING

Photobiology is a new stream in lighting research, revealing that there is an alternative pathway from the eye to the brain in addition to vision, which governs the complex interactions between biological functions and external stimuli .Recent medical and biological research has indeed convincingly proved that Daylighting, other than providing visual stimulation, has also an important non-visual effect on most of the body's biological processes .This study has recognised three routes by which luminous signals interact with human functions: visual, circadian and perceptual. When light passes through the eye, its signals are carried out not only to the main visual areas but also to the parts of the brain responsible for hormonal regulation. Visible radiation hence results in stimuli involving the whole of the physical (energetic exchanges), physiological (transformation of energetic fluxes into nervous stimuli) and psychological (brain interpretations of those stimuli) aspects that inform the body and the mind about the characteristics of the surrounding environment and contribute to the biological metabolism of the human organism. Other than simply providing visual information, adequate light received during the day synchronises the circadian clock, stimulating circulation, increasing the production of vitamin D, enhancing the uptake of calcium in the intestine, regulating protein metabolism, and controlling the level of hormones such as serotonin, dopamine (the ‘pleasure hormone’), cortisol (the ‘stress hormone’) and melatonin (the ‘sleep hormone’, which distributes internal temporal information to the body). (Fig. 1).

For almost two centuries of ophthalmic research, the whole of these processes have been attributed to the role of only two photoreceptors in the human eye: the cones, active mainly in bright light conditions, and the rods, which regulate visual information in dim environments. As light reaches these cells, a chemical reaction occurs which determines electrical impulses to be sent via a nerve pathway to the visual cortex located in the back of the brain where these impulses are interpreted as ‘vision’. However, new studies have shown that the biophysical processes that govern circadian regulation are very different from those that govern visual effects.

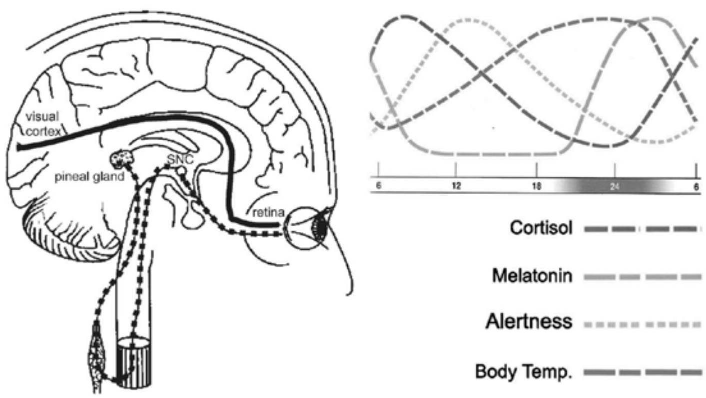

Figure 1: Visual and biological pathways from the eye to the brain

The Figure summarises some of the typical biological processes dictated by a regular 24h light-dark pattern, such as body temperature and the secretion of the main hormones for body regulation.

This result implies that the vertical spatial distribution of the luminous signal is a significant factor for biological stimulation. Finally, also the dynamics of lighting in terms of intensity, spectral composition and direction during the day seem to play an influential role. Obviously, sufficient retinal illumination to entrain biological processes could eventually be provided by artificial lighting, although this solution is less likely to obtain the same results of Daylighting in terms of combined visual comfort and bio-regulation, since natural light usually produces a high illuminance at the eye with a spectrum that matches its circadian sensitivity .

In summary, due to new discoveries, it becomes clear how natural light, other than just providing visibility for tasks, orientation in space and time and environmental stimulation, can also mediate and control a large number of biochemical processes in the human body, which are fundamental for health and well-being. Yet, current practice for lighting design in buildings is still based on outdated visual criteria related solely to horizontal task illuminance and luminance in the field of view (e.g.glare). Conversely, to foster the health of occupants and truly enhance the sustainability of built environments, these criteria have to be extended to non-visual demands.

2.1 Daylighting and Human Factors in buildings

A Daylighting strategy has to be designed to simultaneously reflect the needs of the users and the requirements of the building, finding a balance between conflicting needs of transmission and protection. Specifying Daylightinging solutions for energy efficiency, comfort and well-being can however be a very complex task - often highly dependant on climate, latitude, orientation and functions - where many factors and variables can diverge from each other making selection and optimisation extremely difficult. The task at hand for the designer is generally to identify the most appropriate properties of Daylightinging systems that provide adequate luminous levels and contribute to visual comfort. To do this, illuminance, luminance, colour rendering and Daylighting factor are commonly considered as the physical measures to be comprehensively managed. Nonetheless, in order to design energy-sustainable built environments which are also and foremost conducive to human health, these variables have necessarily to be related with qualitative and behavioural factors such as directionality of light, spectral composition of radiation, time/duration of exposure, metabolic rhythms, psychological stimulation and personal preference.

Daylighting can be a practical means of providing orientation, a focus, a hierarchy, encouraging movement along a path. The result of different questionnaires and simulations finally shows, Daylighting can conceal a symbolism, a meaning which could be related to the mind or the spiritual forces of life. And yet, Daylighting is often considered just at one end of the spectrum of its capabilities; either solely for aesthetic purposes or solely for providing visibility for tasks. In fact, natural light should always render both these aspects and, ultimately, acquire also a further, more ‘vital’, importance. Scientific research has actually widely proven the relationship existing between lighting conditions, well-being, and our very perception of the environment that surrounds us. To feel healthy, people need appropriate visual contact with the external world, the cycle of day and night, seasons, weather, etc. The life of men has always been regulated by a natural luminous rhythm: active outside during the day, and resting at night. Nowadays in Iran, regulations dictate that apartments should have at least eight hours of direct access to sunlight per day. Finally, current wrights state that every workstation in a new office building must be naturally lit and placed at no more than 7.5 meters from a window.

2.2 Non-Visual Effects of Light

The drawbacks of Seasonal changes in the night-day cycle, trans-world travel, night-shift work, etc., could determine, also in the short and medium term, diminished sleep quality, decrease of alertness, mood changes, irritability and, ultimately, lower performances on the work place. In summary, due to new discoveries, it becomes quite clear how Daylighting, other than just providing vision, orientation in space and time and environmental stimulation, can also mediate and control a large number of biochemical processes in the body, which are fundamental for human health. However, current practice for lighting design in buildings is still related to outdated visual criteria related solely to task illuminance (e.g. lux on the working plane, Daylighting factor, etc.)

and luminance. To truly enhance the sustainability of built environments - guaranteeing energy savings and fostering the health and well-being of their occupants - these criteria have to be extended to non-visual factors.

2.3 Light in the practice of design

Most people nowadays spend more than 90% of their time in confined spaces, and more often than not the lighting they are exposed to is solely regulated upon the notion that, independently from the time of day or season, the task should be accomplished efficiently and with a sufficient degree of visual comfort. Regardless of the options offered by the use of Daylighting, internal lighting strategies are often designed to provide luminous conditions which remain fairly constant in time, irrespective of the occupant's preferences, differences in metabolic responses and personal needs for performing their tasks.

2.3.1 lighting standards in Iran

Most standards specify lighting recommendations for a wide range of activities according to visual comfort criteria which are generally limited to horizontal illuminance on the task, uniformity, Daylighting factor, discomfort glare and colour rendering according to the activity to take place in a space. Traditional paper work to be performed on desks is generally still considered as the dominant visual design parameter, with photopic vision measures remaining the determining factors in lighting practice.

The question now is to ascertain how serious are the consequences of living and working almost exclusively in indoor spaces and often at 'unnatural' times, with much less light than outdoors and with a luminous environment fundamentally detached from biological human needs. As an example, the Iranian Norm for the lighting of workplaces is based upon the following visual criteria: the maintained Illuminance -the value below which the average illuminance on the work surface is not allowed to fall - the Unified Glare Rating Limit -. the rate of discomfort glare - and the Colour Rendering Index - which measures how colours appear under different light sources or when light travels through diverse media. It must be noted that the norm, as most other standards, features recommendations that are expressly formulated to "enable people to perform visual task efficiently and accurately", thus not necessarily addressing "the safety and health of workers at work", although the threshold values are established also "taking into account psycho-physiological aspects such as visual comfort and well-being". In order to foster the visual comfort in living and working environments, whilst simultaneously reducing energy consumption and providing for the metabolic stimulation of building occupants, it is worthwhile to analyse how a 'healthy' lighting design can compensate for deficiencies in recommendations.

2.3.2 'Healthy' lighting design

Light (natural and artificial) can be described in terms of a number of characteristics which interactively regulate visual and photobiological functions: quantity, spatial distribution, spectrum, timing, duration.

In first instance, although human processes are physiologically adapted to the availability of large amounts of outdoor illumination and to significant variations in Daylightinging levels, interior lighting practice seems to be governed by different priorities.

For example, external illuminance variations could range from over 100,000 lux on a bright summer day to a few thousands lux on a fully overcast winter day, and for periods that can fluctuate from only a couple of hours to almost 18 hours per day. Conversely, in accordance with the standards, regardless of the source (natural or artificial) internal lighting should be set to maintain fairly constant levels at day and night and with an intensity which could be 40 to 200 times less than outside.

Again, Daylighting is a luminous source whose continuous spectrum can provide for both visual comfort and photobiological functions and thus the importance of its presence in indoor living and working environments should never be underestimated. Daylighting is highly dynamic in its intensity, spatial distribution and direction, and it seems that people strongly prefer to be kept aware of these changes, maintaining a continuous contact with the world outside and its environmental variations. Furthermore, although the receptors for metabolic regulation appear to be spread with a rather random distribution, it seems that the lower part of the retina has greater sensitivity for the entrainment of circadian processes, as it is plausible if considering that the sky tend to selectively illuminate this area rather than the upper part of the retina .This evidence confirms that vertical illuminance entering the eye is a key factor in 'healthy' lighting.

Another aspect that lighting practices should consider in order to simultaneously enhancing the visual and physiological well-being of building occupants is concerned with the timing and the duration of exposure to light. From a visual point of view, obviously, light is needed just as long as a visual task is involved. Yet, metabolically, the timing and duration of exposure should follow the natural biological body rhythms and provide sufficient stimulation during the course of the day to avoid phase advances or delays. In summary, the routes by which light can influence the ocular performance and the well-being of building occupants involve not only visual (quantity, spectrum and distribution of light) but also circadian and psycho-perceptual factors which take over once the luminous image has been processed. 'Healthy' lighting recommendations have thus to consider awareness of many more factors than what is currently suggested in most standards and regulations, involving, other than well-known visual comfort criteria, additional non-visual issues which are conducive for biological and psychological well-being.

3. Sustainable Visual Environments

3.1 Daylighting through windows

Research on windowless office spaces demonstrates that the more rooms are small and give little opportunity to relief and stimulation, the more the occupants become dissatisfied with their jobs and their physical environment. In a small room, a window may actually represent the only source of mental stimulus. Conversely, Daylighting and a view out may not be strictly essential if spaces are well-lit (e.g. with skylights or internal atriums) and characterised by stimulating interactive activities, as it is often the case in open spaces. Given this general preference for Daylighting, it is however quite hard to demonstrate that just the presence of windows for natural lighting and a view out would improve users' well-being (and thus productivity), even because people will give up Daylighting as long as it is associated with visual or thermal discomfort (such as glare, contrast, reflections, solar heat gain or a perceived loss of privacy).

During the day, the presence of Daylighting should render the spaces lively, activating and motivating in accordance with the human circadian rhythm. Daylighting associated with a view should tell about the time of the day, the season, the weather. Views and variations in intensity and colour are indeed extremely stimulating for the brain and the visual apparatus, giving a contribution in terms of perceptual well-being and improving the sense of orientation and feeling of spaciousness.

A good view should normally include both the foreground and the skyline. Specifically, According the research there are three 'layers' that a view out should consist of: upper (distant, the sky, from natural to human-made skyline); middle (natural or human-made objects, such as fields, trees, hills or buildings); lower (the foreground, including plants and paving).The best views contain a lot of information, thus it would be preferable if a part of each layer could be seen. The lower layer is obviously particularly important since it is where people's gaze is often drawn, as it contains movement (e.g. vehicles, pedestrians, etc.) and also provides visual cues about the distance, and hence the scale, of objects in the middle layer. The shape of the opening is another important aspect. Considering that the three layers of view are stacked vertically, if the area of glazing is limited it would be generally better to have a tall, thin window rather than a short, wide opening in order to get as much information content from the view as possible. Yet, this design choice will have to be balanced with the risk of excessive thermal gains and overheating, since tall windows tend to be more exposed to high-angle summer sun, although they provide the additional advantage of bringing natural light deeper into the spaces.

On the contrary, horizontal windows guarantee a better view of the external landscape. If the window is also operable, occupants will have the added option of using it for ventilation. Other than providing psychological relief, views are also extremely beneficial to reduce muscle strain by allowing the eyes to shift from the near field surrounding the task area towards distant objects. Actually, various screen-based tasks require frequent eye movement (up to 30,000 times per day) between display, keyboard and paperwork and a limited change of focus, which in the longer term can determine fatigue, tiredness and, thus, decreased productivity. Muscular pain may add to these problems when users shift their seating position to get access to external information or avoid visual discomfort.

Nevertheless, the ingress of Daylighting through windows can also imply major drawbacks: direct sunlight, bright clouds and reflective surfaces can cause glare, contrast and serious visual impairment. Luminance ratios in the field of view should always be contained into certain limits: too large, and it will be difficult for the eyes to adapt; too small, and there will be difficulties in estimating depths and distances.

Since people are phototropic (attracted to light), areas of high luminance in the background of the visual task should be avoided. Actually, as the eye attempts to even out the contrast between different surfaces, the ocular muscles are subject to harder and more frequent movements; tired eyes and an increased level of stress are a direct consequence.

To enhance visual comfort, the task should thus normally be brighter than its immediate and general surroundings. Glare, in particular, is a serious source of visual strain that can prevent the viewer from executing his task (disability glare) or cause a significant decrease in visual performance (discomfort glare). Disability glare is generally due to a saturation effect or to a bright light source striking directly in the field of view of the observer (e.g. after-images). Conversely, discomfort glare can be associated with visual contrast and is likely to be due to the location and intensity of the light source relative to the average luminance in the eyes of the viewer. Luminance of the glare source, luminance of the background, solid angle subtended by the source to the observer's eye and the position index of the source relative to the line of sight of the viewer, are the main factors that influence the occurrence of glare, although the level of disturbance depends also on the nature of the task and on personal tolerance .

The results of this continuing research are expected to provide further evidence that, when examining visual comfort, a purely physical approach can be insufficient, whereas the usefulness in practice of existing standard measures and formulae would be greatly enhanced if the inclusion of non visual-related factors improved their predictive and assessing power.

3.2 Integrated Daylighting Design

3.2.1 Daylightinging devices and strategies

To control the amount and distribution of natural light entering a space and to guarantee a comfortable and 'healthy' luminous environment, in general a good Daylightinging strategy should be composed of more than a simple opening in the façade (window) or on the roof (skylight). Depending on climate, orientation, functions and requirements, customized solutions or devices may need to be implemented.

Good Daylightinging strategies start from exploring simple solutions (window size, placement, self-shading, etc.) and then integrating advanced elements if required. As a matter of fact, the performances of complex and dynamic systems often depend on maintenance and durability of components, and should be adopted only in extreme situations. The positioning of shading devices for luminous and solar protection depends primarily on orientation: generally, horizontal for equator-facing façades or vertical for eastern and western openings. If internal blinds are used for visual control – as it is often the case in offices - they should preferably be composed of light, diffusive material.

In terms of operational strategies, preferably each individual occupant should be able to manage his luminous environment to suit his own preference. However, it has to be considered that when blinds are closed to reduce luminous discomfort, if manual operation is the only choice human 'inertia' will often cause the blinds to be kept closed even after the source of disturbance has ceased (Escuyer and Fontoynont, 2002). Proper Daylighting design should hence try to minimise the occurrence of the conditions under which actions aimed at reducing or eliminating the ingress of natural light arise and to develop methods whereby the actions taken to decrease or eliminate Daylighting penetration are reversed at the end of the day Several Daylighting-directing and composite shading systems have been developed to enhance Daylighting protection and distribution in spaces. These usually exploit the upper part of the window (clerestory) to provide light penetration deeper into the room in combination with a reflective ceiling, while the lower part of the vertical opening is often expressly designed to optimise visual performances (glare reduction) and to provide a view and a visual contact with the out of doors. For example, light shelves can be used to throw more light on the ceiling and then deeper into the spaces, delivering Daylighting at greater depths without significantly augmenting luminous levels near the window, whilst reducing glare in the areas close to the perimeter. Simultaneously, other than just improving the distribution of natural light, a light shelf may double as a solar protecting device, blocking direct sun when required (Figure 2).

4.Healthy' Daylighting Criteria

Photobiological research leads to the hypothesis that healthy lighting is influenced by many more factors than what is suggested in most standard and regulations, involving, other than well-known visual comfort criteria, additional non-visual factors which can influence the ocular performance as much as the physiopsychological well-being of building occupants.

Daylighting associated with a view should tell about the time of the day, the season, the weather, and improve the sense of orientation and feeling of spaciousness. In addition, views out are also extremely beneficial to reduce muscle strain by allowing the eyes to shift from the near field surrounding the task area towards distant objects.

In any case, these results provide further evidence that, when examining visual comfort and well-being, a purely physical approach can be insufficient. Consideration of non-visual factors, on the other hand, can be particularly important for the design of windows in situations where, due to low-angle sun, discomfort glare is likely to occur and would suggest the design and use of shading devices. The use of obstructive blinds, in fact, by reducing the luminance in the field of view of the observer, would also decrease the amount of available illuminance, to the detriment of metabolic processes and with increased energy demands. In addition, by impairing visual contact with the outside, shading devices would also deprive the observer of the interest, information and variation given by a view that could have increased his tolerance to extreme lighting conditions and discomfort glare.

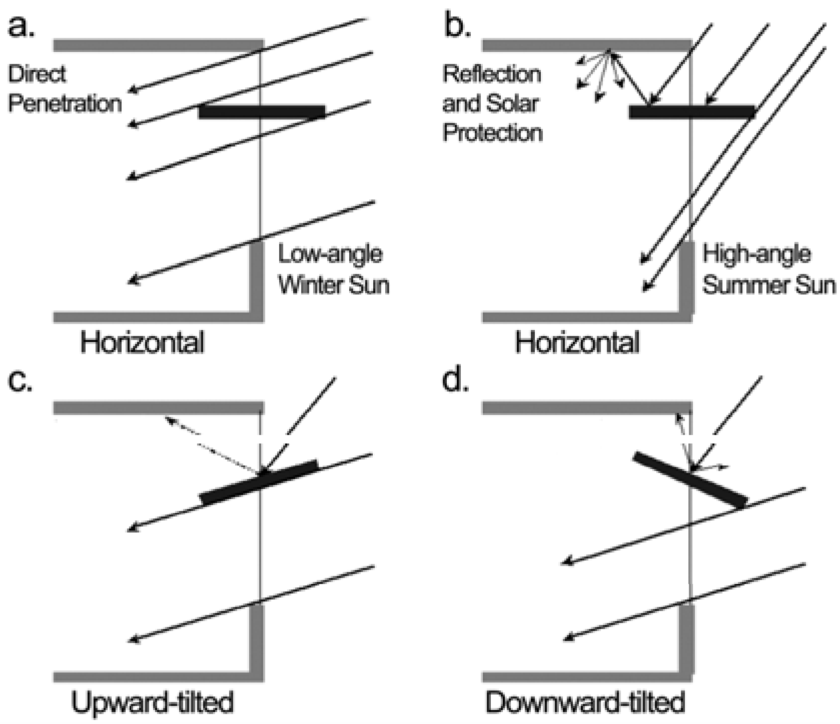

Figure2. Exempla of Light Shelves

The Figure illustrates the functioning principles of a horizontal (a. and b.), upward- (c.) or downward-tilted (d.) light shelf in terms of solar protection and distribution of incident light.

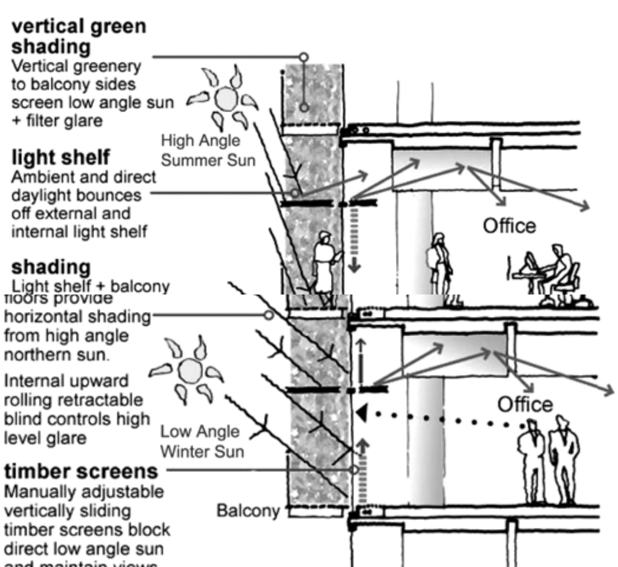

Figure3. An example of successful Daylighting design
The Figure exemplifies the Daylightinging strategy and the use of shading and light-distributing devices applied in the North Façade (solar-facing) of the CH_2 building in Melbourne, Australia.

5.Research Methodology

The research methodology presented based on analysis Daylighting solutions in the traditional Iranian lifesycle.

6. Conclusions

Natural light is a vital force for human beings. Successful Daylightinging in buildings requires trade-offs and optimization between competing design aspects (e.g. light distribution, glare, solar gains, views, etc.), whilst also including consideration of façade layout, space configuration, internal finishes and choice/operation of shading devices. However, to design energy-sustainable built environments which are conducive to human health, these variables have necessarily to be related also with biological and behavioural factors such as metabolic rhythms, psychological stimulation and occupants' preferences. The aim of the study consists in defining a framework to implement existing Daylightinging practices basing not solely on photopic requirements but also containing awareness of the demands for psychological and photobiological stimulation, so as to positively influence the health of occupants whilst enhancing energy savings.

In summary, Daylighting through windows can comprehensively meet the whole of the visual, non-visual and perceptual requirements of the people living and working in built environments, clearly enlightening both the task and the internal spaces, and providing the conditions needed for health and well-being. Furthermore, if properly managed, good Daylightinging can contribute to reduce the energy loads for lighting and heating (solar gains) needs - and, thus, reduce the impacts of buildings on the environment - whilst concurrently creating interesting, inspiring and meaningful architecture.

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