# A METHOD TO CALIBRATE PERCENTAGE DAYLIGHT FACTOR AT ENCLOSED INTERNAL CORRIDOR USING SCALED MODEL AND SIMULATION

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## Abstract

Enclosed corridors are long and they usually have no window provisions and require electric lighting to be switched on for 24 hours continuously to operate. Some corridor designs have openings for daylight at the ends, while others supplement daylight at the middle. The most part of these corridors are dark and consuming a lot of nonrenewable energy from artificial light. This paper explores how enclosed internal corridors do get the benefits of daylight depending on the corridor designs. It explores how percentage DF (Daylight Factor) less than 1%, especially in Malaysia where the skies are bright, can be beneficial and useful. The illumination required for corridors are minimal according to standards. Field work measurements were taken in selected enclosed corridor of a hostel building on typical overcast days and readings on %DF were then recorded. A scaled model of similar design was built to be experimented in the artificial sky to get a same set of readings; followed by simulation using Radiance. Results show that the readings calibrate well between field work compared to the scaled model in artificial sky and simulation with less than 10% differences. It was found that values of %DF of 0.5 and below calibrated well. Comparison were also carried out in terms of absolute illuminance and it was found that daylight illuminance less than 40 lux in corridors should not be underestimated and were still useful even though lower than the usual standards for corridor illumination. This successful calibration will be used for further experimentation how enclosed corridors can be naturally lit by simulations.



**Keywords**: Daylighting, Daylight Factor, Energy Saving, Corridors Design.

## Introduction

Corridor is a narrow passageway or gallery connecting parts of building (Ching, 2011). A corridor often has entry points to rooms located adjacent its path. However, interior corridors are usually provided with artificial lighting 24 hours a day. Therefore this leads to the consequence of huge increase in energy consumption which has several direct and indirect harmful effects (i.e., unhealthy and infertile environments, non energy-efficiency, and production of greenhouse gases and use of non renewable resources for the occupants of the building. Due to the need for energy-saving rising demand in utilization of daylight has become a crucial issue in the design and construction of buildings. Providing natural light in deep spaces of the buildings has always been a challenge for architects and building designer. The question is: how can natural light be transferred into the deep areas in office building to improve visual comfort in workplace

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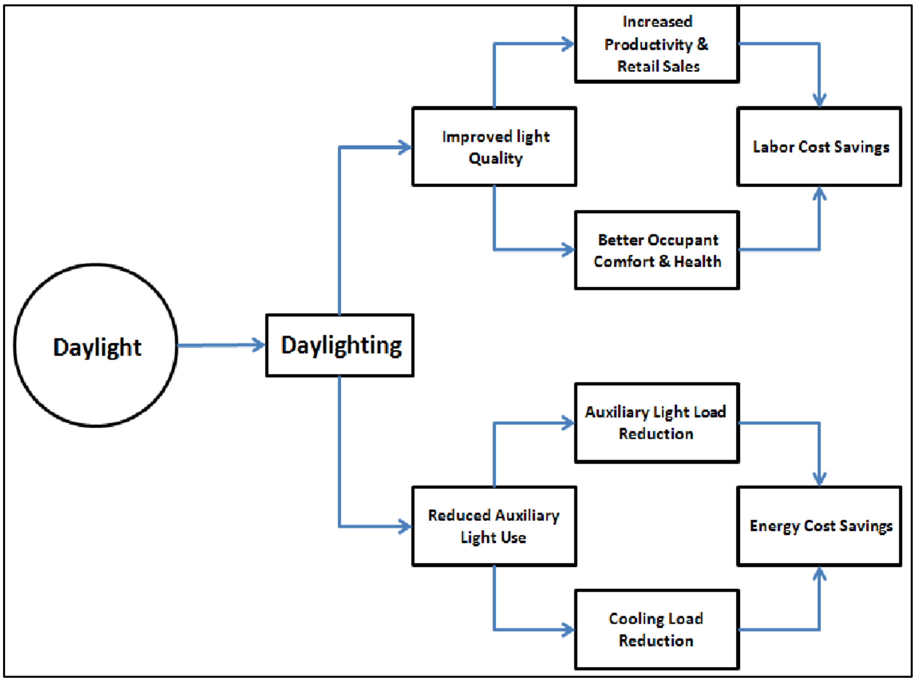
conditions for office workers? The same goes to energy efficiency issues in areas like enclosed corridor spaces. Artificial lighting in tertiary sector buildings presents one of the highest energy-saving potential if using daylight. According to research data conducted by the International Energy Agency (2016), lighting accounts for the 19% of the energy consumed worldwide (International Energy Agency, 2016).

To reduce the use of energy for lighting, one of strategy is reducing indoor artificial lighting and optimize daylighting. One of the strategy used to optimize daylighting is the use of borrowed daylight technique. It is a term used to describe the lighting of an enclosed internal space through a window that connects to an adjacent daylit space. Borrowed light rarely brings much daylight into the internal space but it does provide a connection with the outside and can be useful when the amount of light required in the internal space is less than in the daylit space, e.g. in a corridor. Therefore, the purpose of this study is to examine how lighting internal corridors can be achieved by the borrowed daylight technique. However, to do so to achieve the objective of the study, a method using the % has been used to calibrate between field work to scale model and simulation method .It is applied specifically in enclosed corridor design in topic.

**Day Lighting**

**Figure 1: Benefits of Daylighting**



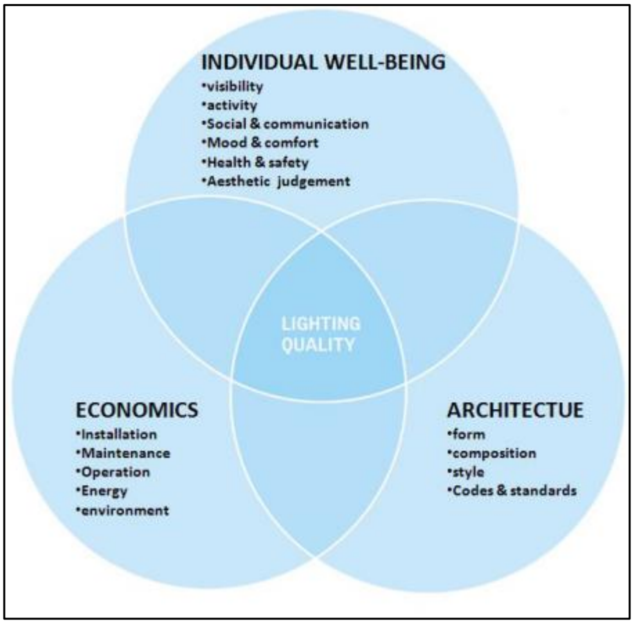

Source: Boyce *et. al.,* (2000).

Daylighting is recognized to have substantial benefits on both the environment, and the well being of people. These benefits include enormous amounts of energy cost savings, as well as enhancing human visual comfort in the indoor environment. In addition, it is being described as the best source of light for good colour rendering and its quality is the one light source that most closely matches human visual response (Tsang & Li, 2007). When day lighting enters the space, not only does it provide a pleasant atmosphere, "as it also maintains a connection between the indoor environment and the outside world. "People desire good natural lighting in their working environments" in which they anticipate suitable day lighting in the environment they work or stay in (Roche *et. al.,* 2000). The benefits of daylighting are far reaching, as the following schematic illustrates in Figure 1.

In addition, the human eye is much adaptable low level of daylight which can not be method with similar low levels of artificial sky.That is why daylight even in low levels should be enough in corridors where task illuminance is at min level.

Until the late 1990s, lighting recommendations were based primarily on lighting needs for vision. In the recent years, the lighting community has adopted a comprehensive definition of lighting quality including human needs, architectural integration, and economic constraints, as illustrated on Figure 2.

**Figure 2. Daylighting Quality.**

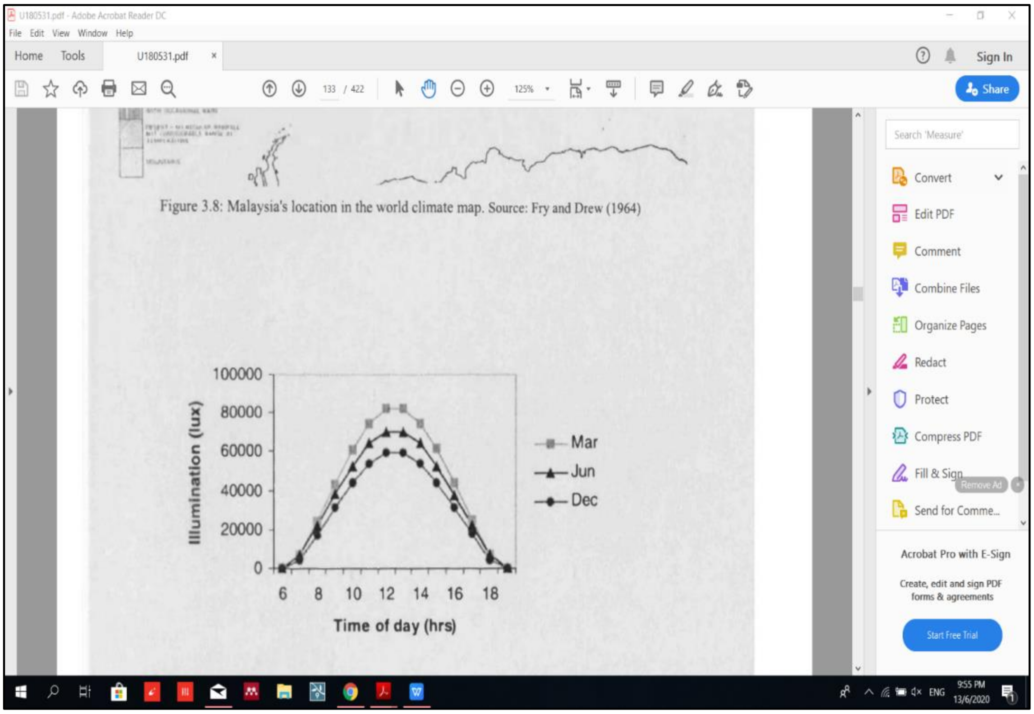



Source: Veitch et.al., (1998)

**The Malaysian Sky**

The type of sky in Malaysia is not easily characterised by the standard classifications of sky condition. The sky condition can be variable and inconsistent over the course of a day. This is due to the formation of cloud which constantly move across the sky. When the cloud is very thick, the sun can be totally hidden and these conditions result in an overcast sky which usually occurs during the monsoon season and in the early morning. Where the clouds are frequently moving, the sunlight penetrates through the thin layer and makes the sky bright with intense daylight around the edges of cloud. Partly cloudy and cloudy skies are also quite common when the moisture content of the air is very high. This commonly occurs when it is about to rain or before the unpredictable rainy spells throughout a typical day.The sky in Malaysia is mostly classified as intermediate; the average coverage of the sky with clouds is 6–7 oktas (Ahmed, 2000; Shahriar *et.al*, 2006). The critical months for daylight in Malaysia are in March, June and December, in which illuminance is about 80,0001ux 70,0001ux and 60,0001ux respectively (Ahmed, 2000).

**Figure 3:The Illumination of Daylight at Critical Months in Malaysia.**



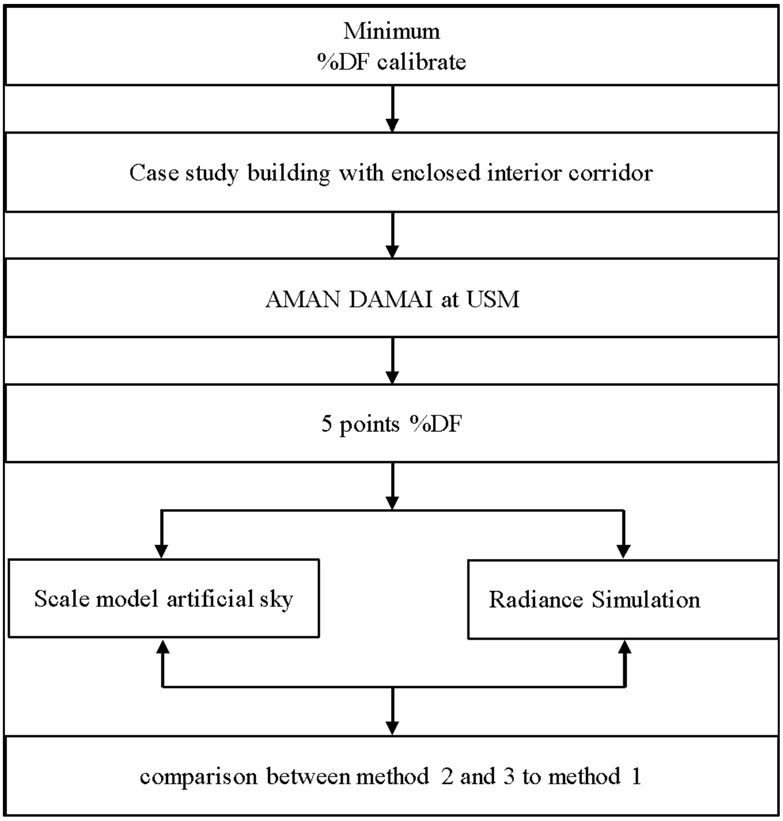

Source: Ahmed, A. Z., (2000).

The enclosed indoor corridor design normally have minimal openings for daylight therefore %DF in corridors can be anticipated minimal indeed. The objective of the paper is to calibrate the minimum % DF in field work to scale model and simulation.

## Methodology

The methodology of research used is experimental research. Experiments are conducted at University of Science Malaysia (USM) Environmental laboratory the artificial sky. Field work measurement carried out for validation of research. The scale physical model was structured to be tested under artificial sky condition. The same model was designed in the Radiance software to performing daylighting simulation experiments. This is sen in figure 4.

**Figure 4. The Methodology**

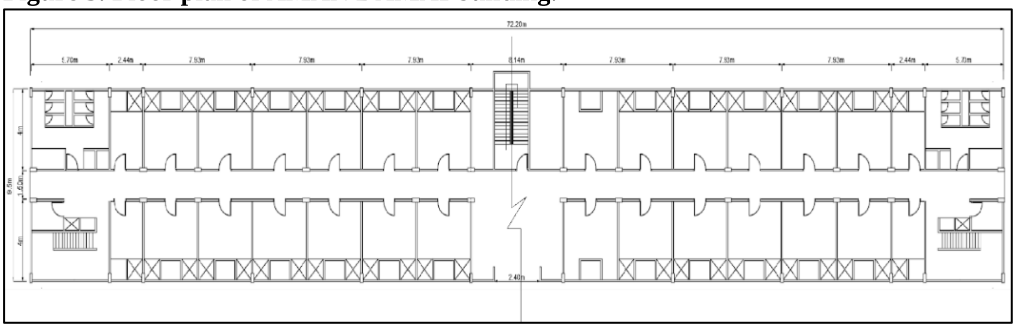



Source: Author, (2020).

**Field Work Case Study**

The case study for corridor was in AMAN DAMAI residential building, located in the University Science Malaysia.The building consists of 3 floors, each floor of the building consists of 24 rooms, 2 bathrooms and 2 wash rooms. The corridor is 1.50 meter width x 72.20meter lenght as shown in figure 5.

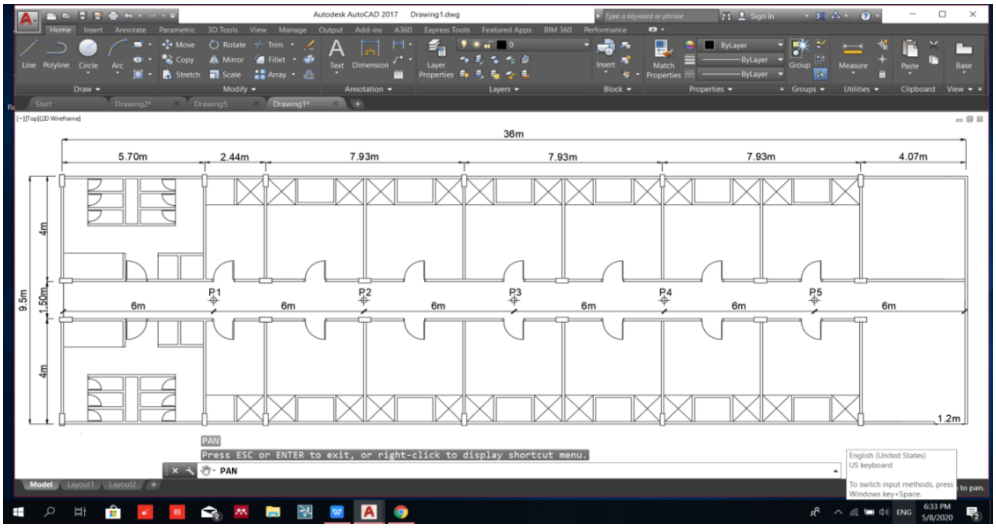
**Figure 5. Floor plan of AMAN DAMAI building.**



Source: Author, (2020).

Because the building is very long we just simplify to half of building to use in this study. Measurements were carried out in (Dec 6, 2019). The illuminance levels were measured by lux meter (LM-8100) at 5 specific points on the chairs surfaces (0.75 meter) as shown in figure 6 .The reading taken every half hour from10 :00 am to 4:00 pm.The daylight factor assessment was done by measuring indoor illuminance level and outdoor illuminance level at the same time.

**Figure 6. Photo of half of the AMAN DAMAI building.**




Source: Author, (2020).

**Table 1: Average of Illumination Values for Field Work.**

| Time | Point 1 | Point 2 | Point 3 | Point 4 | Point 5 | E0 |
|---|---|---|---|---|---|---|
| 10:00 am | 45 Lux | 38 Lux | 33 Lux | 36 Lux | 47 Lux | 30.000 Lux |
| 10:30 am | 36 Lux | 29 Lux | 24 Lux | 27 Lux | 38 Lux | 35.000 Lux |
| 11:00 am | 51 Lux | 44 Lux | 39 Lux | 42 Lux | 45 Lux | 15.000 Lux |
| 11:30 am | 36 Lux | 29 Lux | 24 Lux | 27 Lux | 38 Lux | 30.0000 Lux |
| 12:00 pm | 41 Lux | 34 Lux | 29 Lux | 32 Lux | 43 Lux | 35.000 Lux |
| 12:30 pm | 39 Lux | 32 Lux | 27 Lux | 30 Lux | 41 Lux | 44.000 Lux |
| 1:00 pm | 46 Lux | 39 Lux | 34 Lux | 37 Lux | 48 Lux | 34.000 Lux |
| 1:30 pm | 51 Lux | 44 Lux | 39 Lux | 42 Lux | 53 Lux | 50.000 Lux |
| 2:00 pm | 39 Lux | 32 Lux | 27 Lux | 30 Lux | 41 Lux | 15.000 Lux |
| 2:30 pm | 41 Lux | 34 Lux | 29 Lux | 32 Lux | 43 Lux | 15.000 Lux |
| 3:00 pm | 49 Lux | 42 Lux | 37 Lux | 40 Lux | 51 Lux | 43.000 Lux |
| 3:30 pm | 50 Lux | 43 Lux | 38 Lux | 41 Lux | 52 Lux | 15.000Lux |
| 4:00 pm | 49 Lux | 42 Lux | 37 Lux | 40 Lux | 51 Lux | 35.000 Lux |
| Average | 41 Lux | 34 Lux | 29 Lux | 32 Lux | 43Lux | 25.000 Lux |

Source: Analysis Data, (2020).

**Scale Model Study**

Experiments are conducted at University of Science Malaysia (USM) Environmental laboratory the artificial sky. A physical scale model constructed at a scale of 0:75 for lighting tests. It is built using thick white cardboard paper sheet covered with black sheet to avoid light leakage. as shown in figure 7

**Figure 7: Scale Model Under Artificial Sky**

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Source: Author, (2020).

**Table 2: Average of Illumination Values for Artificial Sky**

| Point 1 | Point 2 | Point 3 | Point 4 | Point 5 | E0 |
|---|---|---|---|---|---|
| 6.5 Lux | 5.5 Lux | 5 Lux | 5.5 Lux | 6.5 Lux | 3743 Lux |

Source: Analysis Data, (2020).

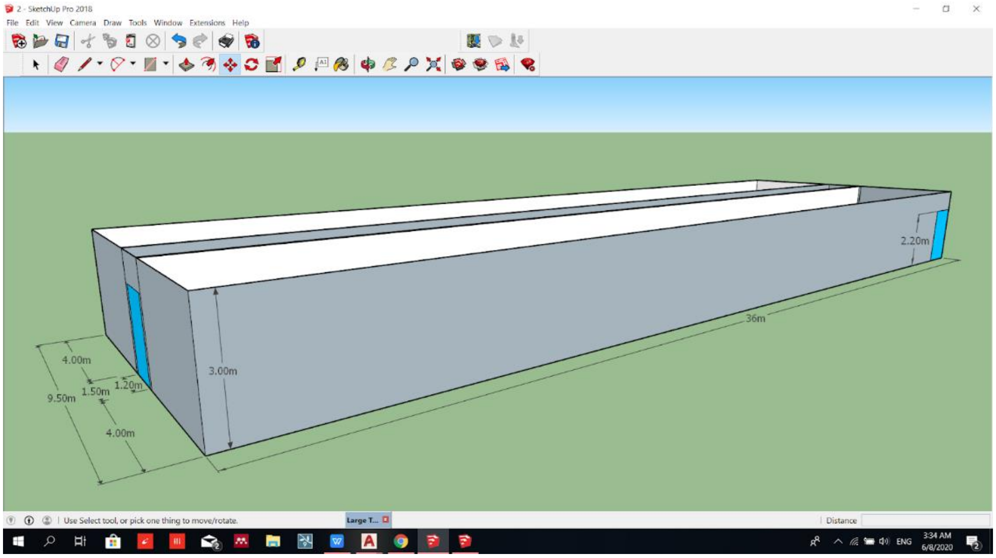
**Radiance Simulation Study**

In this 3rd method, the radiance software was chosen to assess the lighting design of corridor.Radiance is a highly accurate ray-tracing software system for UNIX computers developed with primary support from the U.S.Department of Energy and additional support from the Swiss Federal Government. Several research papers present that dynamic, Radiance-based daylight simulation methods which use the concept of daylight coefficients are able to efficiently and accurately model complicated daylighting elements such as the considered venetian blind system (Mardaljevic, 1995; Reinhart, *et. al.*, 2001). Radiance calculations are performed for a precise moment, considering the climate data file.

## Model Description

Radiance model to exemplify half of the AMAN DAMAI building given in figure8.

**Figure 8. Simulation Model with Dimensions**




Source: Author, (2020).

## Results and Discussion

The results are as follows:

**Table 3: Results**

| | Average of % DF | | | | |
|---|---|---|---|---|---|
| | Point 1 | Point 2 | Point 3 | Point 4 | Point 5 |
| Aman Damai hostel | 0.16 | 0.13 | 0.12 | 0.13 | 0.16 |
| Artificial sky model | 0.15 | 0.12 | 0.11 | 0.12 | 0.15 |
| Radiance | 0.17 | 0.14 | 0.13 | 0.14 | 0.17 |
| %Differences between field work and Artificial sky | 6.25% | 7.6% | 8.3% | 8.3% | 6.25% |
| %Differences between field work and simulation | -6.25% | -7.6% | -8.3% | -8.3% | -6.25% |

Source: Analysis Data, (2020).

As can be seen in the field work data, %DF from the artificial sky model and the radiance simulation model were found to be in similar pattern with the field work data with differences less than 10%.

The results show DF less than 1% in the corridor of Aman Damai building is below the standard recommended. According to the critical months for daylight in Malaysia are in March, June, and December, in which illuminance is about 80,000lux 70,000lux and 60,000lux respectively (Ahmed, 2000). During clear sky in Malaysia, the daylight can even reach higher than

100,000lux. Therefore, good enough to get around without injuring yourself and see where you are going.

## Conclusions

Overall, the integration of daylight into deep spaces is an essential feature of building design. When done properly and with careful planning, daylighting will reduce the costs associated with a building's energy needs; positively impact the social interactions and health of staff, administrators, and students; and, reduce negative environmental impacts. Using natural light as much as possible is important to preserving the environment and supporting human health. Natural lighting is free and in unlimited supply so designing more daylight into buildings easily boosts cost-savings. Increasing daylighting also mitigates human health issues that have been found to be related to over-illumination by artificial light. This study discussed calibration of methods using scale model and simulation in Internal enclosed corridors for reducing energy consumption, and how the %DF less than standard recommended can improve the level and distribution of daylight into the corridor area. In the research methodology, three methods were studied to use in corridors.

There are several ways this research could be expanded and therefore result in even more energy reductions. This research could continue in the path of using Borrowed daylight technique in Internal enclosed corridors for reducing energy consumption, and how the borrowed lights from corridor walls can improve the level and distribution of daylight into the corridor area. The effect of horizontal and vertical alternatives and indirect daylighting alternatives on daylight penetration. The present interest in sustainability and the need for environmental solutions will ensure continued research efforts in the area of daylighting in deep plan offices as well as its effects on human health. The most ideal selection of daylighting strategies will continue to be an area of interest since it's a broad area depending on the research objectives. Daylight is an intriguing infinite topic that continues to challenge researchers while creating endless possibilities for further research.

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