International Journal of Computer Science and Engineering (IJCSE)
ISSN (P): 2278-9960; ISSN (E): 2278-9979
Vol. 7, Issue 1, Dec - Jan 2018; 9-20

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

A SIMULATION STUDY OF THE PERFORMANCE OF LIGHT -WELL IN AN OFFICE BUILDING TO IMPROVE THE LUMINOUS ENVIRONMENT BY INCLUSION OF USEFUL DAYLIGHT

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ABSTRACT

Now-a-days most of the office buildings are high-rise in dense urban cities, such as Dhaka, where there is a scarcity of land. The depths of the commercial buildings are usually large and the employees suffer lack of sufficient daylight. Daylight penetrates 1.5 times of the lintel height of a window located at the floor. Therefore, maximum daylight penetration is restricted to 14'-15' from the window opening when a floor to floor full height (10') window is placed. So, it is hard to get daylight in a deep high rise office building. Light –well, which permits daylight to penetrate from above in urban office buildings could improve the luminous environment considering the climatic context of Dhaka. The aim of this research is to study the effectiveness of light-well in a high-rise office building to improve the lighting condition of the work space as well as the performance of the employees. At the beginning, daylight simulation is done using the software ECOTECT. Finally, the office building is redesigned introducing light-well(s) following trial and error method to ensure sufficient daylight in typical floors. It is expected that the outcome of this research will help architects and designers to introduce light-wells to improve the daylight performance of deep multi-storeyed office buildings.

KEYWORDS: *Daylight, office building, simulation, light-well, daylight performance*

Article History

Received: *06 Dec 2017 | Revised: 04 Jan 2018 | Accepted: 18 Jan 2018*

INTRODUCTION

Dhaka, being the capital of Bangladesh is the most densely populated mega city of the world. Its population is 14.4 million (2013) in a small area of 315 m². As there is a scarcity of land, the most commercial and office buildings are built high-rise in Dhaka city. The depths of the buildings are mostly large due to accommodating cores in a high-rise building. The building to building gap is also minimal due to scarcity of land and lack of tendency for following rules and regulations. These conditions are highlighted on the basis of daylight penetration. The availability of daylight largely depends on the climate of the area as well as the surroundings of the building. Daylight penetrates 1.5 times of the lintel height of a window located at the floor. Therefore, maximum daylight penetration is restricted to 14'-15' from the window opening when a floor to floor full height (10') window is placed. So, it is hard to get daylight in a deep high rise office building. There are several means of penetrating daylight deep into a high-rise office building, such as light shelves,

light-wells etc. In these highly dense urban environments created by built up surroundings, no generalized way exists to describe or predict the luminous microclimate. However, simulations can be used as a design tool to design the luminous environment. The aim of this research is to study the effectiveness of light-well in a high-rise office building to improve the lighting condition of the work space as well as the performance of the employees.

Research Objectives

To present a concept of improving illumination level in deep high-rise office building, the following two objectives were developed_

- To identify the effectiveness of light-well in a high-rise office building to increase the useful daylight at working space in context of Dhaka
- To improve the performance of the employees by increasing the luminous environment

Skylights and Light-wells

In architecture a light-well, light well or air shaft is an unroofed external space provided within the volume of a large building to allow light and air to reach what would otherwise be a dark or unventilated area. Light-wells may be lined with glazed bricks to increase the reflection of sunlight within the space.

Light-wells serve to reduce the necessity for electric lighting, add a central space within the building, and provide an internal open space for windows to give an illusion of having a view outside (Wikipedia).

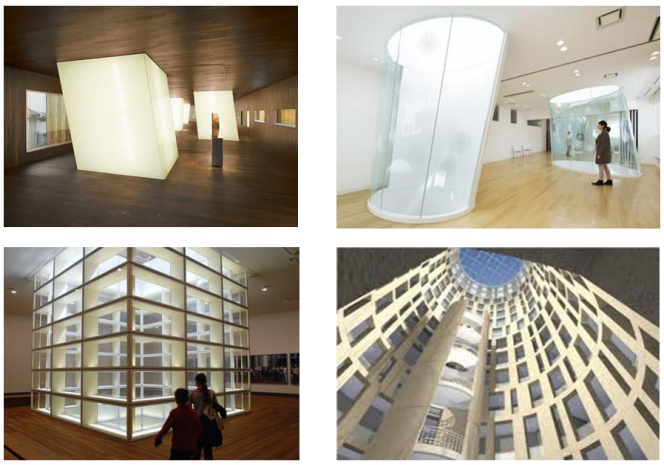


Figure 1: Light-wells (Google)

The skylight by definition permits daylight to enter from above, through a glazed opening in the roof protecting the interior from wind and weather(phillips,2004). For single story buildings, or the top floor of multi –story buildings, the entire floor area can receive daylight from the roof. As the sky is generally brighter at its zenith than near the horizon, a horizontal skylight is proportionately three times more effective as a source of daylight than a vertical window (Egan,2002).

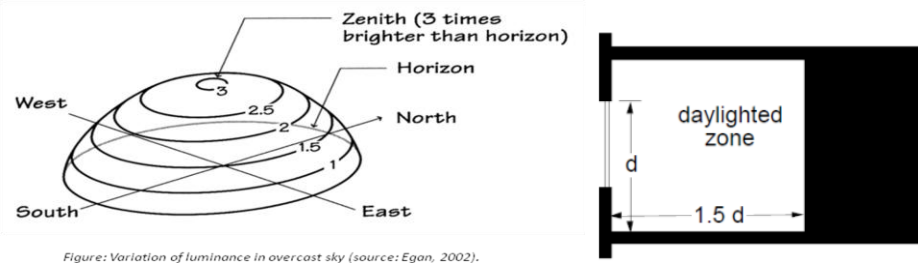


Figure: Variation of luminance in overcast sky (source: Egan, 2002).

Figure 2: Skylighting and Daylight Penetration

In case of skylighting, the incoming daylight is spread over an interior space in a more uniform way, and are less likely to be obstructed either internally or externally. A disadvantage of horizontal skylights is that, compared to vertical windows horizontal skylights is that, compared to vertical windows, horizontal skylights collect more light and heat in summer than in winter- usually the opposite of what is desired. For these reason vertical or near-vertical skylights, oriented to north, south, east or west as circumstances demand, and screened with conventional devices are often preferred (Joarder & Nahid).

Research Method

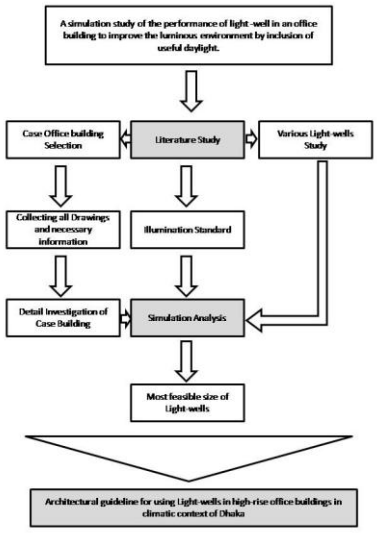


Figure 3: The Research Methodology

Case Studies

Sky Conditions of Dhaka

The city of Dhaka lies between longitude 23°42′37″ N, and between latitudes 90°24′26″ E. In context of Dhaka, during summer 9 Mar-May) the sky can be both clear (with sun) as well as overcast. However, during the warm humid (Jun-Nov) period, which includes the monsoons, the sky remains considerably overcast at most of the time. It is only during the winter (Dec-Feb) that the sky remains mostly clear. In the cool period, Dhaka has more than eight hours of sunshine per day. During monsoon months, this comes down to four hours per day due to cloud cover. It is after June and July that this once again increases steadily (Joarder and Ahmed 2013).

Case Space in Dhaka

My case high-rise office building is "Midas" also known as "EMK Centre" designed by famous Bangladeshi architect Bashirul Haque. It is located at Dhanmondi 27, Dhaka which is a commercial road of 60 feet width. There is a 12 story building at the East of the building, a two story building at the West, a 60' road at the North and a Six story building at the South side.

Figure 4: Arial View of Midas Building

The 13 storied office building consist floor area of 451321 sqm per floor. The length and width of the building is 33m and 23m respectively. The front and rear facade of the building is designed as curtain glass where as the side facades are of concrete walls with regular openings. The floor to floor height is 3350 mm.

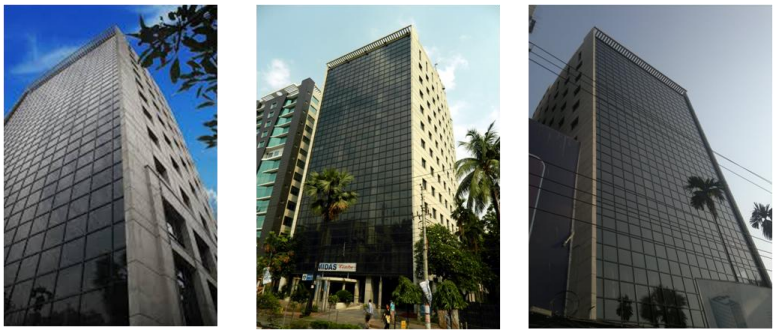


Figure 5: Exterior View of Midas Building

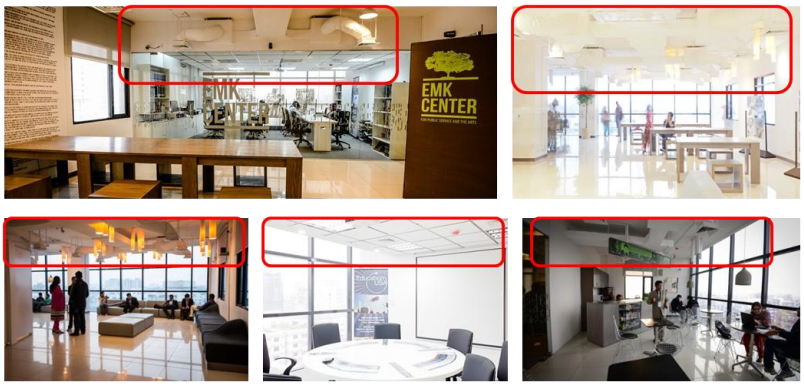


Figure 6: Interior View of Midas Building

Simulation Parameters

The simulation model was created with the existing surroundings, window size, work plane height and different

material reflectance found during physical survey. The design illumination level fixed at work plane height for official work (1m from floor level) is minimum 300 lux and should not exceed 2000 lux to avoid glare(Nabil et al., 2005).

Table 1: Material Properties from Field Survey

Building Element	Material Description	Material Properties
Ceiling	False ceiling with panels	60% diffuse reflectance
Walls	Concrete walls, either side	60% diffuse reflectance
Floor	Homogenous Tiles	70% diffuse reflectance
Window	single glazed low-e aluminium frame	90% diffuse reflectance
Furniture	Plywood	60% diffuse reflectance
Mullions	Aluminium	50% diffuse reflectance
External Ground	Grass	25% diffuse reflectance
Skylight	Single glazed low-e aluminium frame	Transmission:90% Pollution factor: 0.70 Framing factor: 0.90 Maintenance factor:0.85

Performance Evaluation Process

With reference to structural grid, the entire typical floor was divided into grids with 172 intersecting points at work plane height. Ten points on the CC axis from the north window facade were selected as the work plane sensor points.

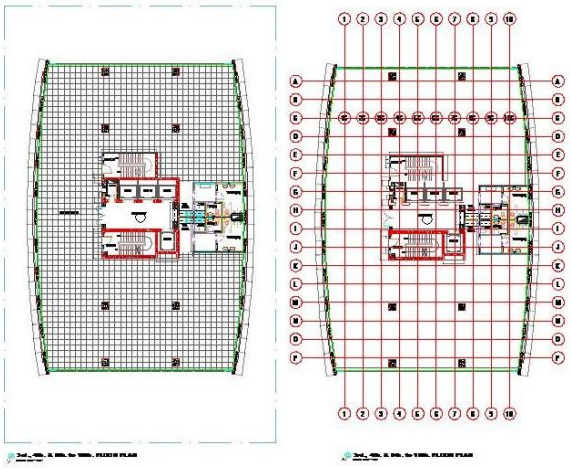


Figure 6: Plan and Grid Plan of Midas Building

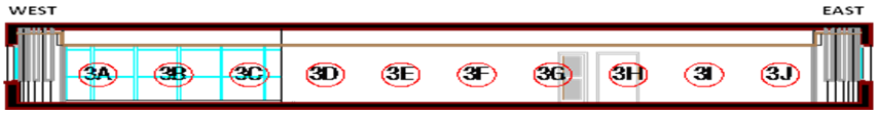


Figure 7: Points on Section of Midas Building

Simulation Studies

First of all, the existing plan is imported into the daylight simulation software ECOTECT. Then the model of a typical floor is built with all the peripheral walls, structures and core. In the wall the windows are inserted. Then the grid plane is fixed with 1m height. The daylight simulation is done then with the weather data of Dhaka, Bangladesh.

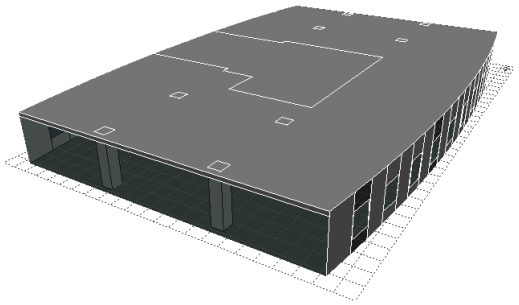
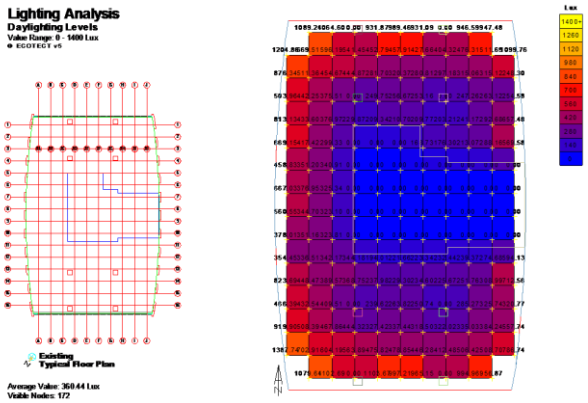


Figure 8: 3D ECOTECT Model of Midas Building

In order to improve the illumination level of the office, light-wells could be beneficial. That is why, five options have been tried to determine the best solution considering the work plane axis. The size of the light wells came from the module 2m* 2m, sometimes single module is used, and sometimes two or three modules sit side by side and create a larger light-well.

Results



Existing

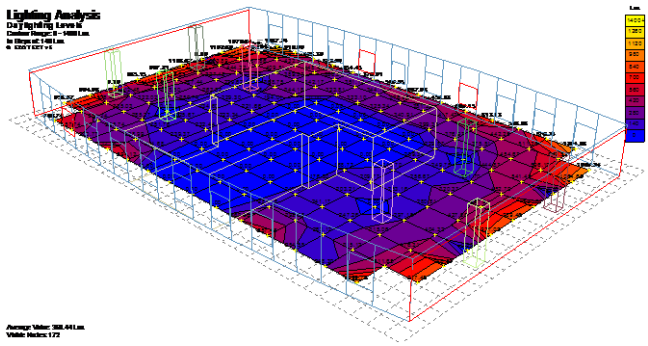
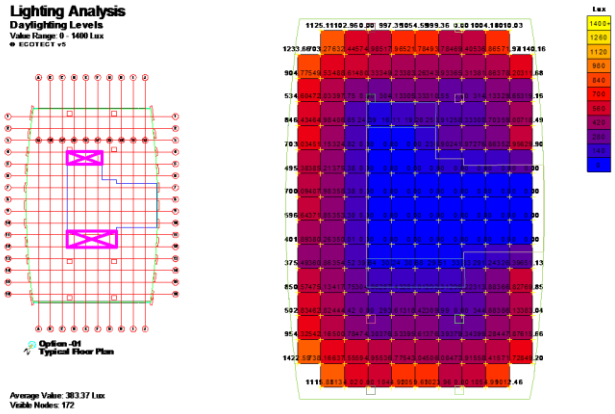


Figure 9: Simulation Model of Existing Situation



Option 01

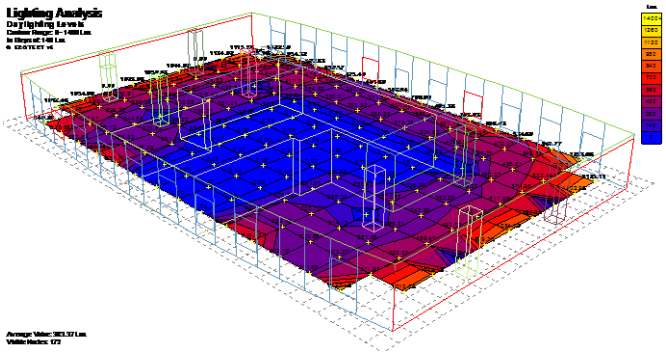
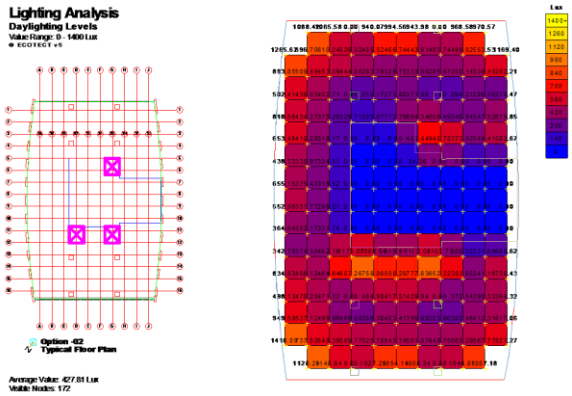


Figure 10: Simulation Model of Option 01



Option 02:

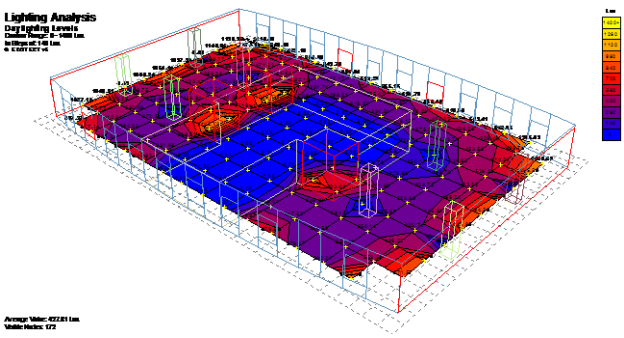
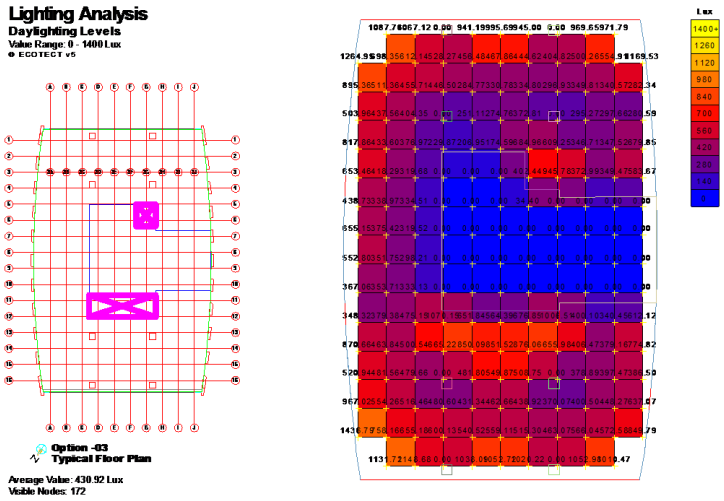


Figure 11: Simulation Model of Option 02



Option 03:

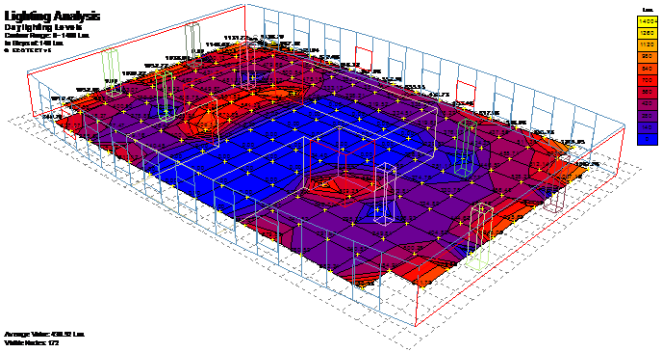
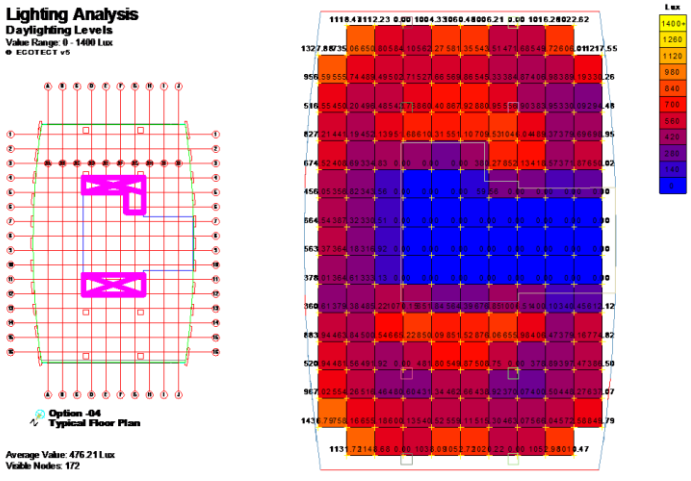


Figure 12: Simulation Model of Option 03



Option 04:

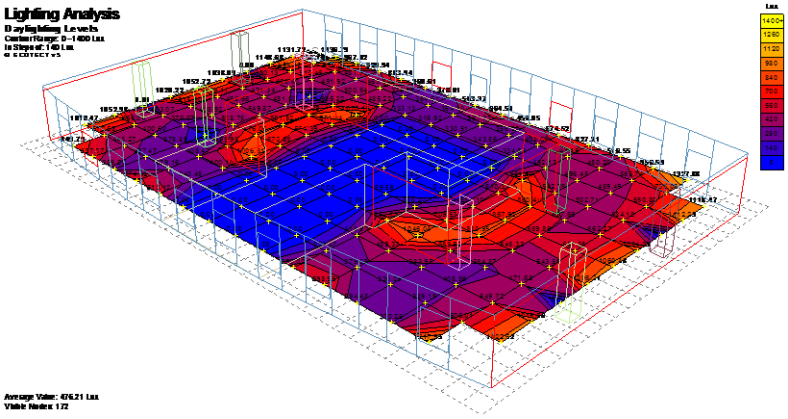
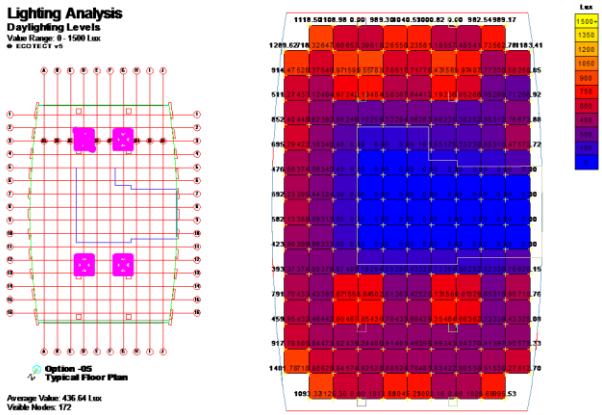


Figure 13: Simulation Model of Option 04



Option 05:

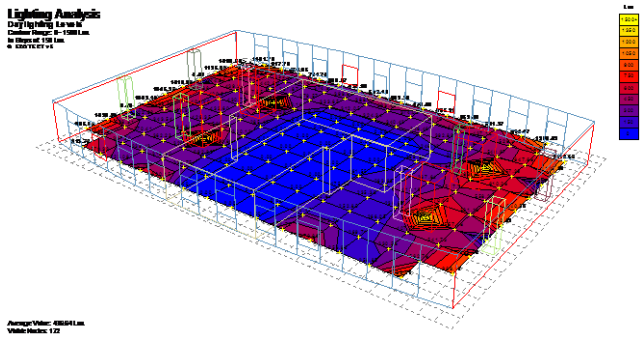


Figure 14: Simulation Model of Option 05

The illumination level at the work plane sensor points 3A, 3B, 3C, 3D, 3E, 3F, 3G, 3H, 3I, 3J are shown in the chart considering the existing situation and option 01, option 02, option 03, option 04 and option 05. The average values of the existing situation and all the option tried are also given in the chart in order to facilitate the comparison. The unit of these data is Lux. The chart is given below_

Table 2: Data at Work Plane Sensor Points

Option No.	Average Value	3A Point	3B Point	3C Point	3D Point	3E Point	3F Point	3G Point	3H Point	3I Point	3J Point
Existing	360.44	511.36	454.67	444.87	281.70	320.37	280.81	297.18	315.06	315.12	248.30
Option 01	451.15	549.53	488.61	480.33	349.23	383.26	343.93	365.31	381.86	378.20	311.68
Option 02	427.81	509.49	453.59	444.80	283.79	329.75	333.86	295.87	350.14	339.40	283.21
Option 03	430.92	511.36	455.71	446.50	284.77	330.78	334.80	296.93	349.81	340.57	282.34
Option 04	476.21	555.74	489.49	502.71	527.66	569.86	545.33	384.87	406.98	389.10	330.26
Option 05	436.64	528.37	540.97	1599.55	703.78	517.71	770.43	1599.97	407.77	330.58	258.85

DISCUSSIONS

The work plane sensor points has been taken at the position where the employees tables are situated. That is why it is important to evaluate the overall luminous condition as well as the condition at the work plane sensor points.

Existing: From the table 01, it is seen that in the existing luminous condition is not satisfactory at all. The standard illumination level for office work is 300 lux. However, it is seen that in four points the illumination level is below 300 lux out of ten. The average value is 360.44 lux which is not satisfactory as well.

Option 01: In this option the illumination level is satisfactory as at all the points the illumination level is above 300 lux. The average value is 451.15 lux which is also satisfactory.

Option 02: In this option the illumination level is not satisfactory as in three points the illumination level is below 300 lux. However, the average is 427.81 lux which is satisfactory.

Option 03: In this option the illumination level is not satisfactory as in three points the illumination level is below 300 lux. However, the average is 430.92 lux which is satisfactory.

Option 04: In this option the illumination level is satisfactory as at all the points the illumination level is above 300 lux. The average value is 476.21 lux which is also satisfactory.

Option 05: In this option the illumination level is not satisfactory as in one point the illumination level is below 300 lux. However, the average is 436.64 lux which is satisfactory.

From the above discussion it could be said that option 01 and option 04 are satisfactory as at all the points of the work plane sensor they meet the standard illumination level.

Table 3: Data at Work Plane Sensor Points of Option 01 & 04

Option No.	Average Value	3A Point	3B Point	3C Point	3D Point	3E Point	3F Point	3G Point	3H Point	3I Point	3J Point
Option 01	451.15	549.53	488.61	480.33	349.23	383.26	343.93	365.31	381.86	378.20	311.68
Option 04	476.21	555.74	489.49	502.71	527.66	569.86	545.33	384.87	406.98	389.10	330.26

But if the values are compared, the average value, and the values at every point Option 04 gives better illumination than Option 01. So it could be said that, in all the five option tried, Option 04 gives the best luminous environment.

CONCLUSIONS

The analysis of this result shows, the right size and position of light-wells in a deep office building can improve the luminous environment in context of Dhaka. Therefore, the improved luminous environment would help to improve the physical and psychological health of the employees as well as productivity of the institution. Thus, it will be beneficial for our country. So, it is recommended that, before designing such deep high-rise office buildings, the architects should consider luminous environment.

REFERENCES

1. *Joarder, M.A.R and Price, A.D.F. (2013). Impact of daylight illumination on reducing patient length of stay in hospital after coronary artery bypass graft surgery. Lighting Research & Technology. 45 (3): pp. 435–449*
2. *Joarder and Nahid,Green daylit industry for Dhaka: An evaluation of integrated skylights and solar panels for RMG factory buildings.*
3. *The Workplace Intelligence Unit was founded by forward thinking inc. and Herman Miller-Daylight in the Office – A Matter Of Balance*
4. *Yin,R. (2003) Case Study research: design and methods. Third edition. USA: Sage publications.*
5. *S.Elizabeth Amudhini Stephen, R.Mercy Shanthi & A. Joe Ajay, Optimization of Thermal Comfort in Office Buildings Using Non-Traditional Optimization Techniques, International Journal of Mathematics and Computer Applications Research (IJMCAR), Volume 3, Issue 1, March-April 2034, pp. 151-170*