Study of Façade Treatment for Optimum Daylight Usage in Open Plan Offices in Context of Dhaka

Adeeba Ahsan Amina, Primeasia University, Bangladesh

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Abstract
Electricity consumption is the highest energy drainer when it comes to artificial lighting used in offices even though maximum office-hour coincides during the day time. Although few simple design inclusions in the initial phase of designing can reduce electricity consumption as well as add bonus effects such as physiological and psychological improvement through use of daylight, it is still neglected due to lack of awareness and negligence. Even if not included in the design phase, simple design modifications might change the scenario altogether. Proper daylight use can be of economic and health benefit. The author aimed to evaluate on the use of solar panel louvers in existing buildings to avoid glare from excessive daylight and its optimum utilization in open plan offices in context of Dhaka. To achieve this, it required field survey, questionnaire survey, user satisfaction interviews, background study and software simulation. Daylight simulation has been performed by producing the virtual urban environment based on the survey of a true site urban office building located in Dhaka, Bangladesh. Through software simulation Climate based daylight modelling has been done using Ecotect, RADIANCE- based DAYSIM. It was made possible to assess possible solar panel louver options with varying angles, that would provide optimum Daylight use and help reduce unwanted glare as a more sustainable option. ECOTECT is used as a modelling interface to launch the DAYSIM program. For a sustainable building design, general methodology and information provided in this paper will accompany in future scope of research and implementation.

Keywords: Daylight Use, Open Plan Office, Ecotect Simulation, Solar Panel Louver, Sustainable

INTRODUCTION

Open office spaces are becoming a beneficial trend in the commercial sectors due to the scope of its resource sharing, space flexibility and interactive environment. As open plan provides much flexibility of space usage it also means that much of the daylight, if façade treatment is done properly, can be used by most of the daily users. Lack of partitions maximizes the use of daylight to the maximum of the spaces. Proper use of daylight is going to have a huge impact in the amount of energy consumption with the help of better improvised ideas and statistics for using it in offices.

Many options are available for preventing solar heat gains, excessive glare from abundance admittance of daylight in modern building offices with glass facades. Some of which are cost effective but tedious to maintain, automated but costly to maintain. Options such as manual or automated blinds are quite common and on-the-go solutions for such situations. Although automated solar shading can be a cost effective and sustainable solution in the long run usage of the building. Automated shading will be helpful in operating as it will adjust itself in accordance with the sun path and generation of electric power will be supplementing its operational power needs.

There are many variables of solutions available for optimum daylight use but the ultimate goal of these design solutions are user satisfaction in work places and to provide optimum illuminance level which is 300lux Standard for Office work and desk level works (Joarder M., 2009)

Although proper daylight usage through improvised solutions are available but it is not advisable to come up with design solutions later after completion of building design rather during the initial design phase any building should be designed by considering such vital factors which has negative impacts on energy consumption, user comfort and well-being. Specially in office places where people spent most of their vital time of the day inside, losing health and mental balance.

1. Literature Synthesis

The criteria of visual and thermal comfort, productive and sustainable use of power consumption defines a well-designed office which are directly related to as well as can be achieved by successful use of daylight. Visual comfort is very important for well-being and productivity of the occupants in buildings (Leech et al., 2002; Serghides et al., 2015). The effect of visual comfort on occupant work performance, productivity, comfort and satisfaction can be assessed from many past studies where natural light plays a vital role in physical and therapeutic ways (Veitch, 2001). Visual comfort defines lighting conditions, even distribution of light, prevention of excessive glare and optimum light level ambience. Insufficient light and especially daylight or glare reduces the ability to see objects or details clearly (Leech et al., 2002). Architectural design has a direct impact on office lighting and office lighting has a direct impact on well-being and productivity of the users. The access to natural lighting as well as artificial lighting is essential in order to ensure well-being of occupants in areas where natural lighting is missing or during evening when the natural lighting fades (Aries et al., 2010).

Visual comfort at work has an impact on comfort after work as well. Open plan offices have negative effect on visual comfort which leads to a negative impact on occupant as well. Visual comfort plays such a vital role in the overall productivity, comfort and well-being of the occupants that buildings need to avoid excessive use of artificial lighting yet still maintain some level of optimality (Yun et al., 2012). Therefore, one needs to study daylight, artificial lighting, glare and visual comfort together in order get a more sustainable design in resource as well as occupant comfort.

1.1 Statement of the problem

It is a common practice in offices to use artificial lighting even though maximum office hour takes place during the day time. Electricity consumption is the highest energy drainer when it comes to artificial lighting used in office spaces. Even though few simple design inclusions in the initial phase of designing can reduce electricity consumption as well as add bonus effects such as physiological and psychological improvement through use of daylight, it is still neglected due to lack of awareness and negligence. Even if not included in the design phase, simple design modifications might change the scenario altogether. Proper daylight use can be of economic and health benefit.

1.2 Aim and objectives

Aim

The author tried to come up with a comprehensive study of the benefits and efficient use of daylight in open plan office space by thorough analysis of primary and secondary data sources. With proper deduction and simulations, it can be ensured that daylight use will eventually reduce pressure on electricity consumption and benefit the users on physiological and psychological levels.

Objectives

- Analysis of current indoor luminance quality to understand the existing scenario.
- Comparison with Standard requirement with the existing situation and the design best solution to achieve the desired effect.
- Determine the effects of daylight inclusion along with interior finishes and elements such as- floor finish, furniture tops, ceiling height, window configuration and relevant items, as such.
- Determine the effect of daylight use in economic, physiological and psychological parameters for user satisfaction.
- Software simulations to determine the feasibility of hypothetical solutions.
- Analyze and draw conclusions from the simulations of the overall impact of daylight for office work efficiency.

1.3 Scope and limitation of the work

Scope

The study provides opportunities for considerations of façade treatment inside and outside of a building in more sustainable ways with variable aspects as of solar panels.

Limitation

If compared with other variant or simultaneously work with another variant could make some result or approach of the study less sustainable.

Constraints like time limit is a huge factor, since only one office's performance was considered for drawing conclusions.

2 Research Methods

Dynamic Simulation is the main research method selected for this study. The flow chart below explains the process:

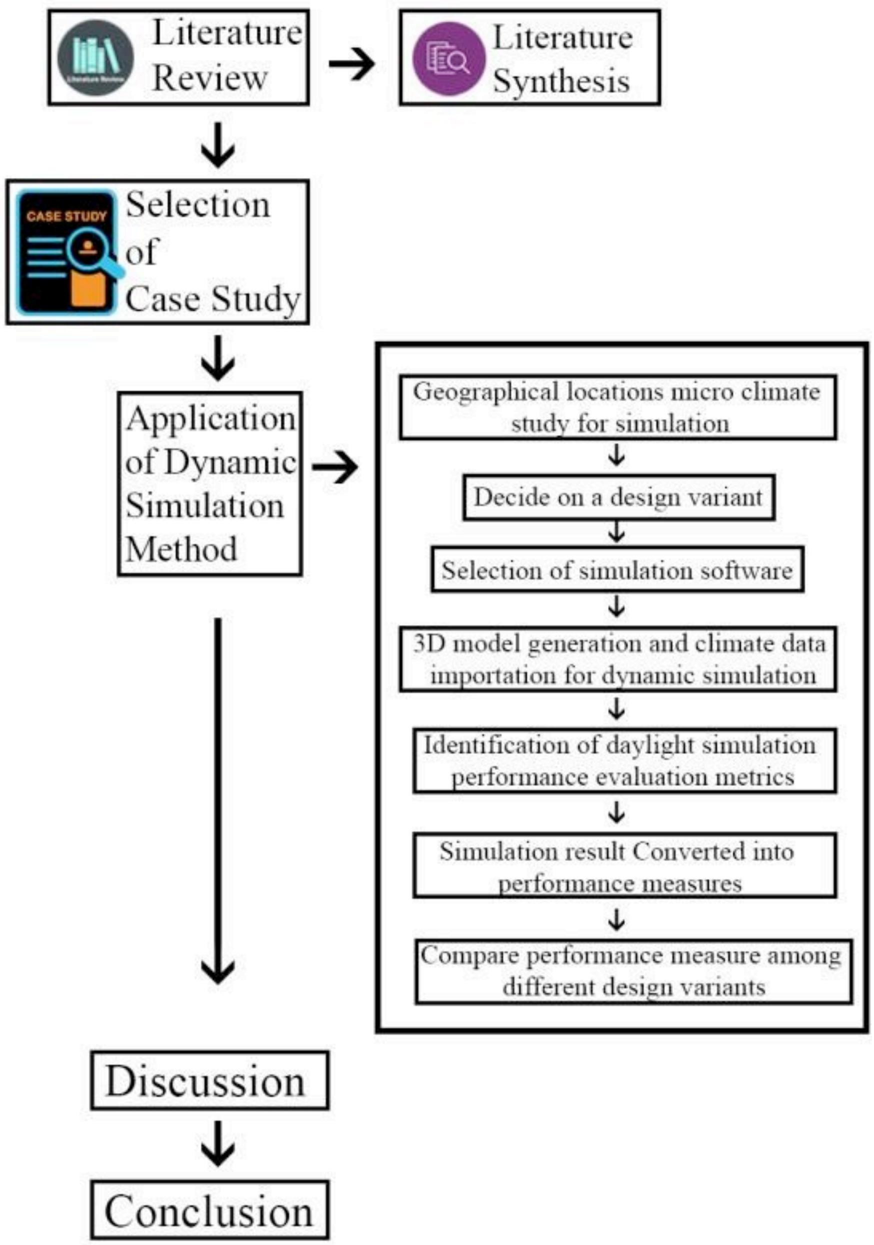

Figure 1: Flow diagram of the simulation process (after Rahman, H. 2018)

3 Case Studies

3.1 Selection of Case Study

For the purpose of this simulation study, an open plan office building was selected with glass façade on maximum sides. Simulations were done considering the surroundings of the site.

- **Location:** House 37, Road 11, Block H, Banani, Dhaka 1213, Bangladesh.

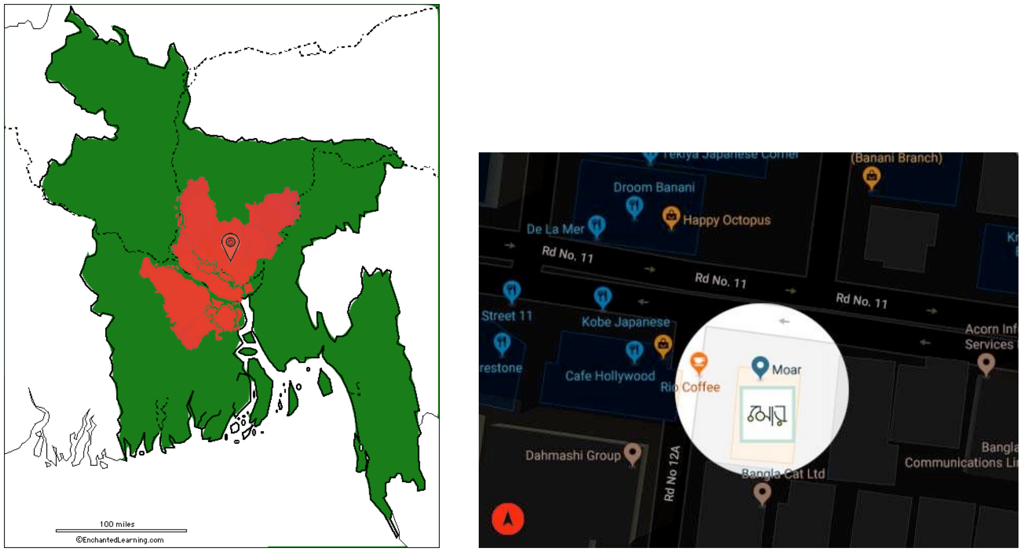

Figure 2: Location Map of Office "Moar"
Source- Google Maps

- **Zone type:** Mixed Use Zone of the “Posh” area of Banani

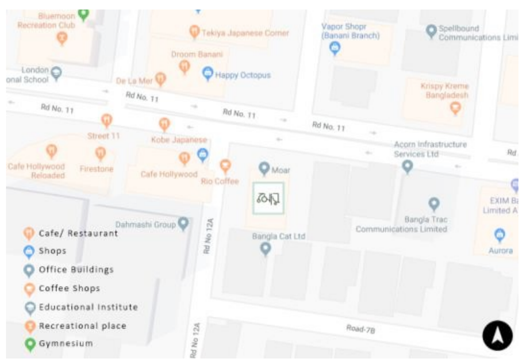

Figure 3: Land Use Map | Source- Google Maps

- **Office Plan Layout:** Open plan

Figure 4: Office Floor Plan | Source- Author

(a) (b)

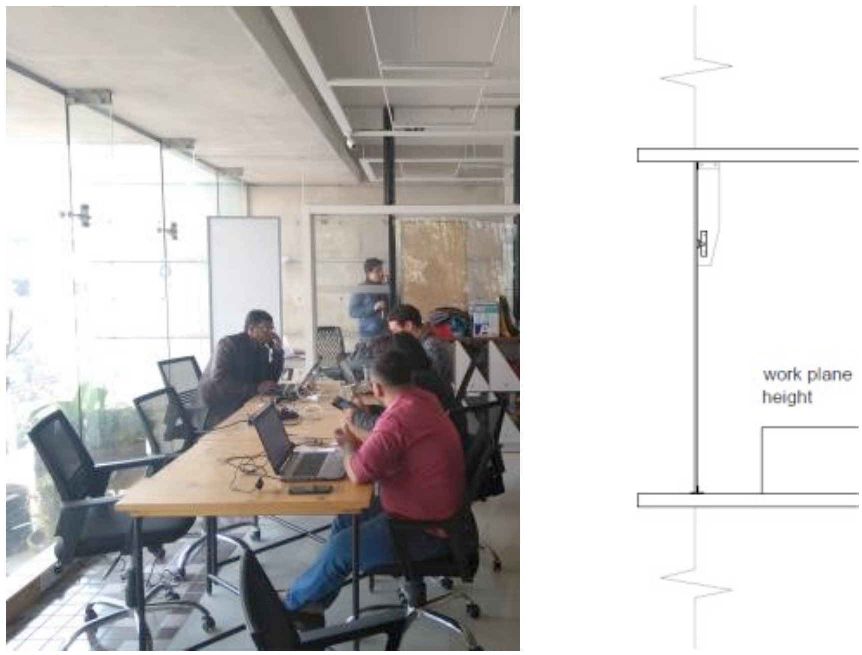

Figure 5: Images- (a) South side of the Office allowing excessive daylight, (b) Existing Window Section | Source- Author

4 Application of Dynamic Simulation Method

This section describes application of the simulation methods. Simulation is done to make the decision about the configuration of skylight influencing light inside the open plan office structure. To complete this stage, the author has gone through the steps that has been shown in above diagram (Figure 1). Others steps described in detail, below:

4.1 Geographical Locations Micro Climate Study for Simulation

Dhaka has tropical climate and three distinct seasons. Those are the hot-dry (March-May), the hot-humid (June-November) and the cool-dry season (December-February) (Ahmed, K. S., 1995). Throughout the hot-dry or summer, the sky can remain both clear with sun and overcast. During monsoon period which is hot-humid, the sky remains significantly overcast at most of the time. During the winter which is cool-dry, the sky remains typically clear. Composite climates as Dhaka, where mutually overcast and clear conditions are experienced during the course of every year. This guides designers for the suitable daylight enhancing solution (Ahmed, Z. N., 1987).

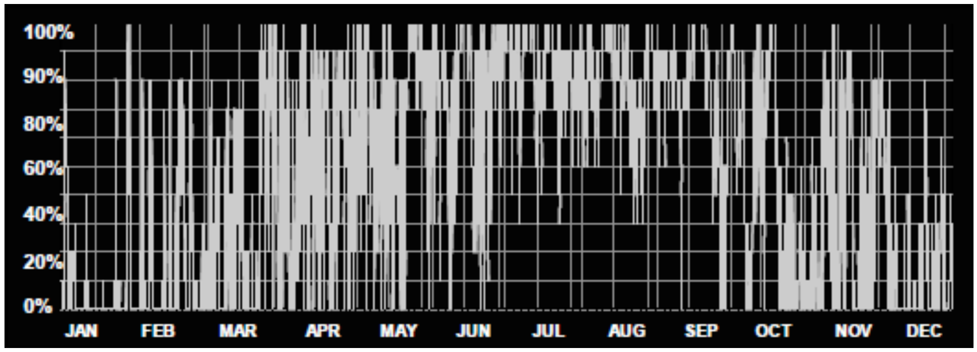

Figure 6: Cloud cover for TRYs, Dhaka (Source: U.S. Department of Energy [61])

4.2 Decide On a Design Variant

During site survey, Solar panel louvers seemed more logical and sustainable, considering visual and thermal comfort, productive and sustainable use of power consumption. As it is a commercial building, one successful application of solar panel louvers will encourage others to do so.

Solar panel louvers come in many combinations of shape, size, finish, frame and installation details. Solar panel louvers can use transparent or translucent finish, in glass or polymer of various configurations to achieve the goals of even light distribution, glare prevention and solar control. (Mestek Architectural, 2012)

A variety of solar panel louvers exists for applications on exterior façade.

(a) (b) (c)

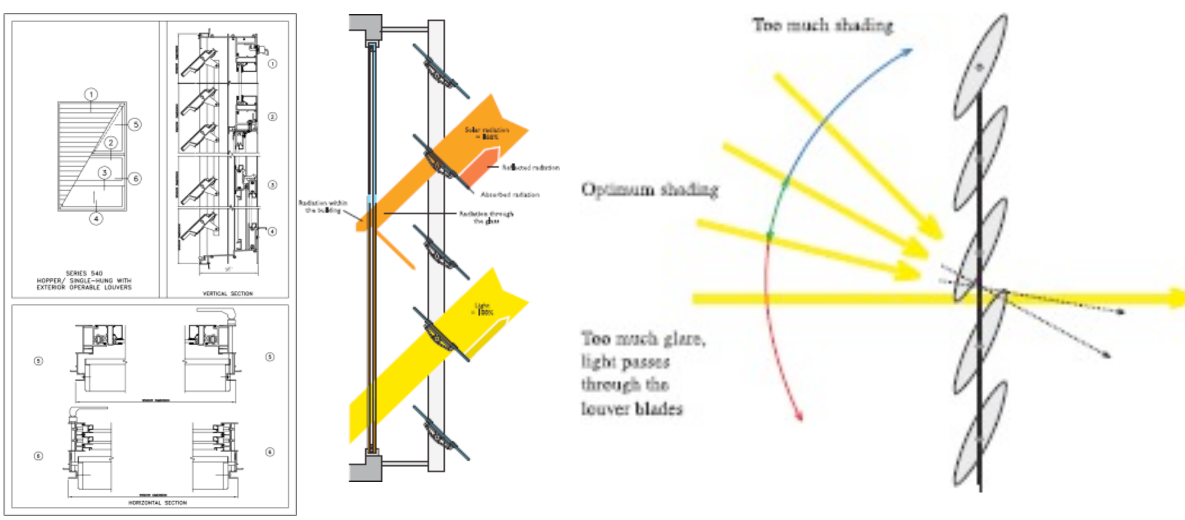

Figure 7: (a) Solar Panel type, (b) Solar Radiation & Light interaction with the Panel, (c) Image showing different angles' situations

Figure 8: Image of the Shadovoltaic panels and its features | Source- MESTEK Architecture(2012*)*

4.3 Software Used for Simulation

AutoCAD, Ecotect, RADIANCE and DAYSIM are the software used for whole simulation process. AutoCAD has been used to produce 2D diagrams, 3d modeling has been produced in Ecotect. For further depth simulation RADIANCE and DAYSIM has been used. Both RADIANCE and DAYSIM have been authenticated widely and successfully for daylighting analysis (Joarder, A.R., n.d) Ecotect also used for running Radiance and Daysim.

4.4 3D Model Generation and Dynamic Simulation Parameters

Physical survey data

- Total floor area: 193sqm Usable space: 182sqm Service area: 11 sqm
- Ceiling: Plastered concrete ceiling painted white Internal wall: Glass Partitions (transmittance- 0.8) Floor: Tiles (reflectance: 0.3)
- Glazing: Double Glazed floor-to-ceiling windows/ façade

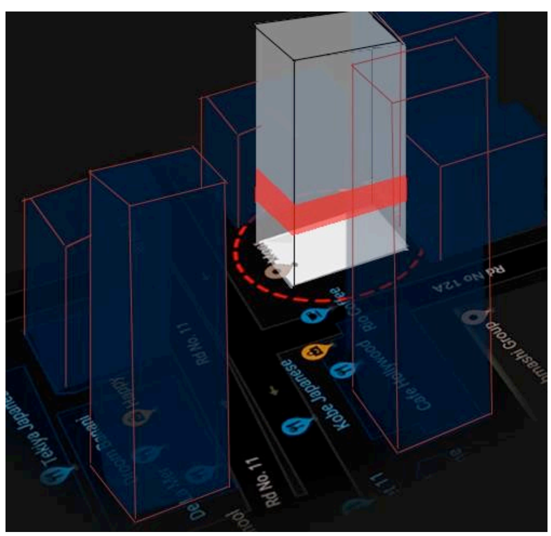

Figure 9: Office building(case study) | Source- Author

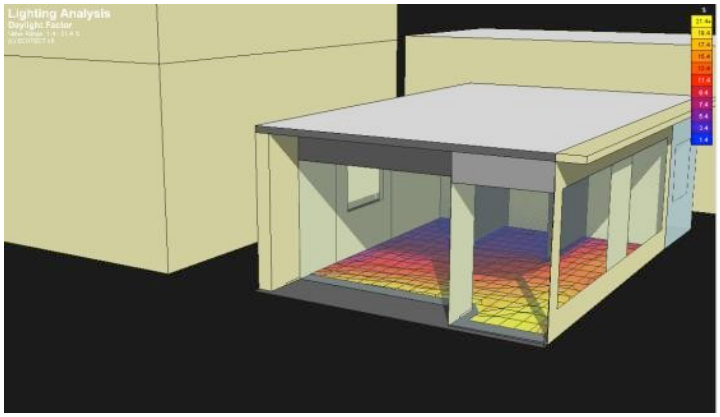

Figure 10: Ecotect Model of the Office Floor showing the existing luminance condition
| Source- Author

The Office has glass façade on the South and East side which provides abundance of daylight but at the same time excessive glare. The image below shows the level of daylight entering the office.

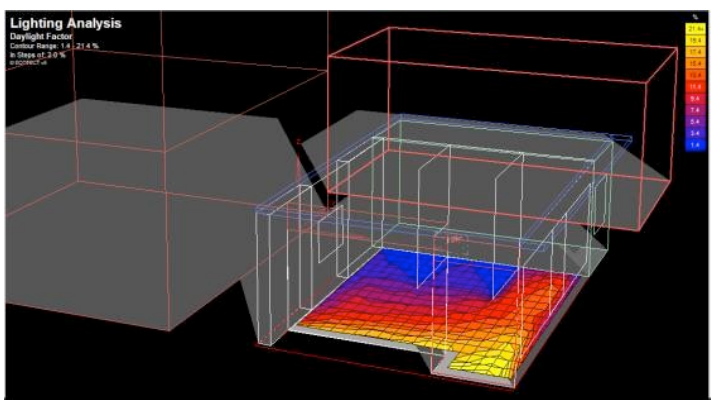

Figure 11: Ecotect showing Daylight level inside the Office | Source- Author

Shadovoltaic Solar panel louvers will not only control the daylight entering the office but will generate and store energy required to run the automated panels. Automated panels make it easier with maintaining the panel angles in accordance with the Sun angle.

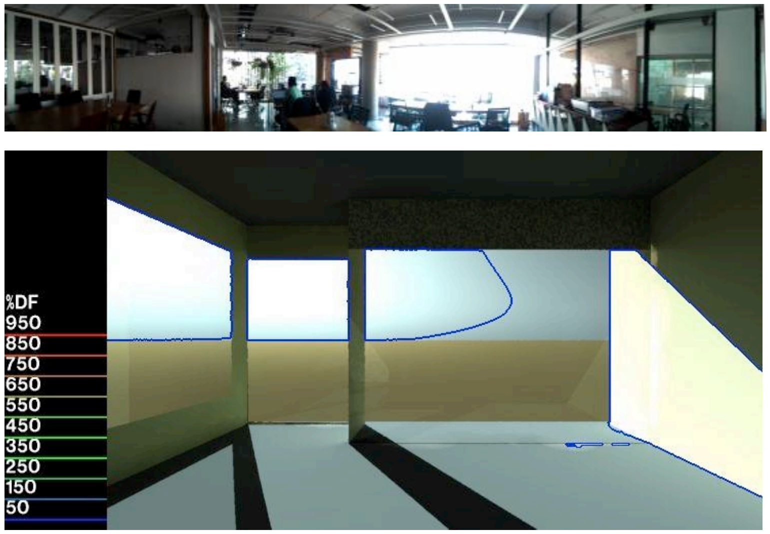

Figure 12: ***Above*-Existing South side image of the Office, *Below*- Ecotect Simulation image | Source- Author**

The assessments for the daylight simulation were based on the following parameters:

- Location: Dhaka, Bangladesh (longitude: 90.2 deg; latitude: 23.5 deg)
- Local terrain: Urban Ground reflectance: 0.2
- Time: 9.00 am – 5.00 pm Window (dirt on glass): Average Design illumination: 300 lux
- Dynamic sky model: Perez sky model Duration for dynamic simulation: Month of January

(Joarder, A.R., n.d)

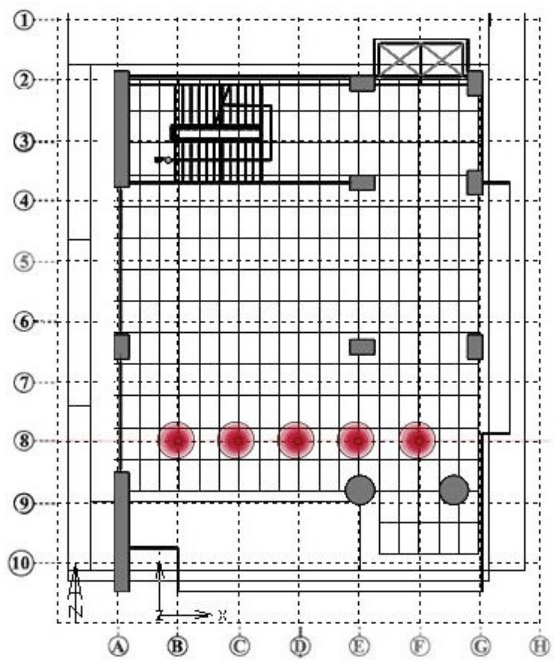

Figure 13: Plan showing the column/structural grid with node references | Source- Author

4.5 Identification of Daylight Simulation Performance Evaluation Metrics

The findings of simulation are evaluated based on the following dynamic performance metrics done with Daysim to get an overall annual understanding

- **Daylight Factor (DF): It** is the ratio of the light level inside a structure to the light level outside the structure. It is defined as: DF = (Ei / Eo) x 100%
- **Daylight Autonomy (DA):** It is the percentage of the occupied times of the year when the minimum illuminance requirement at the sensor is met by daylight alone (Joarder, A.R., n.d).
- **Continuous Daylight Autonomy (DAcon):** The percentage of the minimum illuminance requirement met by daylight alone at the sensor during the full occupied times of the year (Joarder, A.R., n.d).
- **Maximum Daylight Autonomy (DAmax):** The percentage of the occupied hours when the daylight level is 10 times higher than design illumination represents the likely appearance of glare (Joarder, A.R., n.d).
- **Useful Daylight Illuminances (UDI):** The aims of UDI are to determine when daylight levels are 'useful' for the user and when they are not. Based on occupant preferences in daylit offices, UDI results in three metrics, i.e. the percentages of the occupied times of the year when daylight is useful (100- 2000lux), too dark (<100 lux), or too bright (> 2000 lux) (Nabil, A., et al, 2006)

About this metrics details with example are described in Joardar, A. R. "Climate

Based Daylight Modelling and Dynamic Daylight Performance Metrics for Sustainable Building Design in Bangladesh" research paper.

4.6 Performance Measurements from Simulation Results

Ecotect simulation showing the existing sunpath, daylight level condition and the 3 solution options. The images are shown below:

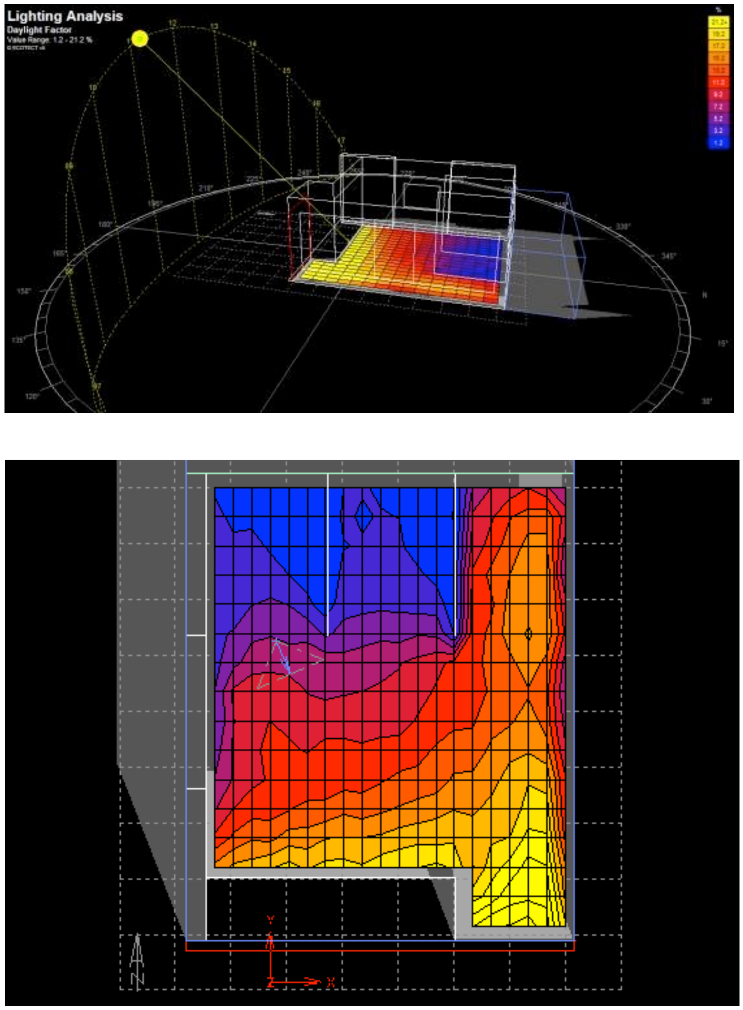

Figure 14: Sun Path for simulation & Ecotect Daylight level intensity | Source- Author

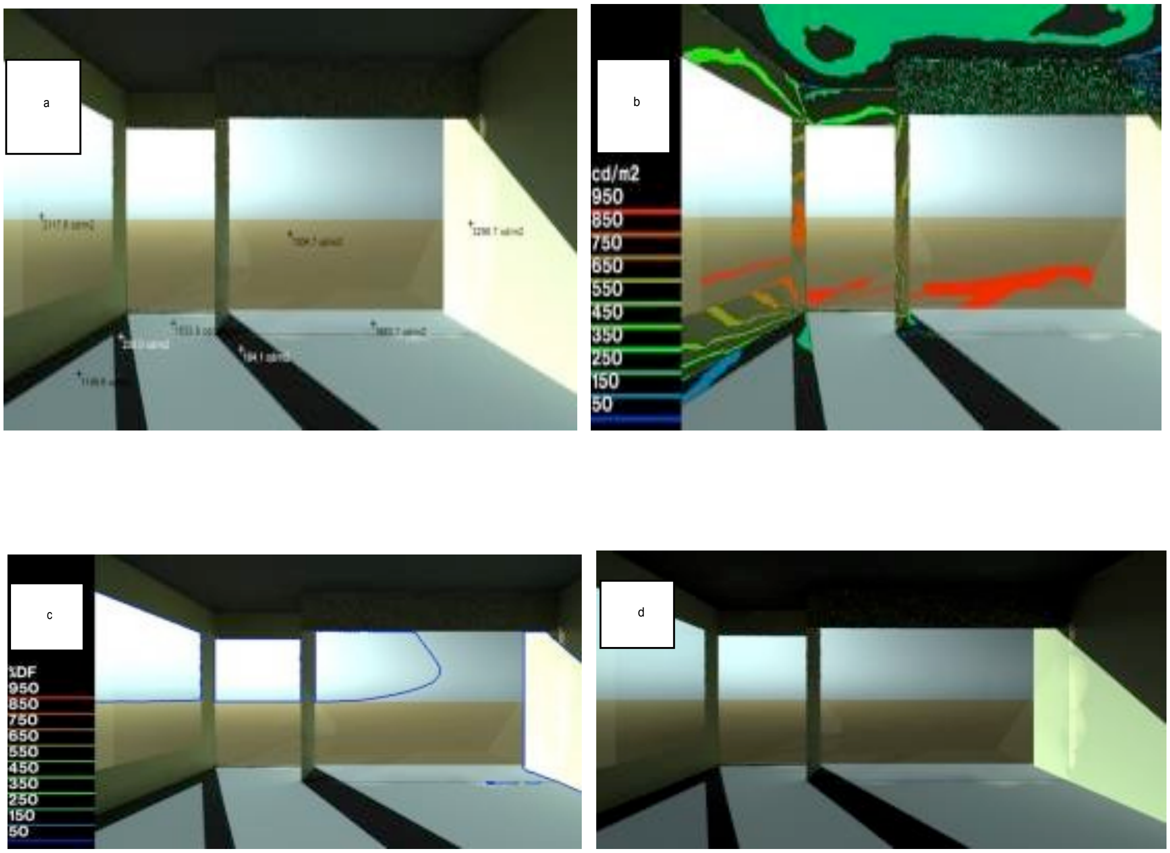

Figure 15: (a) Lux Intensity (b) Contour Bands (c) DF% (d) Human Sensitivity |
Source- Author produced via RADIANCE simulation

Possible Solutions of Louvers

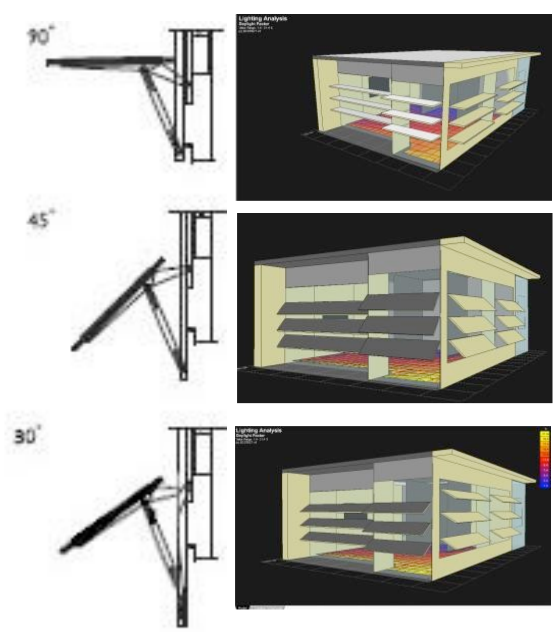

Figure 16: Louver Options- Solution:1 | Solution:2 | Solution:3 shown respectively Source- Author

5 Simulation Studies

The table below summarizes the performance metrics of Panels on indoor daylighting level:

Table 1: Simulation results for three solar panel louvers at different angles Source- Author

Lighting Configuration	(Existing) %	Sol_1 %	Sol_2 %	Sol_3 %
DA %	100	99.95	99.85	100
DA max % UDI<100	87.1 0	63.85 0	16.25 0	32.25 0
UDI % 100-2000	2.15	15.45	42.85	29.8
UDI >2000	97.35	84.45	56.85	69.7

Table 2: Ranking Metrics of the Three Solutions Compared with the Existing Condition | Source- Author

Type	(Existing)	Solution_1	Solution_2	Solution_3
DA	4	3	2	4
DA max	1	2	4	3
UDI 100-2000	1	2	4	3
UDI >2000	2	4	3	1
Total Rating	8	11	13	11
Place	3rd	2nd	1st	2nd

6 Result

From the readings of the DAYSIM analysis report, final result from the core points of the work plane has been shown in the tables above. It can be seen that Solution- 2 came 1st through ranking system.

7 Discussion

7.1 Solar Panel Louver Configuration:

Soltuion-2 seems to be the best Louver option as the simulation result shows that even though its DA (99.85%) is lower than the rest, the other factors such as DAmax, UDI100-2000, UDI>2000 is at desired level than the rest.

7.2 Solar Panel Louver Features:

Figure 17: Features of Shadovoltaic panels | Source- MESTEK Architecture (2012*)*

Such features as the solar shading property, generation of electrical power are preferable for sustainable daylight use design solution elements. Solar shading would mean reduction of unwanted glare, even distribution of daylight and generated power can be used for driving the sensors o f the automated solar panel louvers.

CONCLUSION

Daylight can be a great source of passive energy, supplementing electricity consumption. Thus resulting economic efficiency. Statistics have also showed the beneficial factors of daylight use on users mental and physical health (Yousef Al horr, 2016). Through proper analysis of simulations, modifications can be made in existing offices to make efficient use of daylight. The author aimed to emphasize on the efficient use of daylight to improve indoor illumination and work efficiency. Through simulations of different modification propositions, these design strategies might give scope for further modification ideas and act as a general guideline regarding daylight usage and indoor luminous environment of offices in Dhaka's context.

Acknowledgements

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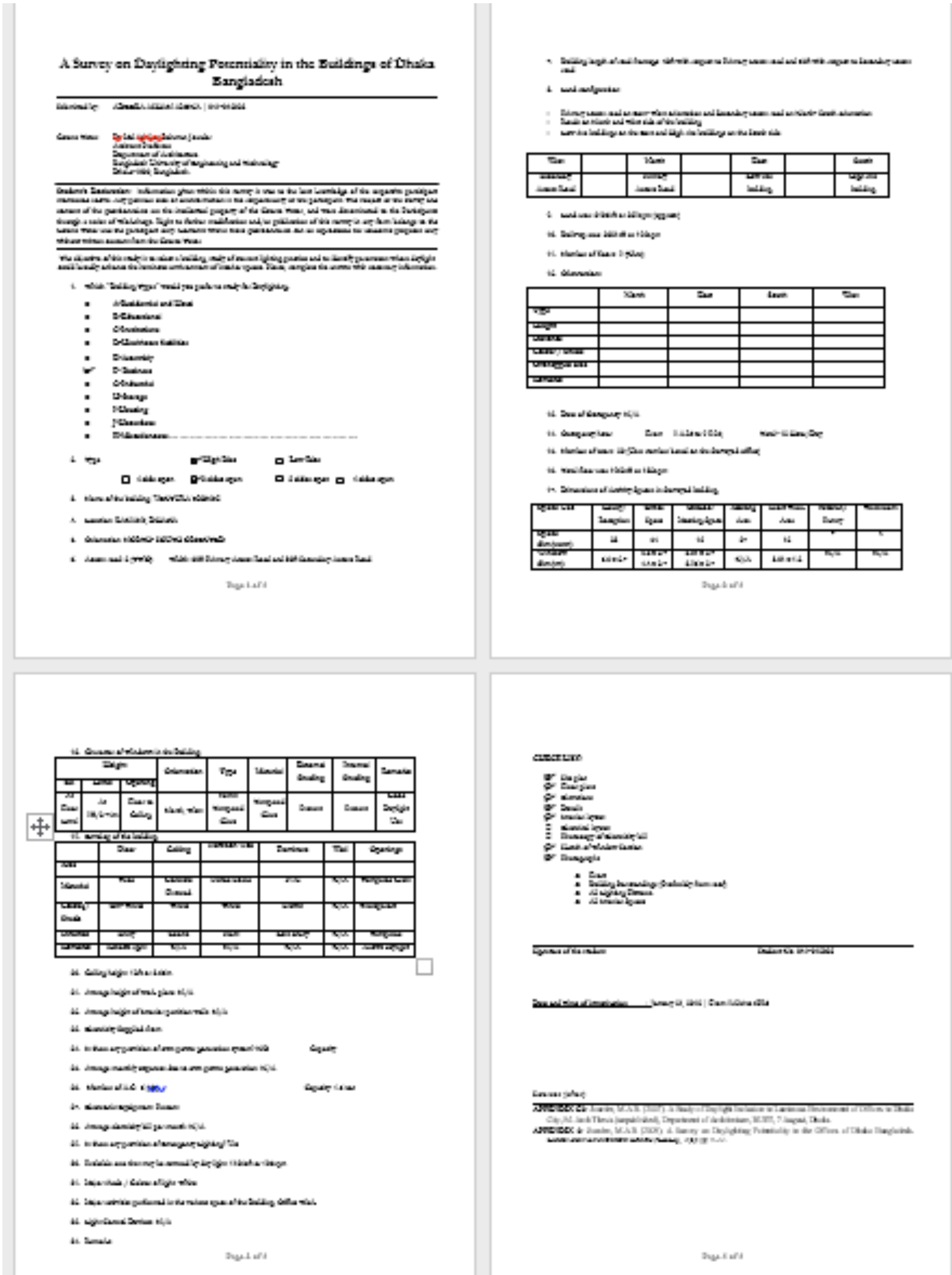
Contact email: archist.aaa@gmail.com

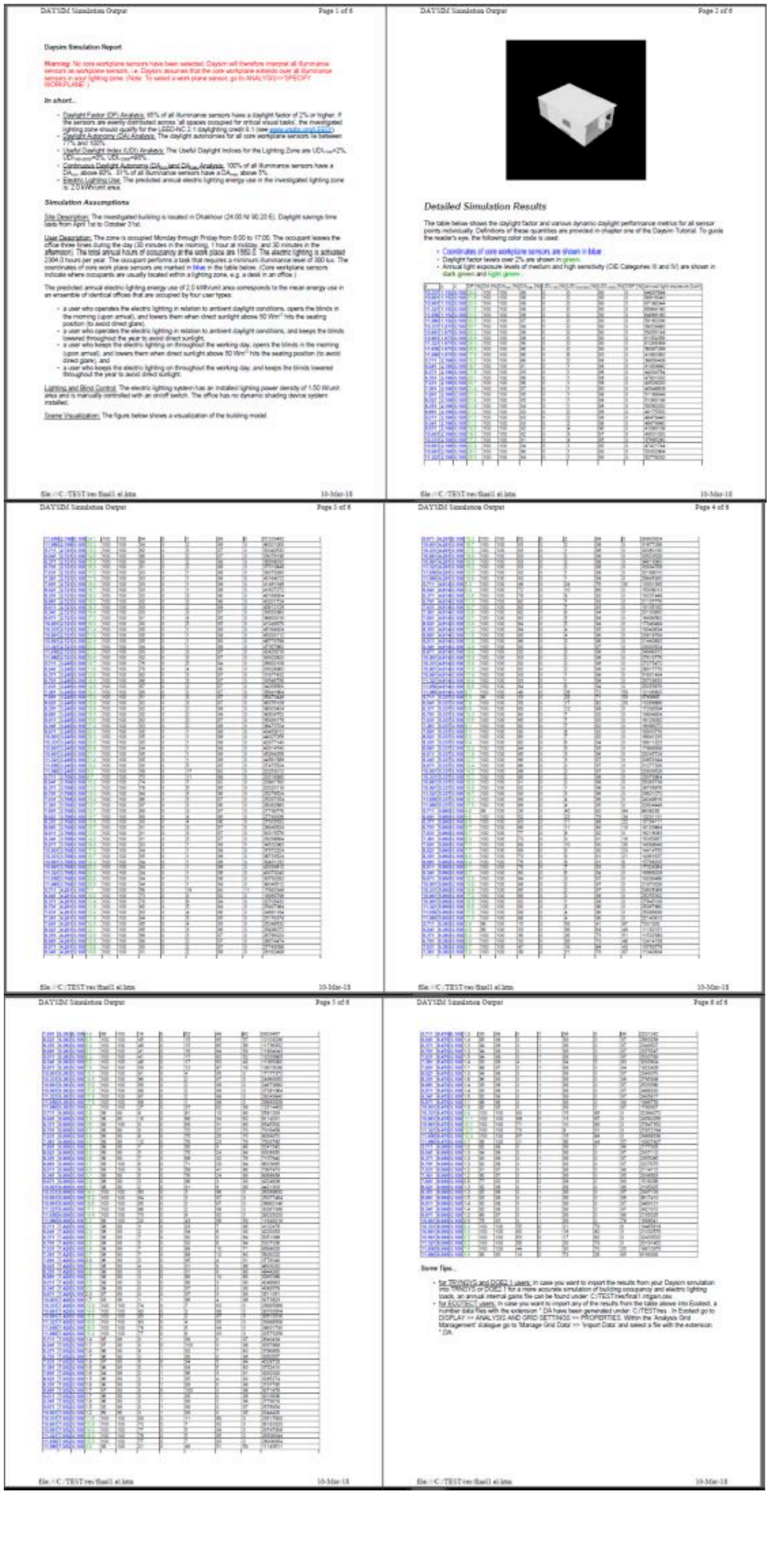
Appendices

Survey Questionnaire:


A Survey on Daylighting Potentiality in the Buildings of Dhaka Bangladesh

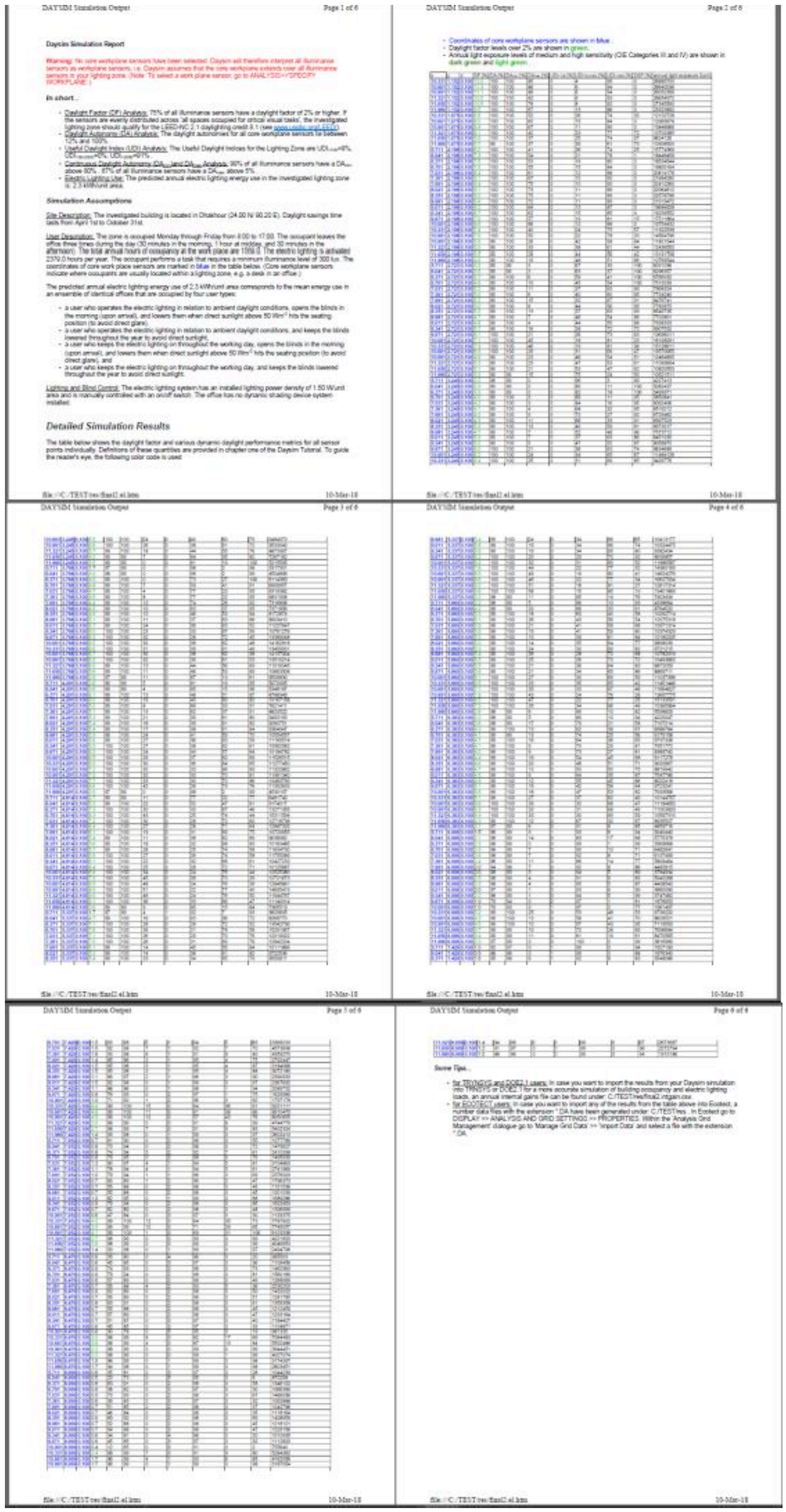
DAYSIM Analysis Reports:

Of Existing Condition

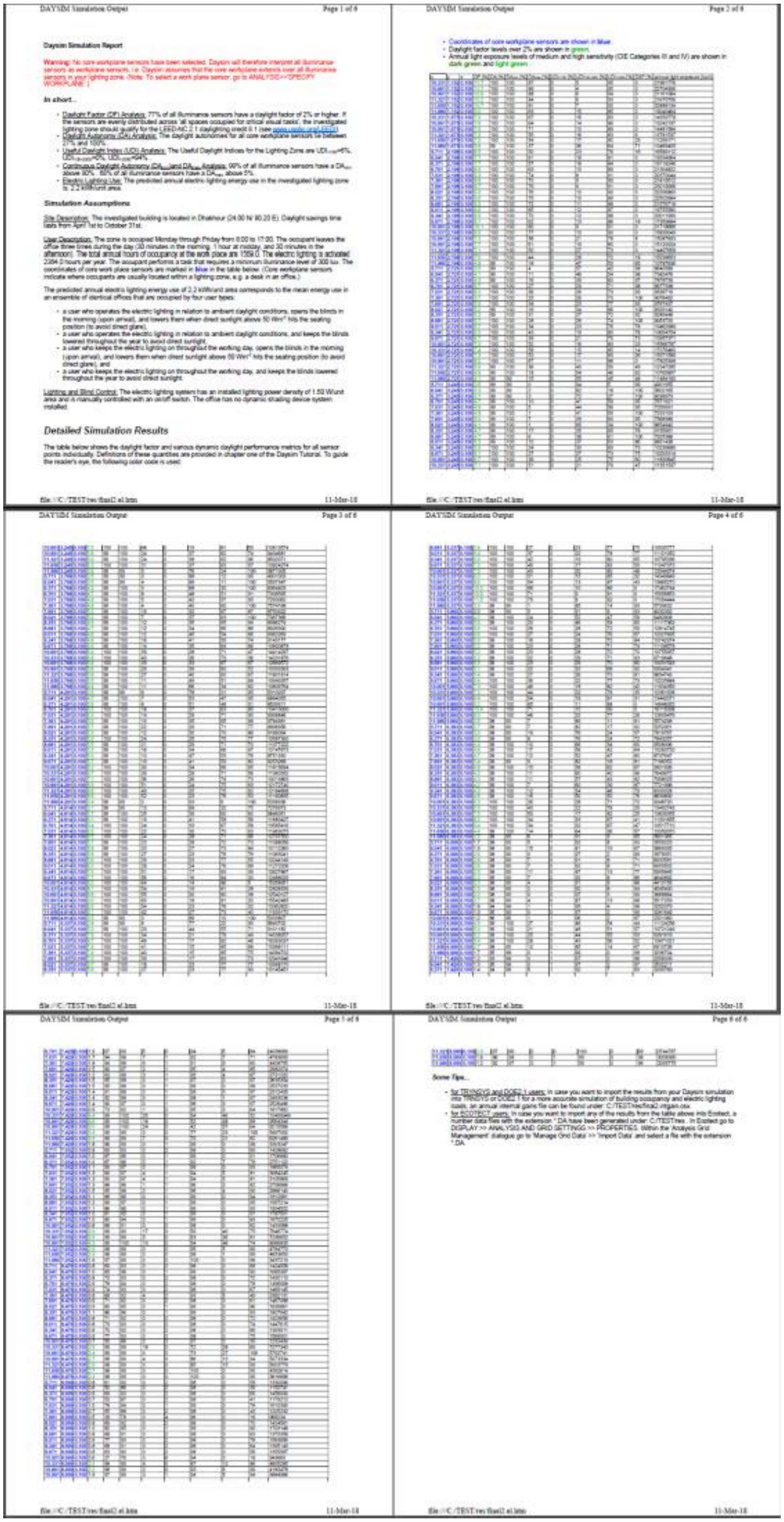


Solution-1:

Solution-2:



Solution-3:



DAYSIM Simulation Output

Daysim Simulation Report

In short...

Simulation Assumptions

Detailed Simulation Results

Some Tips...