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An Observation on Daylight Inclusion in the Lighting of Offices in Dhaka

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Abstract

This paper reports the findings of a study of existing office buildings in Dhaka City aimed at an understanding of their luminous environments. It was found that artificial light is the main contributor to the visual environment, even though there is an abundance of daylight during office working hours. Daylight should be encouraged in office spaces because, not only would it save on lighting energy, but it would also carry immense physiological and psychological benefits. This paper highlights the findings of the study and compares them with internationally accepted lighting standards for office activities. Measurements of illumination levels were taken in the surveyed offices and found to be much lower than international standards. Space usage by users seemed to indicate their unawareness of light issues. Design strategies to improve the luminous environment under daylight, artificial lighting and supplementary lighting have been discussed explaining design strategies to achieve standards, followed by a discussion of the extent these practices are followed in the surveyed offices of Dhaka.

Key words

Daylighting, Luminous environment, Supplementary lighting, Office lighting

1. Introduction

Daylight is one of the most important natural forces available to architects in their quest to enhance the visual quality of interior spaces. It is an abundant resource in the tropics, indispensable both as a primary source of illumination as well as an ingredient of drama, excitement and dynamism in the architecture and aesthetics of spaces.

Among the advantages of daylight are physiological as well as psychological benefits for users (Robbins, C.L, 1986, Ch 1). Not only does daylight allow one to save on electricity consumption for lighting, but some studies show that provided glare can be controlled, people perform better when exposed to daylight (Boyce, P, et al; 2003; p65).

The question of daylight inclusion in office buildings is extremely important for energy efficiency, as it reduces dependence on artificial lighting sources, and being day-use buildings, a significant portion of the use of these spaces coincides with times of substantial outdoor lighting.

At the same time, it must also be recognised that all the effects of daylight may not be beneficial for the users. In the tropics, with the daylight may enter unwanted heat. Too much or unguided daylight may cause glare (Bell, J; Burt, W, 1995). All these negative effects have energy implications, ie electricity consumption may be required to rectify these adverse effects. Therefore an informed balance must be struck between energy saved from artificial lighting use by daylight inclusion, and that spent to get rid of excess heat by air-conditioning (Ahmed, Z.N; 2006). Likewise, there will be other balances to be taken into account, related to ventilation, acoustic and other subjective concerns of privacy and view.

This paper examines the existing state of the lighting environments of typical office spaces in Dhaka city and

the issue of daylight inclusion within the lighting schemes surveyed. The findings have been compared with internationally accepted practices and standards, and some general guidelines and recommendations have emerged from the exercise.

2. Aims / objectives

One of the aims of this paper is to present an understanding of the nature of, and influencing factors of, the luminous environment found within office buildings, under the dense conditions found in Dhaka city. Lighting research in general, and daylight research in particular, is a very neglected field of research in Bangladesh, but this state of affairs cannot continue if we want to use our limited energy resources optimally. Through this paper, Architects will be able to develop awareness regarding issues relevant to lighting design in offices of Dhaka, and to improve consideration for daylight inclusion in these spaces.

3. The Investigation

This paper is based on a study[1] conducted for evaluating the visual environments in typical offices of Dhaka city, to investigate the lighting practices and to establish lighting levels under which users work and experience comfort. Typical examples, representing three trends of office layouts noted during the study, were chosen for a physical survey. The case studies were:

Type A: A corporate office in a high-rise building inserted within a commercial block, without any setback on the sides: represented by Anwar Group of Industries located in Baitul Hossain Building (Fig.1), 27 Dilkusha Commercial Area (size 630m^2, 14th floor, top floor).

Type B: A corporate office in a low-rise converted building at a corner plot of a residential area, represented by Parvin Properties & Technologies Ltd (Fig.-2), House no-4, Road no-6, Block- D, Lalmatia (size 406 m^2,Ground floor).

Type C: A corporate office in a high-rise building surrounded by wide roads and with shaded glass window façade, represented by Delta Brac Housing Finance Corporation Ltd, Landmark Tower (Fig.3), Gulshan (size 735 m^2, 11th floor)

The plans of the three surveyed offices, along with measured values of illumination at relevant points, are shown in the Appendices at the end of the paper.These offices were surveyed to determine:

- the physical dimensions of the different spaces and characteristics of the various features which affect the luminous environment, like window size and detailing, wall surface, space and furniture layout, etc
- measurements of illumination levels at three points in each area (see Plans shown in the Appendix), one near the window, the second one in the centre of the space and the third, furthest from the window. The measurements were taken using a Lux-meter[2], both in presence and absence of artificial light, at a height of 0.75 m above and parallel to floor level, signifying the work plane.

Once the existing details of the surveyed offices were recorded, they were compared with internationally accepted practices in lighting design.

4. Findings of the Survey

A study of the plans of the surveyed offices revealed that each of the offices includes the following major activity spaces/zones:

- lobby, with reception and waiting spaces
- large open office spaces for general desk work
- individual office rooms for key executives
- a conference room for meetings and consultations
- corridors for circulation between the zones

Fig :1 Type A , Dilkusha

Fig : 2 Type : B , Lalmatia

Fig : 3 Type : C ,Gulshan

Table 1a: Illumination level measured in the Surveyed Offices in Dhaka (lux)

		Lobby		Corridor		Individual office Room		Large open office space		Conference Room	
		i	*ii*	*i*	*ii*	*i*	*ii*	*i*	*ii*	*i*	*ii*
Type A	*1*	185	18	570	570	620	620	170	7	75	30
	2	275	12	290	20	200	115	170	6	250	25
	3	120	8	130	4	45	25	170	4	62	17
Type B	*1*	72	15	26	26	950	900	30	30	600	600
	2	112	5	48	10	88	35	65	15	170	105
	3	38	2	37	4	40	20	40	5	31	22
Type C	*1*	190	60	260	55	1500	1500	3200	3200	1700	1700
	2	275	45	180	35	227	170	380	220	270	180
	3	120	28	60	20	250	87	155	95	120	58

i – with Artificial Light *ii – without Artificial Light*
1 - near the window *2 - centre of the space* *3 - furthest from the window*

The different zones within offices have different lighting requirements. Measured illumination levels of these zones (shown in the Appendix) are compared in Table 1a. One set of measurements were taken with the artificial lights switched on (i) and another with them off (ii), to test the daylight penetration and its contribution to the illumination of the space during the day. In the absence of task lighting, only ambient lighting data could be obtained.

The comparison reveals that near the window, illumination levels are often equal, or close to equal, with and without artificial lights (Corridor in Type A; individual office rooms and open office space in Type A and C; Conference Rooms in Type B and C). The implication of this is that near the window it is natural light that is the dominant lighting source, and artificial light often has no contribution under these circumstances. In other spaces it

Table 2: Dimensions of Activity Spaces in Surveyed Offices (m)

		Lobby	Corridor	Individual office Room	Large open office space	Conference Room
Type A	Space dim	8x3	22x1.5	6x4	18x4	6x4
	window	nil	4.5x1.25	6x1.25	nil	nil
	Window: Floor ratio	0.00	0.17	0.31	0.00	0.00
Type B	Space dim	3x5.5	16x1.25	4.5x4	5.5x5.25	7x4
	window	2x2.25	4x2.25	2x2.25	2.5x2.25	1.25x2.25, 1.25x2.25, 2.5x2.25
	Window: Floor ratio	0.27	0.45	0.25	0.19	0.40
Type C	Space dim	6x8	12x2	8x10	5.5x6	5.5x4
	window	nil	nil	10x1.5	10x1.5	5.5x1.5
	Window: Floor ratio	0.00	0.00	0.19	0.45	0.37

Table 1b: Measured Outdoor Illumination level during Survey (lux)

During Survey of:	Av. Outdoor illumination	Max. Outdoor illumination	Min. Outdoor illumination
Type A	31,500	47,000	16,000
Type B	19,960	44,000	5,500
Type C	14,030	18,500	9,600

is seen that there is a sharp drop from measured artificial lighting level to daylight level. This is when the effect of daylight is extremely low, due to distance or lack of openings.

Outdoor daylight level data during the measurements at 2:30 pm in the afternoons of three separate days of the survey, in September and October, are shown in Table 1b. Relating Tables 1a and 1b, clearly very little of this abundant resource penetrates the interior even near windows. Calculating the Daylight Factor[3] using the average outdoor illumination of Table 1b and measured illumination data from Table 1a, it is seen that only the large office and conference room of Type C, with three sides open uses this daylight near the window, and it falls sharply as distance from the window increases.

5. Comparison with internationally accepted practices and standards

One of the aims of the study was to evaluate the lighting conditions in these existing offices in terms of nationally and internationally accepted practices and standards. Whether using daylight or artificial light separately or in conjunction with each other, lighting in offices in the developed world distinguishes between the ambient component and the task lighting. Ambient lighting gives the space its general operable illumination by which people can move around freely. The ambient lighting is usually relatively uniform, giving the space a well-lit appearance without patches that are overly bright (thus energy intensive) or under-lit and gloomy (which create the illusion of low lighting even under functional/standard levels of aver-

Spaces	International standards (Lux)	BNBC standards (Lux)	Range of average illumination in Survey (Lux)
Lobbies and hallways	100–200	150	100-200
Typical offices	400–600	300	35-200
Computer work with task lighting	200–400	Not specified	50-150
Paper tasks with task lighting	400–600	Not specified	50-150
Specific tasks (fine details)	600-1200	Not specified	50-200
Conference and meeting	300–500	300	150-230

Table 3: *Comparison of Standards[4] and Actual illumination levels for different activity zones (lux)*

The main dimensions of the different activity spaces surveyed, of the three case studies are presented in Table 2, along with window size and the ratio of window: floor of the different spaces.

Most of the installed lighting is overhead and there is almost no instance of artificial lateral lighting, which to a limited extent only, is provided by the windows.

The main light types used in these offices are:
- Imported Louvered Shade Light: 2'x2' (four 2' tubes making a square fixture, total 80W) or 4'X1' (two 4' tubes in a rectangular box, total 80W) fitted into the false ceiling.
- Energy Saving Down Lights (CFLs): ceiling mounted concealed type light shade 18W/20W each.
- Halogen Down Spot Lights: ceiling mounted conceals type light shade, 100W each.
- Single Tube Light: 2' (20W) and 4' (40W) used in toilets, tearooms and storerooms.

age illumination). Table-3 gives comparison between international illumination standards (Architectural Graphic Standards, 2000) and local recommendations (BNBC; 1993; p8-7) for the different zones and illumination measured in the surveyed offices. These values include ambient as well as task lighting.
The illumination level comparison shows that in the surveyed cases the highest levels are reached in Conference/meeting rooms and in lobbies, though standards require higher lighting in other task areas, eg where desk work is likely to be more intensive.

6. Lighting Design Strategies as found in Case Studies

Whether a space is lit exclusively by daylight or by artificial light, or whether by a combination of the two, ie, by supplementary lighting, some general design strategies can help to make the visual environment comfortable,

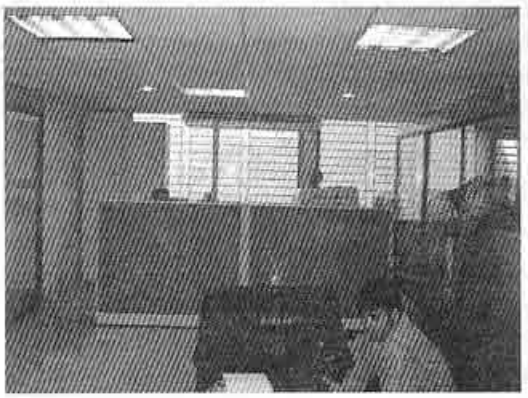

Fig: 4 Lower False Ceiling, Type A

Fig: 5 Glazed Windows

glare free and energy efficient. These strategies are discussed separately in this section explaining design strategies to achieve standards, and to what extent these practices are followed in the surveyed offices of Dhaka.

6.1 Daylighting strategies as found in Case Studies

Daylight penetration will be greater if, among factors like large window size, light coloured internal surfaces, regular maintenance and a large angle of open sky can be seen from the window (Bell, J; Burt, W; 1995; p31).

Strategies available to architects to achieve good daylight distribution are:

- *Positioning windows high on the walls*: Windows placed high in the wall near the ceiling provide the most daylight for any given window area, permitting daylight to penetrate more deeply into the interior (Egan, M.D; Olgyay, V.W, 2002). But introduction of false ceiling in almost all the surveyed office interiors terminates this option, allowing only low level windows. (Fig.4)

- *Sizing windows according to orientation and use:* as high sky areas may create sky glare (Evans, M; 1980), especially from non-polar orientations, glazing should be kept to a reasonable minimum. Separate windows may be designed for needs such as view, visual relief, ventilation, etc, which may be positioned low in the walls at level with activity areas, and for daylighting, higher up. In the surveyed offices, such consideration is not given to the design of windows, where apertures are provided on the exposed wall, regardless of orientation, or of daylighting possibilities (Fig.5). These windows are mainly designed with geometric and aesthetic considerations.

- *Considering the window: floor area ratio:* The ratio between window: floor area is a significant factor in the spread of daylight. Many countries around Europe use this ratio as minimum requirement just to ensure daylight provision, eg. in Greece it is 0.1 depending on the building type. In France designers tend to use the rule of 1/6 = 0.17 as a way to size correctly the windows in a space to be well daylit, and the rule of 1/8 = 0.12 for the minimum size (Fontoynont, M, et al; 2004). The survey shows that the highest value of this ratio was found to be 0.45 in Type C, in the general office space where there are windows on three sides (Table 2). Such a high ratio should be treated with caution, as the incoming daylight is likely to have high heat content. In all spaces with windows, the ratio was found to be larger than standards require.

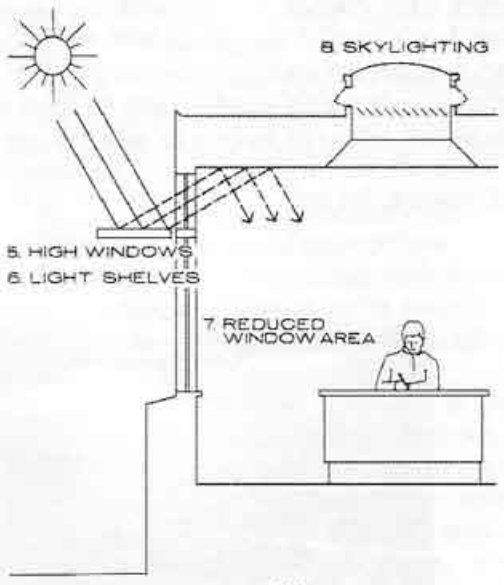

Figure 6: Daylight Options. (Source: Architectural Graphic Standards, 2000)

- *Utilizing sunshades to act as light shelves*: Light shelves can be used to reflect daylight onto the interior ceiling, making it a light-reflecting surface (Fig.6). A light shelf shades the lower portion of any window, reducing the amount of light near the window, which typically has much higher illumination than the deeper parts of spaces, while allowing in light from higher levels to penetrate deeper into the space. The result is a balanced luminous environment, with less contrast and glare. In Dhaka, consideration for shading is only given to protect from sun and rain. The concept of glare control and ceiling illumination using reflections off a light shelf is not practiced consciously.

- *Installing skylights where possible*: Skylighting, when properly sized and oriented, is an efficient and cost-effective source of daylighting. Cost-effective, energy-efficient skylights can be small, spaced widely, with "splayed" interior side walls that help reflect and diffuse the light. (Fig.6). White-painted ceiling and walls further improve the efficiency of daylighting (by as much as 300% if compared with dark interior finishes) (Architectural Graphic Standards, 2000). However, in tropical areas, because of the high heat content of daylight, skylights should be carefully evaluated for the additional solar radiation gains. Moreover, this option is not available unless the space is on the top floor with a roof available for such manipulation. This option was not found in any of the surveyed offices. However, the trend of adding skylights on top floors is not a new one even for Bangladesh and can be found on atriums around the city. More research needs to be conducted on the balance between energy saved from daylighting and that expended in cooling the space because of the additional solar radiation.

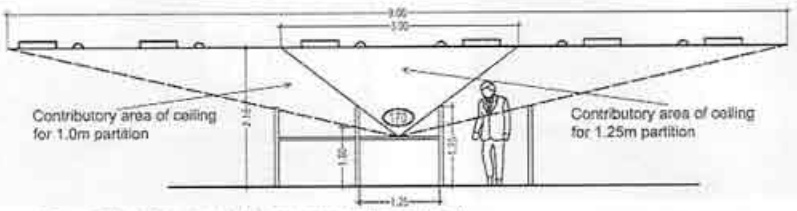

Figure 7: Light fixtures contributing over partitions, Type A.

6.2 Artificial Lighting strategies as found in Case Studies

Early in the history of lighting, illumination systems were designed for minimum use of interior space at night. Today, however, electric illumination systems generally are often designed to be used in place of natural light, even during the day. Among aspects affecting the general lighting condition of an office space are room dimensions, geometry and reflectances, type, number and height of source/fixtures above work plane, etc. (Architectural Graphic Standards, 2000) These aspects are discussed in this section with reference to the Case Studies.

- *Room dimensions, geometry and reflectances*: In the surveyed offices, dimensions and geometry of which are given in Table 2, all surfaces were found to be light in colour, having high reflectances. Fixtures were almost all overhead, attached to the ceiling, with hardly any task lighting. However, the shades often increase the light loss factor, as their design concentrates more often on aesthetics and economy of manufacture, rather than luminance distribution.

Figure 8: Lower Partitions with glass. Gulshan 1.

Figure 9: Equidistant lights, Type A.

- *Source type and position:* In the developed world, different types of lamps are available to meet various viewing purposes, ranging from the incandescent lamp invented in nineteenth century, to the more recent discharge lamps of neon, high pressure mercury, low pressure sodium, metal halides, fluorescent tubes, compact fluorescents, etc (Phillips D, 2000). While the position of light can be from overhead or from lateral directions.

But in Bangladesh only a few types of lamps are popularly used, although numerous types of lighting shades are available. The survey revealed only three types of electric lamps being used for electrical lighting in the office interiors, irrespective of activity and work. These types were fluorescent tubes, compact fluorescent energy saving down lights and halogen spot lights. According to the local and international lighting appliance supplies, 60-80 million units of lamps are sold in Bangladesh each year, of which 90 percent are incandescent lamps, 9 percent are fluorescent tubes, while only about 1 percent are Compact Fluorescent Lamps(CFL) (Haq, A.S.M.B; 2005). But because CFLs use only about a quarter of the electricity used by incandescent bulbs of similar illumination outputs, their use for artificial lighting should be encouraged. Regarding position, only ceiling mounted lights were found in the surveyed offices, with no examples of lateral artificial lighting.

- *Partitioning the space*: Partitions influence the distribution of light within large open office spaces, as they are capable of cutting off light from overhead fixtures to workstations. In the Type A office in Dilkusha, workstations are contained within 1.25 m high panels. Extending "sightlines" (as if the desk top could "see" the ceiling) from the centre of the station out to the ceiling over the top of the panels, it can be seen that in a 1.25 m by 1.25 m workstation, a ceiling area of 9 m^2 (3m x 3m) has the potential for contributing light to the workstation. In this area of ceiling, four pairs of lighting fixtures were installed 2m apart, each containing one 2'x2' Louvered Shade Light (each of 80W) and one Energy Saving Down Light (20W). The illumination level on the desktop from these fixtures was measured to be 170 lux (Fig.7). If the same 1.25 m by 1.25 m workstation had lower partitions of 1.00 m, the projected lines would enclose a ceiling area of 81 m2 (9m x 9m). This area includes another 32 pairs of lighting fixtures. This inclusion would cause significant increase in incident light, the exact amount depending on distance of lighting fixture from the desk top, and its angle of incidence (Fig.7). The effect of partitions can be minimised by making them transparent, thus increasing the illumination level, as seen in Fig.8 in a Gulshan office.

6.3 Supplementary Lighting strategies as found in Case Studies

When artificial lighting is used in conjunction with daylight, it is better known as supplementary lighting (Hopkinson, R.G; 1963), and results in energy savings. This form of lighting is extremely relevant for tropical areas like Bangladesh, despite the abundance of daylight, to cut down heat input and to avoid glare. Window areas can thus be kept to a minimum, allowing greater noise, dust and rain protection, while plans can be deeper. In spaces with supplementary lighting, natural light can provide ambient illumination, reducing the use of electric light, which can be used for task lighting.

Figure 10: Windows are blocked with furniture, Type A.

The general characteristics of supplementary lighting are (Robbins, C.L; 1986)

- the daylight character of the space should be maintained so that occupants far from windows do not feel deprived of daylight
- total illumination levels should decrease away from window, to keep the impression of daylight penetration, even though illumination from artificial lighting increases with distance from the window
- the colour of artificial lighting should give good daylight rendition and sources should be unobtrusive
- there should not be uneven patches of brightness in the space, and blending of levels should be aimed for

separate daytime and night-time switching should be provided

- automated controls should be installed to minimise waste and save energy (Energy Research Group; 1994; p12). Manual controls to dim lights when daylight contribution rises, and to increase levels when outdoor light falls, is not practical, as in general offices rarely would anyone be sufficiently interested enough, or aware enough, to consider these aspects. Thus lights would remain at a high level for visual performance and continue at the same level irrespective of daylight increase outside.

In the surveyed offices, almost no indication was found that the installed lighting system was designed with consideration of daylight. For instance:

a. It was found that the overhead lights were equally spaced, whether near the window or far from it, controlled through general switching (Fig.9) Moreover, the illumination levels measured in many of the spaces were found lower than international or local standards, showing that the numbers of fixtures are not based on calculations related to functional lighting requirements.
b. Users seem unaware of the need for outdoor light in their visual tasks, as they use spaces with curtains drawn, working under artificial lighting conditions. Similarly cabinets and other furniture are placed adjacent to window walls, blocking daylight penetration (Fig.10)

The supplementary lighting strategies discussed in this section are not followed in the lighting design of surveyed offices, despite the fact that daylight is available and should be considered in such day-use buildings.

7. Conclusive Remarks

Surveys show that lighting design in general is a neglected aspect of the overall design of spaces in Bangladesh. From the measured illumination levels, it is clear that lighting levels are well below acceptable standards, indicating that lighting levels are not considered during design in an organised way, to fit the function or to satisfy any standards. And even rarer is any consideration given to including the available daylight to supplement the scheme.

However, the importance of trying to save on energy consumption by including this abundance of daylight that exists in Bangladesh cannot be disputed. Other than energy savings, daylight is also preferred due to the physiological and psychological benefits it can impart to users.

It has been one of the aims of this paper to present an overview of the luminous environment found within different types of office buildings that exist in Dhaka city, where aspects of the interior that affect this environment have been examined in a limited number of case studies. Daylight and artificial lighting research is a relatively neglected field in Bangladesh, and this paper attempts to highlight the need for such research, and to create awareness among Architects regarding the myriad issues that affect the luminous environment.

End Notes

[1] *Joarder, A.R; (2006); Investigation of Luminous Envronment of Office Buildings in Dhaka City and it's impact on Energy Consumption; unpublished report for M.Arch course ARCH 6103; Luminous Environment and Built Forms, BUET; Supervisor Z.N.Ahmed*

[2] *TES 1332 Digital Lux Meter; range 0-200,000 lux*

[3] *The ratio of indoor illumination to the simultaneous outdoor value expressed in percentage.*

[4] *Internationally accepted standards on lighting tasks from Architectural Graphic Standards, 2000*

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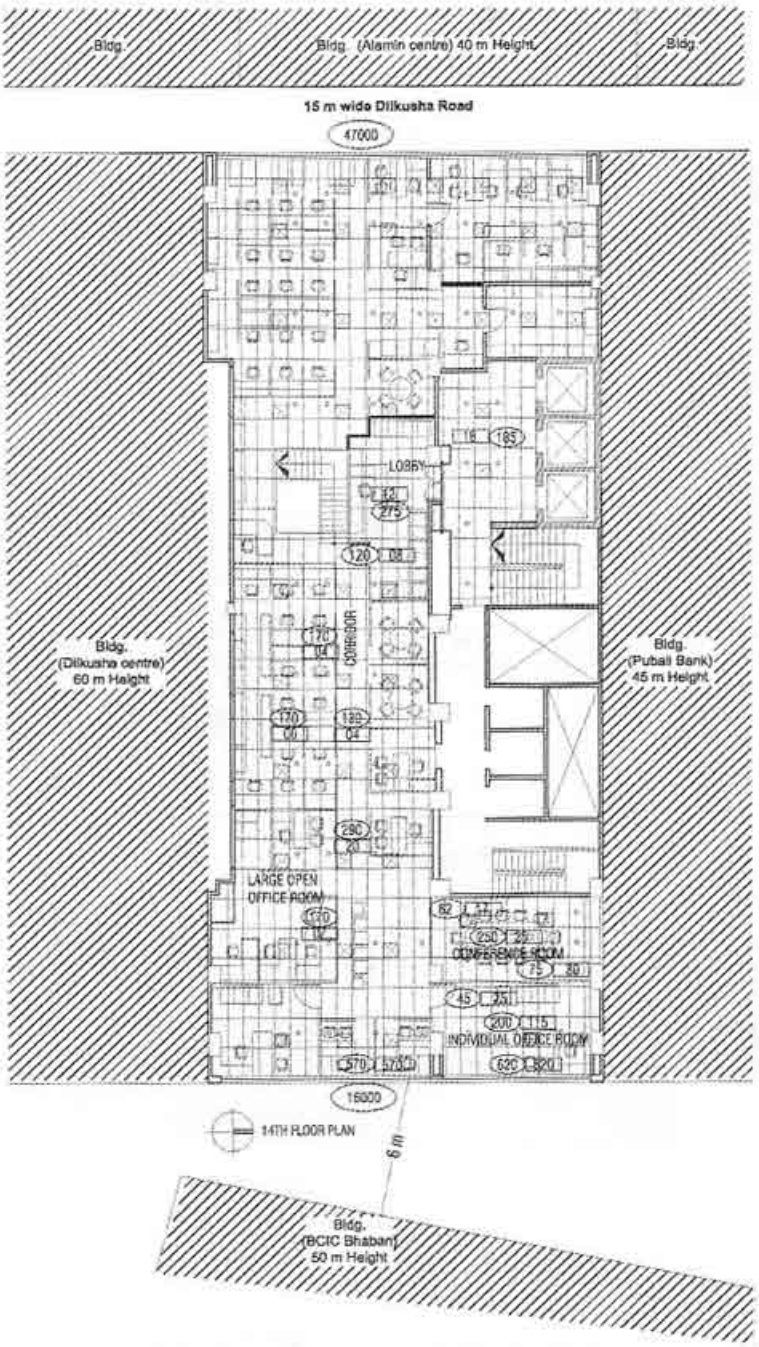
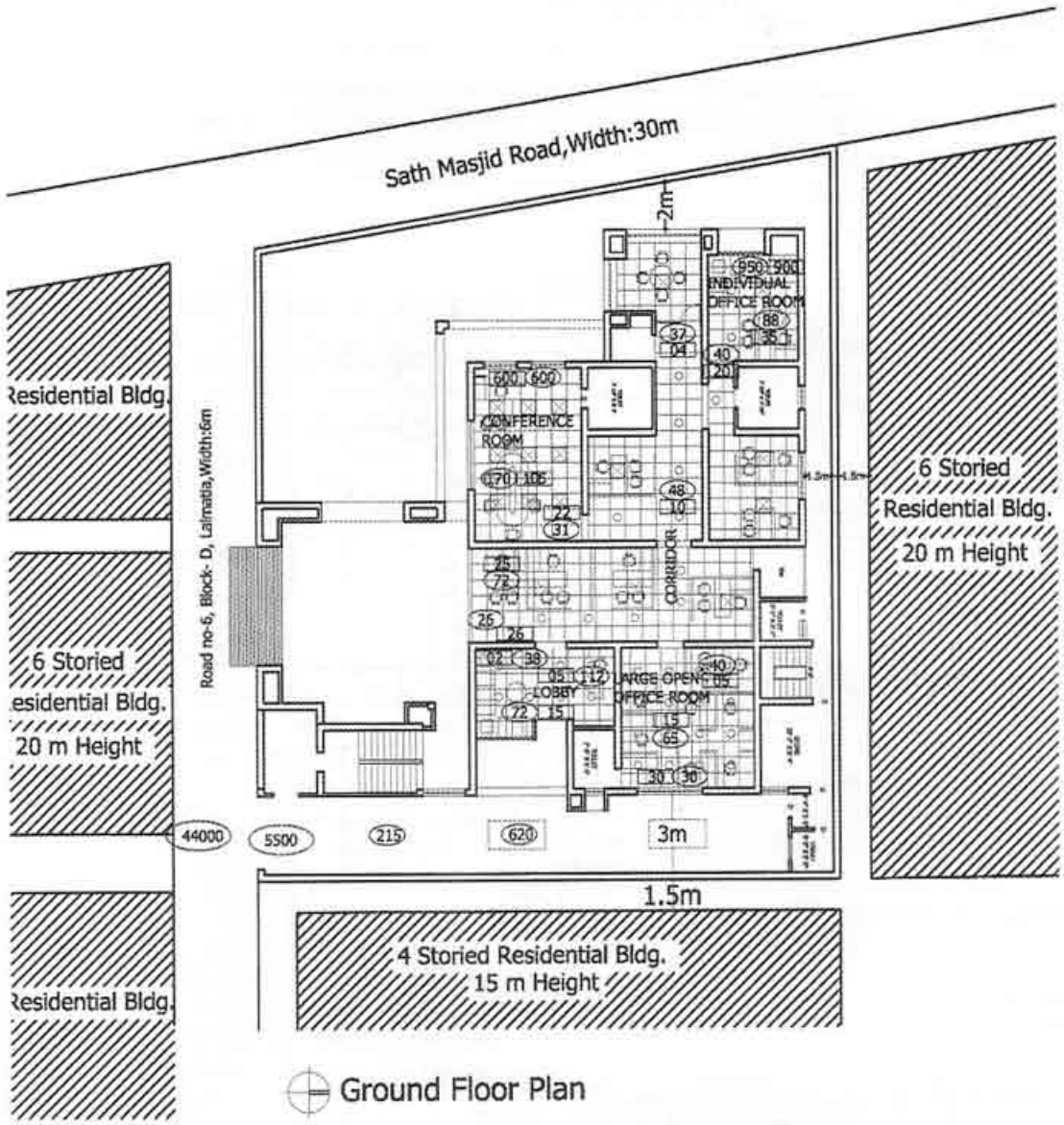
Note: Values in ellipse are measured by lux Meter with the artificial lights switched on (i)and in rectangle are measured



Apendix (1) : Layout plan of Anwar Group of Industries (Type : A)

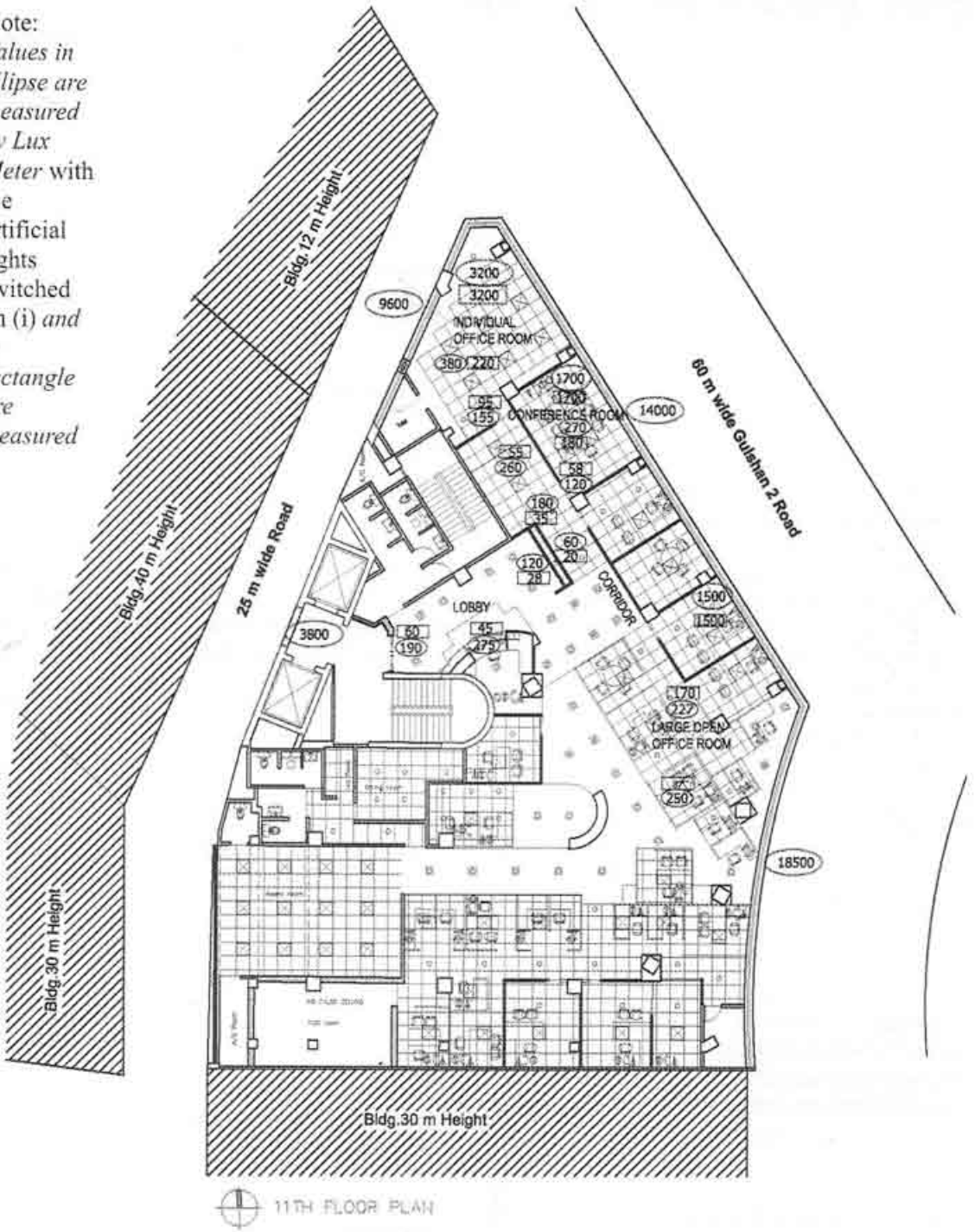
Note: *Values in ellipse are measured by Lux Meter* with the artificial lights switched on (i) *and in rectangle are measured* with switched off (ii) *as shown in Table 1a of the paper.*



Ground Floor Plan

Apendix (2) : Layout plan of Parvin Propertoes and Technologies Ltd (Type : B)

Note:
Values in ellipse are measured by Lux Meter with the artificial lights switched on (i) *and in rectangle are measured*



Apendix (3) : Layout plan of Delta Brac Housing Finance Corporation Ltd (Type : C)