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DAYLIGHT FOR SUSTAINABLE REGENERATION BUILT HERITAGE SITES ONLINE

Hisham Elkad and Sura Al-Maiyah

School of Architecture, Deakin University, Melbourne, Australia
School of Architecture, University of Portsmouth, United Kingdom

ABSTRACT

Daylight is an essential contextual ingredient of place making. Research in daylighting has recently received major attention for its valuable contribution to the sustainability of the built environment. Previous research has investigated the role of daylighting in energy efficiency, its regional qualities in relation to the façade configuration, and its contribution to the sense of visual comfort. This paper argues that appropriate use of daylighting will ensure not only visual and thermal comfort in an urban setting, but also contributes to the place identity and hence sustainability of urban regeneration projects. The paper identifies the daylight variables that affect the place-making process in the urban fabric of the Eastern Mediterranean. Daylight variables in public open spaces, a combination of sunlight, skylight and the reflected light from the facades and the ground, are identified. The *Solar altitude*, *the geometry of sectional profiles*, *the reflectance of the opposing facades*, *the width of the street* and *the density of the urban built environment* are applied as the main variables that determine the daylight performance. Located in the historical Darb al-Ahmar district, Aslam Square is recently selected as part of one of the rehabilitation project in Cairo. This paper examines the photometric and morphological properties of the existing configuration using daylight simulation software. Various spherical projections were developed to represent full 3D visual environment. The paper calculates and analyses the direct radiation energy, the sky diffused energy and the reflected energy in the case study.

Keywords: climate responsive static sunshade, small-scale experimental models, sunlit area, shaded area

1. DAYLIGHT PERFORMANCE & PHYSICAL CONTEXT

Daylight performance in an urban context depends on a combination of direct sunlight, diffused skylight and the reflector of light from the facades and the ground. Daylight literatures identified a number of technical variables that are related to the characteristics of space configuration that impact on the daylight performance.

- ***The frame Configuration Variables***

Reflected light of the other building facades is one of the well-recognised strategies that have been used to illuminate the building interiors and the areas around buildings (Robbins 1986, Lam 1986). Matus (1990) has suggested that facades surfaces, as source of reflected light, have a role in the enhancement of urban open spaces. Tregenza (1995) has also introduced a split-flux technique of determining the mean internal illuminance of space in a sunlit street with an opposing façade. Wa-Gichia (1998) has argued that the opposing façade of the buildings is a potential passive daylighting device to the internal sphere under clear sky conditions. He stated that the *reflectance of the opposing facades* and the *geometry of the sectional profiles* are among the main variables that affect daylight propagation and performance. Similarly, Tsangrassoulis *et al.* (1999) have investigated the potential of vertical south-oriented facades to reflect daylight onto the opposing facades under sunny conditions. Under clear sky conditions, three parameters determine the contribution of the reflective vertical plane to the total energy. These are the reflection specification of the plane, its orientation, and the horizontal distance separating this plane from the target point in the space.

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- ***The floorscape Configuration Variables***

Ground plane is also considered a potential source of reflected light that could play an important role in increasing or decreasing the total amount of light reaching a station point in a room or space (Robbins 1986, Lam 1986). For dayligting of open spaces, the contribution of ground reflected light to total energy is mainly influenced by *floorscape* (ground plane) surface area, the reflection specification of the floor materials and the height at which the daylight is calculated. The influence of the ground reflected light is however diminished for spaces further away from the ground (Wa-Gichia, 1998). Effective ground reflection, on the other hand, is a function of predominant sky conditions. It has been stated that horizontal surfaces are more effective on overcast sky conditions, whilst vertical surfaces are more useful in clear sky conditions (Robbins, 1986).

- ***The Space Configuration Variables***

Studies concerned with the morphological definition of the space have introduced a set of geometrical variables to evaluate the enclosure quality of the space. A number of such morphological variables, such as the width to height or the height to ½ length ratios, have an influence on the daylight propagation of the space. Daylight literature has highlighted the impact of built density or the width to height ratio of the space configuration (street) on the daylight performance. Dekay (1992), for example, has recommended that the height width relationships to be between 1:1 and 3:1 in built urban environment if adequate daylight is to be obtained. Sky opening (sky view) factor, which has been primarily introduced as an urban quality factor, is also used in prior work as a measure of daylight availability in the urban fabric (Ratti, 2004) representing *the percentage of the sky visible from a point* (Teller& Azar, 2001,Teller 2003). To explore the impact of built density and sky openness on the daylight performance of the examined case study, comparative analysis of daylight is conducted in section 3 between the different located- points within the space.

2. THE DAYLIGHT SIMULATION MODEL OF ASLAM SQUARE

The regional characteristics that endow the daylight phenomenon its' peculiarity is subject to a list of meteorological, seasonal and geographical parameters. Previous studies showed that daylight performance is directly related to the predominant sky conditions, solar altitude, the sky cover, humidity and pollution ratio and the season type (the track of the sun).

The impact of such technical and the environmental variables on the daylight accessibility energizing the internal (indoor) sphere has been previously explored, yet there is a room for investigation such influence in respect to external (outdoor) sphere. This paper examines the daylight performance in open spaces within the urban fabric in old Cairo. The paper investigates the dynamic nature of such performance at different times of the year.

- ***Phase One: The Simulation Workflow***

The adopted methodology utilizes a combination of *photogrammetric* and CAD software with lighting simulation tool. Similar integrated approach has been conducted by Mantzouratos *et al.* (2004). The *photogrammetric* approach is used to extract the geometry of the building in the lack of the required detailed architectural drawings of the historical buildings. The understanding of the morphology of fabric and its features in urban places requires similar *photogrammetric* analysis. Three-dimensional CAD model for the selected case study is created and two dimension CAD drawings in the case of the Aslam Square are used to set up the digital model (Figure 5). A set of digital photographs of the facades of the selected configuration is used to identify the geometry of the three-dimensional *frame* of the space.

Following the exportation of a 3D CAD model in 3D Studio, the second phase of the method was to assign the photometric properties of the scene. Variables for the photometric properties are assigned to the developed 3D model. The variables are selected from the in-built library of the selected simulation software (TOWNSCOPE III). Information of the reflection and diffusion properties of materials of Aslam Square is obtained from the daylighting key textbooks. The percentage of the quality of opacity was applied equal to 0 in the case of transparent surfaces and 100 for the opaque materials. The regional characteristics of the daylight is partly identified by assigning the latitude and altitude parameters of the target context. The definition was however completed after detailed hourly meteorological data for the cloud cover, diffused and direct solar energy (vie using the meteo-file in the software) and parameters for the relative humidity and atmosphere turbidity were all fed into the package. The simulation is primarily conducted to assess the *solar access* and *sky opening* characteristics of the developed model. *Direct*, *diffuse* and *reflected* components of daylight via solar access analytic tool of a selective setting in the Cairene context are simulated for the mid of June and December.

- ***Phase Two: The Case Study Definition***

Although traditionally the international significance of Egypt has been ascribed to the wealth of Pharaonic heritage, the legacy of historic Islamic Cairo has recently awakened growing interest. The uniqueness of the city has been ascribed to its unequalled density of monuments where supreme historical value dates to the Middle Ages (Fletcher, 1996). Located in the old Darb al-Ahmar district in Cairo, the selective Aslam Square is selected as part of a rehabilitation project, recently conducted by Aga Khan Trust for Culture (AKTC). In order to encourage informal contact and community life, number of objectives has been addressed where the square targets for improvements. Its proximity to Bab al-Mahruq, one of the principal historic gates existed along the eastern side of the Ayyubid city wall (Figure 1), stems an interest in the area and inspires an idea of re-creating the old threshold. With the creation of the Azhar Park on the west side of the walls, it is visualised that, "*this old connection will be re-established and Aslam Square gradually equipped to serve both as pedestrian link and as a forum for commercial activity and social interaction*…" (Siravo, 2001, p.45).

Aslam square represents, therefore, an important ingredient of the regeneration of the area. With the ongoing debate in Cairo on the levels of success and the loss of identification in similar projects in the old city, it was decided to select Aslam Square as a case study.

Figure 1: Site plan of Aslam Square in Darb al-Ahmar district/Historic Cairo

Figure 2: The stone Façade of the Islam mosque occupying the northern boundaries of the square

The configuration of Aslam Square is marked by the composition of ASLAM mosque dating back to the *Mamluk period (1344-45).* Series of local commercial shops facing the southern stone facades of the mosque occupy on the southern side of the square. Multi use commercial and residential blocks are lining the square on the east and the west sides. The square is 15.10m by 28.53m with a range of width to height ratios. Shading devices are found covering parts of the southern portion of the ground in front of the shops adding to the shading devices on the eastern and the western facades. Reflection specification of the vertical and horizontal planes of the configuration is given in Table 1.

Table 1: Reflection coefficients of the square configuration

The frame characteristic			**The floorscape characteristic**	
The northern façade				
Reflectance coefficient (surface)	Stone	0.40		
Reflectance coefficient (apertures a)	Glass	0.08	Reflectance coefficient (ground surface)	Asphalt 0.2
Reflectance coefficient (apertures b)	Oak	0.05	Reflectance coefficient (northern platform)	Stone 0.4
The southern, eastern and western façades	Plaster	0.65		
Reflectance coefficient (surface)	Glass	0.08		
Reflectance coefficient (apertures a)	Oak	0.05		
Reflectance coefficient (apertures b)	Corrugate iron	0.16		
Reflectance coefficient (shading devices)				

Source: (Azar, S., 2004), (Baker, N. and Steemers, K., 2002)

- ***Phase Three: The Simulation***

A number of scenarios are employed to explore the performance of daylight in the selected space configuration. Four sets of points are arranged at 1.8m height to explore the daylight performance at the eye level height. The points are assembled on the main axes (A1, A2, A3 and A4) that go through the square. The four axes are plotted within the square field of vision (Figure 3). Apart from axis 4, which includes 9 points in response to the width dimension, each of the other axes (1, 2 and 3) has 11 points. The sky opening value at each point is also calculated and the overall solar access of the Aslam square setting is simulated.

3. THE ANALYSIS

Various phases of analysis are carried out to identify the peculiarity of daylight performance in the case study. As previously mentioned, a system of four axes that are consisted of 39 points is used to examine the daylight's performance in the square. Each point occupies particular portion within the square field of vision that would affect the received energy due to the impact of orientation, proximity of the skin and other related variables. Preliminary investigation shows that the performance of daylight in the examined site is closely related to the geometrical and photometrical characteristics of the space's planes. Different daylight levels are obtained according to the location of the points within the square field of vision.

In order to examine the impact on the visual experience of the users of the square, two sets of scenarios are analysed. The first one is the changes in visual experience during movement between the entrances and the mid point of the square. The second scenario is the change in the visual experience between the shaded points and the mid point of the square.

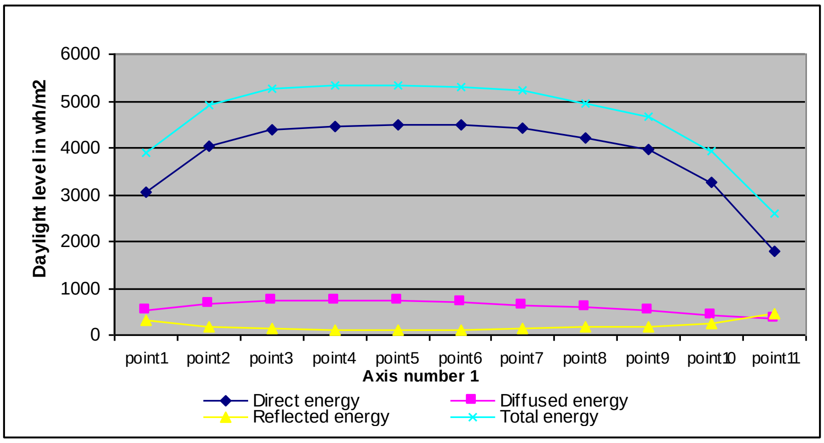
- ***Analysis of light transition between entrance points and the mid square points***

The paper simulates the different energy levels at the square's entrance points, where a high compact ratio reflects the closeness of the place. The results of the simulation show immediate changes of daylight levels at the entrance points. The narrow lanes leading to the square, which have very low daylight levels, has led to sudden changes of the quantity and hence, the quality of light at the identified entrance points. Alleyways have an integral part of the visual experience of the users of open spaces in those cities. The calculations at the four points located at axis 1 between the entrance (point 1 and 11) and the mid square (point 6) show, on the other hand, a gradual reduction in the energy from the direct and the diffuse components (Figure 4) towards the mid square points. Similar results were obtained from the simulation of points on axis 2 (Figure 4 -b). Conversely, the reflected energy is reduced in the mid points of the square as the contribution from the vertical surfaces decrease (Figure 4).

Figure 3: Benchmarks distribution system in the square

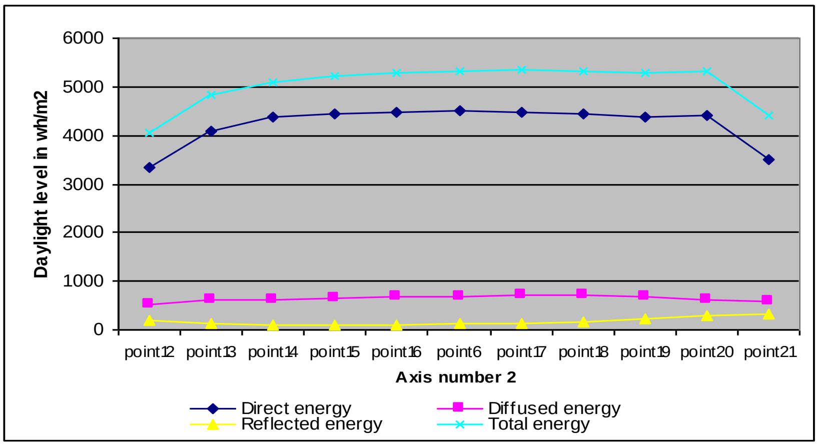
The above analysis in mid June shows that the direct energy component has the highest impact on the overall performance of daylight (Figure 4). Simulation of daylight performance during wintertime (Mid December- Figure 5) shows that the diffused energy component has the highest contribution to the total energy. The complementary effects of both direct and diffused energy on one hand and the reflected energy on the other provided the designers with a useful tool to control daylight levels through a variety of compactness ratios in the medieval cities. There are reasons to believe that this phenomenon was well understood in the South European environments. Designers have continued to use light finishing materials to increase the reflection components in the urban spaces to compensate for the low lighting levels in winter times (Lam 1986). In Cairo environment with clear sky in winter as well as summer times, increasing the reflected components doesn't seem to be necessary as the overall daylight levels in such configuration led to similar daylight levels all year around. This conclusion supports the observations reached by Ratti et al (2003) in their study on the courtyards of North Africa.

a) Distribution of daylight levels at axis 1



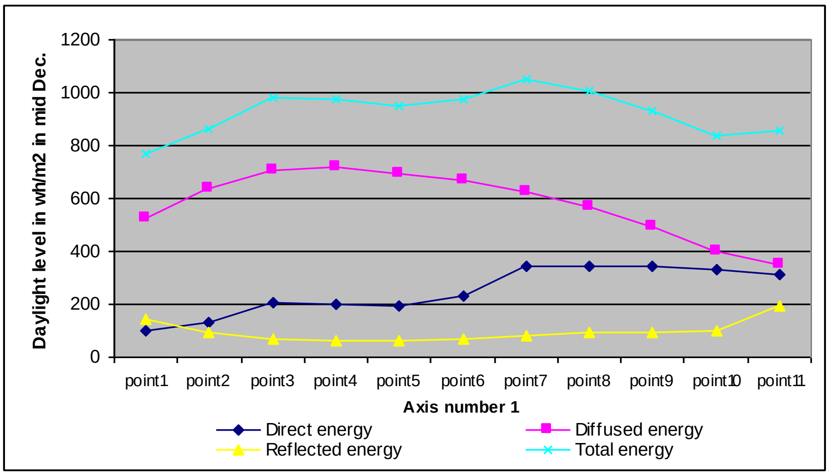
	Point 12	Point 6	Point 21
Direct	3047.5	4494	17775.5
Diffused	543.5	695.5	365
Reflected	303.16	122.75	452.75
Total	3894	5313	2593.38

b) Distribution of daylight levels at axis 2



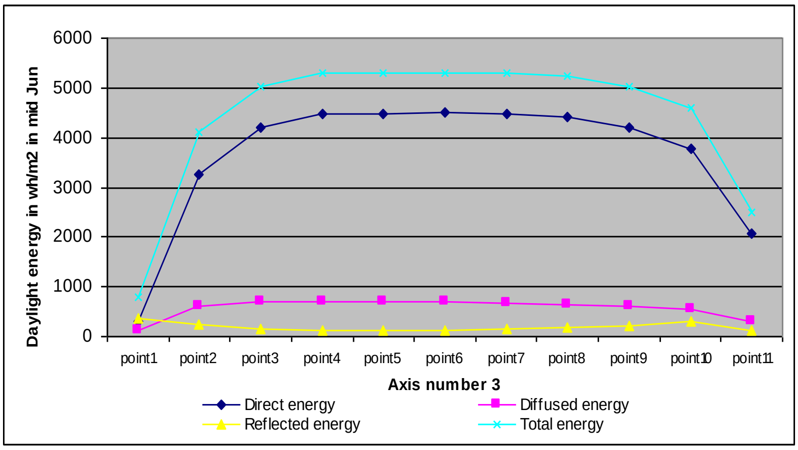
	Point 1	Point 6	Point 11
Direct	3339.75	4494	3507
Diffused	530.75	695.5	585.38
Reflected	190.63	122.75	320.75
Total	4060.88	5313	4413

Figure 4: Average Direct, Diffused, Reflected and the Total energy in mid June



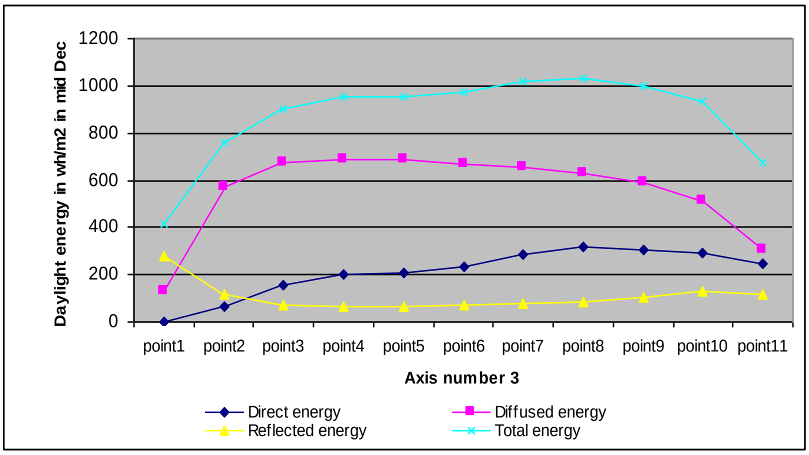
	Point 12	Point 6	Point 21
Direct	100.75	233.75	313
Diffused	523.38	669.88	451.63
Reflected	144.25	70	191
Total	768.88	973.25	855.75

Figure 5: Average Direct, Diffused, Reflected and the Total energy for axis 1 in mid Dec



	Point 22	*Point 6*	*Point 31*
Direct	295	4484.88	2063.13
Diffused	136.38	695.5	317
Reflected	366.5	122.75	111.5
Total	797.86	5313	2491.63

Figure 6: Average Direct, Diffused, Reflected and the Total energy for axis 3 in mid June



	Point 22	Point 6	Point 31
Direct	*1*	*233.75*	*247.63*
Diffused	*131.5*	*669.88*	*305.25*
Reflected	*281.125*	*70*	*120*
Total	*413*	*973.25*	*673.13*

Figure 7: Average Direct, Diffused, Reflected and the Total energy for axis 3 in mid Dec

- ***Analysis of the impact of the geometry of the 3D frame on daylight performance***

The analysis of the results also shows the impact of the projecting features of the three dimensional frame of the square on the different daylight components. The performance of daylight, which is influenced by the sectional profiles of the frame, has been explored through the simulation of the three different components of the daylight energy along the first and the last points of axis 3. Point 22 and point 31 occupy a portion of the square that is shaded by projection features of the facades. The results (Figures 6 and 7) show that the projecting features of the eastern facades have led to reduction of direct and diffuse components and increase in reflected component on point 22 as compared with the mid square (point 6).

The results show the impact of the projecting shading devices in the square during winter and summer time. While reductions are evident during summer time the shading features of the facades showed much less influences during wintertime. The results showed different patterns in the North facing façade as direct component is much more influential during the summer time. The temporary shading installations using tent like canopies (point 39) is therefore a welcomed feature as it significantly reduced both the diffused and reflected components in the summer time (Table 2). In winter dismantling of such features would ensure an increase in both direct and reflected components and maintain a comfortable daylight levels throughout the year.

Table 2: Daylight energy level in the southern shaded portion of the square in mid Jun (left) and mid Dec (right)

	Point 39 June /Shading	Point 39 June/ Without	Point 39 Dec/ Shading	Point 39 Dec/ Without
Direct	4325.07	4492	18.75	293.25
Diffused	651.5	751.38	666.63	720.25
Reflected	128.05	147.38	63.38	71.63
Total	5104.86	5390.25	749	1088.13

- ***Analysis of the impact of the space configuration-related variables***

The paper simulates the diffused energy level across axis 4, where differences in height between the Southern and Northern boundaries (point 32) exist. The impact of this morphology, expressed in the sky opening factors, on diffused energy levels was investigated. Figure 8-a shows the distribution of diffused energy in axis 4 during summer and winter. Figure 8-b illustrates the sky-opening factor of this axis depicting a pattern similar to diffused energy component.

Figure 9-a shows that the relationship between the sky opening factors and the diffused energy is

linear. The impact of the sky openings is however much stronger during wintertime. In Cairo environment, where sky condition is clear most of the year, a lower sky-opening factor is therefore essential in order to reduce the impact of high level of both direct energy in summer (Figure 9-b) and diffused energy in winter (Figure 9-a). In a typical Mediterranean environment, such as South Europe, or even Alexandria in the North of Egypt, where the sky is overcast during winter months, a slightly higher sky opening ratios are welcomed as it increase the required daylight level during winter months.

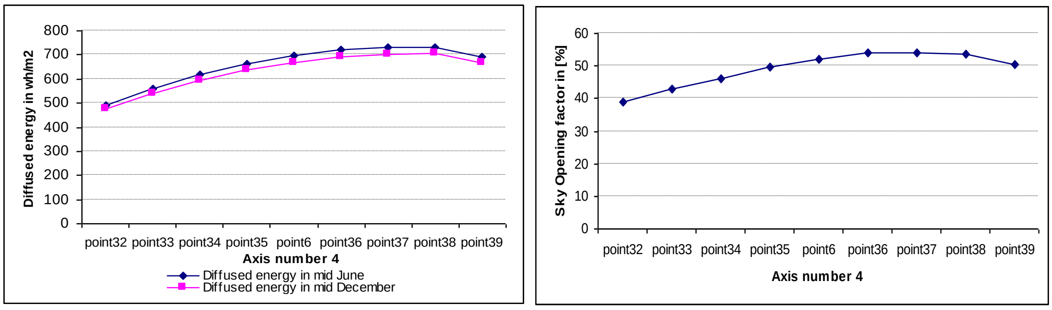


Figure 8: Diffused energy in Watt per square meter area calculated at axis 4 in mid Jun. and Dec. (a-left) and Sky opening factor calculated at axis 4 (b-right)

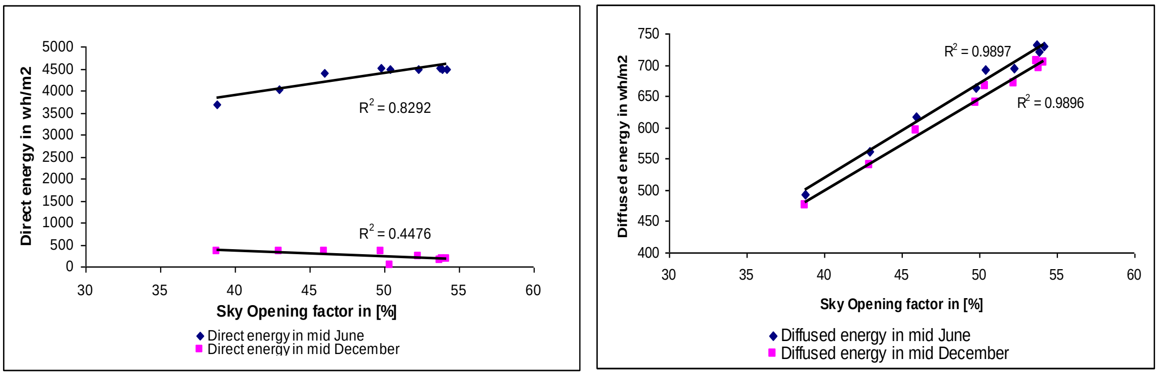


Figure 9: The relation between the diffused component and the sky –opening factor calculated at axis 4 on mid Jun. and Dec (a-right) and the relation between the direct component and the sky –opening factor calculated at axis 4 on mid Jun. and Dec (b-left)

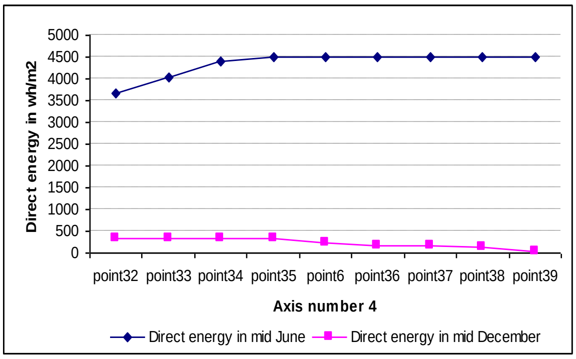


Figure 10: Distribution of Direct energy in watt per square meter area of axis 4 in June and December

Analysis of daylight levels across axis 4 (running north – south) shows that all points on this axis receives approximately equal amounts of direct components on mid June (Figure 10). This is related to the impact of the high solar altitude revealing similarly the different portions of the square during summer time.

Conversely, the square experiences low daylight levels closer to the shaded area on the south part of the square during wintertime. As it was previously explained, these shading devices were meant to be temporary. The current fixed corrugated sheets has badly influenced the homogeneity of the day lighting levels during wintertime (Figures 11-a). Figure 11-b shows the simulation results of the original configuration of the square where temporary shading devices in the summer are removed in winter.

The results show more homogeneity of daylight levels across the square in both summer and winter months (Figure 12).

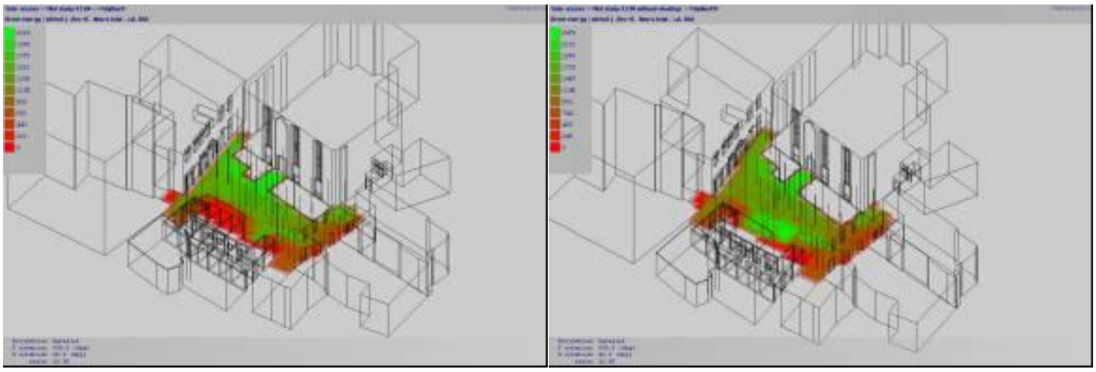


Figure11: Direct component propagation at mid Dec (a-left) and Direct component propagation at mid Dec after removing the temporary shading devices (b-right)

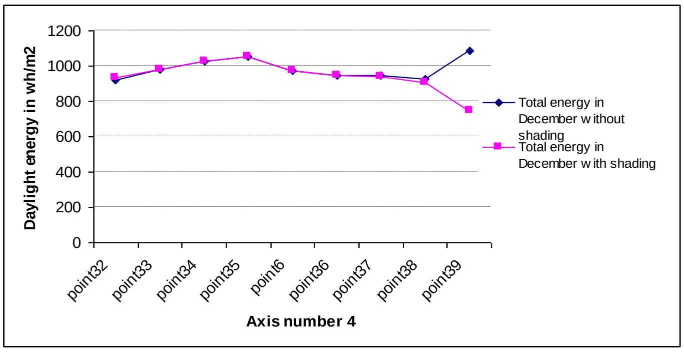


Figure 12. Total energy of daylight of axis 4 during mid Jun and Dec

4. CONCLUSIONS

Supreme medieval values of Cairo's Islamic heritage are embedded in the urban fabric. The unique urban qualities have focussed research on the related urban regeneration efforts in the area. Currently in Cairo, there is an ongoing debate on the levels of success of such projects that entails in some parts a loss of identity. The debate highlights the needs to identify the ingredients of original context in planning suitable regeneration strategy. Daylight is an essential contextual ingredient that characterises particular place from its counterparts. Appropriate use of daylight performance contributes to a place identity and should be understood in any regeneration efforts. Aslam square is selected as a part of a rehabilitation project within the old fabric of the city. The square was taken in this paper as a vehicle to examine the peculiarity of daylight performance in such medieval Cairene context.

A model is built using a combination of *photogrammetric* and 3D digital techniques. The paper uses a lighting simulation tool to trace the dynamic performance of the daylight within the selected case. Analysis of the different daylight energy components shows a close relationship between the daylight performance and the geometrical and the photometrical characteristics of the space's planes.
Despite the different contribution of direct and diffused components in different seasons, the configuration of the square has led to equilibrium of total daylight energy level in both summer and winter. The three dimension analysis of the *frame* also shows that all points located within this 3-dimension enclosure at different heights tend to have similar total daylight energy in both seasons.

The simulation results provide an insight of the visual experiences of users as they gradually move from the dark alleyways towards a more comfortable daylight levels in the square. The effects of such morphological quality highlight the importance of squares and their landmarks in the urban experiences of passers-by in the medieval city.

The linear relationship between the sky opening ratios and the gained daylight levels within the enclosure indicates a strategic approach that was utilized to control the daylight performance within the urban fabric under different sky conditions. While the lower sky opening ratios contributes to the desirable reduction of direct component in clear sky conditions in Cairo, the higher sky opening ratios would ensure a provision of the required diffused component within a fabric located under more overcast conditions.

The analysis of the impact of the geometry of the 3D frame of the square shows the usefulness of the temporary shading installations in achieving homogeneous daylight performance across the space in both seasons. While the shading devices reduce the harsh direct energy during the high solar altitude in summertime, the dismantling of those features during wintertime increases the required level of the diffused and direct energy.

This paper examined the dynamic nature of daylight performance in Aslam Square. The description highlights the importance of the configuration of the square as well as the selection of specific materials and shading devices. Designers and urban planners should be more aware of the sensitive role of daylight that can be easily skewed with any inappropriate deliberate interventions.

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