Daylight for sustainable development of historic sites

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ABSTRACT: Consideration of daylight is one of the contextual ingredients for maintaining a sustainable identity when intervening in a heritage site. Appropriate consideration of daylighting ensures not only visual and thermal comfort in the urban setting, but also contributes to the preservation of the place visual identity. The historic district of el Darb al-Asfar is undergoing a rehabilitation project that raises questions about the new ‘sparking’ look of the place. The ongoing cultural debate in old Cairo on the extent of success of the rehabilitation efforts in preserving the place identity identified a gap in literature regarding the ingredients that constitute identity in heritage settings. The paper argues that the project using new finishing materials of facades has led to changes in daylight levels in the space and hence the visual perception of the place itself. This paper aims to assess the impact of such intervention on the visual perception and the place identity. A digital model is built utilising a combination of photogrammetric and 3D digital technique. The TOWNSCOPE simulation package is used to trace the performance of direct, diffused and reflected components of daylight within the original and recently resorted scenes. The output of the simulation exercise has been validated by empirical data. The paper concludes by suggesting a set of measures for achieving an appropriate daylight performance in heritage sites Eastern Mediterranean climatic conditions.

Conference theme: Detail
Keywords: Place identity, daylight, solar simulation, urban morphology, Heritage

1. VISUALISING IDENTITY: REHABILITATION OF MEDIEVAL CAIRO

The internal narrow alleys are one of the most recognisable urban configuration features of medieval Cairo. Among the outstanding examples of these Cairean built fabric components are the alleys that lay in the centre of what is now Old Cairo. El Darb El Asfar is an alley in the district of Gamaliya located off al-Mu’izz Street, near Bab El Futuh, Bab El Nasr, and the old city walls. Since the mid-1990s, Gamaliya’s Darb Al Asfar has experienced a pilot restoration project focusing on three rare surviving examples of domestic architecture and one sabil-kuttab (school and fountain). In recent years, this phase of restoration was extended and introduced as the first rehabilitation project in historic Cairo exceeding the single restoration of monuments by applying renovation strategy of the landmark’s background (Ministry of Culture Press, 2002). The debate of the new look of the alleyway has occupied the cultural debates in Cairo since the completion of the project. Two opposite positions have surfaced as a result of the different criteria of assessment. One viewpoint has perceived the process as a model providing inspiration for the rest of Fatimid Cairo. Other views regret the loss of the place identity and the negative impacts on the visual quality of the alley. Following the completion of the work, William (2002, p.178) summarised the opposite views “enthusiasts applaud the sparkling new quality of work; purists bemoan the lost of patina of age.” The debate regarding the new sparkling look of the alley is directly related to the visual perception of the place, and daylight performance in relation to the photometrical characteristics of the alley’s surrounding skin. The ongoing debate makes the alleyways of El- Darb al-asfar an important case study for other rehabilitation projects in the area.

Within the fabric of the alley, stand four of the most importance examples of Cairene domestic architecture. The four buildings were part of the restoration project. Built in 1648 and 1796, al-Suhaymi House, the most charming example of an old Cairo house, provides invaluable information concerning the character of the traditional Caireane architecture prior of the 17th century. The delicate wooden lattice (mashrabiya) widows are the most distinctive features that were developed to provide a comfortable microclimate regulating the flow of natural energy and daylight. Another key building of the 18th Century is the house of al-Khurazati, which occupies an area of 400 square metres west of al-Suhaymi house. The three-story house of Mostafa Ja’far also stands a little further at the corner of the alleyway facing al-Mu’izz Street. It was built in 1730 as private residence of coffee merchant, and has for a long time served as offices for the North Cairo Antiquities department. Its wooden mashrabiya windows and marble floors bear unmistakable mark of artists in the late Ottoman period. At the other corner of the alleyway, on the side of al-Gamaliya Street, is the other fourth resorted building. Situated across from Baybars mosque, the school and water fountain of Qitas Bey was built in 1630 and retains the simple style of the Ottoman period.
The alley has experienced various statuses of deterioration due to the natural aging process, ground movement, underground water, lack of maintenance and others. Such deteriorated conditions highlighted the need for an urgent upgrade and necessitate intervention and regeneration efforts. A rehabilitation project, a comprehensive development strategy of the whole district was launched in early 1990s.

2. 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 literature identifies a number of technical variables that are related to the characteristics of space configuration that affect the daylight performance.

2.1 The Frame Configuration Variables

Reflected light of the other building facades is one of the well-recognised strategies that were 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 also argued that the opposing façade of the buildings is a potential passive daylighting device to the internal space 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.

2.2 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 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 the 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.

3. THE DAYLIGHT SIMULATION MODEL OF THE HISTORIC CASE STUDY

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 environmental variables on the daylight accessibility energizing the internal (indoor) sphere has been previously explored, yet there is a room for investigation of such influence in respect to external (outdoor) sphere. This paper examines the daylight performance in one of the indigenous urban pattern of the built fabric in old Cairo. The paper investigates the dynamic nature of such performance at two different times of the year: in mid June and mid December.
3.1 Phase One: The Simulation Workflow

The adopted methodology utilizes a combination of photogrammetric and CAD software with a selected lighting simulation software. Mantzouratos et al. (2004) used similar integrated approach. In the lack of the required detailed architectural drawings of the historical buildings, the photogrammetric approach is used to extract the geometric characteristics of the building. The understanding of the morphology of the fabric and its features in urban places also requires photogrammetric analysis. Two dimension CAD drawings are used to set up the digital model and a three-dimensional CAD model for the selected case study was constructed (Figure 2). A set of digital photographs of the facades of the selected area were used to identify the geometry of the three-dimensional frame of the space. Following the enhancement of a 3D CAD model in 3D Studio, variables of the photometric properties were assigned to the developed 3D model. Information of the reflection and diffusion properties of used materials was obtained. The percentage of the quality of opacity was given 0 in the case of transparent surfaces and 100 for opaque materials. The regional characteristics of the daylight is partly identified by assigning the latitude and altitude parameters of the target context.

![Figure 2: axonometric view illustrates the benchmarks distribution system in the alleyway](image)

<table>
<thead>
<tr>
<th>The Old scene characteristic</th>
<th>The New scene characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflectance coefficient (lower surface)</td>
<td>Reflectance coefficient (lower surface)</td>
</tr>
<tr>
<td>Reflectance coefficient (upper surface)</td>
<td>Reflectance coefficient (upper surface)</td>
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<tr>
<td>Reflectance coefficient (apertures a)</td>
<td>Reflectance coefficient (apertures a)</td>
</tr>
<tr>
<td>Reflectance coefficient (apertures b)</td>
<td>Reflectance coefficient (apertures b)</td>
</tr>
<tr>
<td>Stone</td>
<td>0.40</td>
</tr>
<tr>
<td>Old paint</td>
<td>0.55</td>
</tr>
<tr>
<td>Glass</td>
<td>0.08</td>
</tr>
<tr>
<td>Oak</td>
<td>0.10</td>
</tr>
<tr>
<td>New paint</td>
<td>0.75</td>
</tr>
<tr>
<td>Oak</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Source: (Azar, S., 2004), (Baker, N. and Steemers, K., 2002)
The model was however, completed after detailed monthly meteorological data for the relative humidity; atmosphere turbidity, clouding rate and Edhcs/ Ethcs parameters were all fed into the package. Edhcs / Ethcs factor is the mean ratio (for the month) of the diffused energy received to the total energy received in clear sky condition and on a horizontal surface. In other words, it = diff / (diff + direct) (Azar, 2004). 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 were simulated for June and December.

3.2 Phase Two: The Simulation

This paper utilises a system of reference points alongside the selected alley (Figure 3). A set of 22 points is employed to examine the change in the daylight performance in the two simulated old and recently restored scenes. The points are assembled on main axis that goes through the alleyway configuration. This axis is plotted within the square field of vision (Fig 3). 1.8m height has been selected to explore daylight performance at the eye level height. The sky opening value at each point is also calculated and the overall solar access of the space setting is simulated.

Figure 3: site plan of the darb al-Alsfar alley way illustrates the contour line of the adopted axis as a sum of points

4. PERFORMANCE OF DAYLIGHTING IN THE ORIGINAL AND THE RESTORED CASE STUDY:

Empirical data of daylighting levels were collected in 2004. Daylighting levels of a total of 44 points have been recorded in the alleyway. Figure 4 shows the correlation between the empirical and the stimulated data. The figure indicates a reasonable confidence in the simulation exercise.

Figure 4: the relationship between the empirically data and the stimulated output of daylight in the case study

Preliminary investigation shows that the performance of the daylight’s three components along the alleyway is closely related to the compactness ratio (geometrical characteristics) of the examined urban form. The simulation of daylight across the alley showed continuous changes in the alleyway’s (street) width to height ratio with corresponding change in daylight levels (Figures 5 and 6). The smooth transition of daylighting levels across the alley during winter period (Fig. 5) is contrasted with the sharper changes in summer time. While the earlier would lead to comfortable
visual experience in the alleyway during wintertime, the later provides a rather sudden change from dark to strong daylight and add to high reflection and glare (Figure 6). It is however, important to point out the role of the temporary covers and shading devices that are used to be employed (and still in use in many other original settings) during summer time in areas with wider sky openings. Such temporary shading devices would play a major role in, once again, harmonising the visual experience during the summer time similar to the daylight pattern during the winter.

Figure 5: average direct, diffused, reflected, and total energy in mid Dec at the Old scene specification case

Figure 6: average direct, diffused, reflected, and total energy in mid Jun at the Old scene specification case

Figure 7: the relation between the total energy of daylight and the sky-opening factor in both season types at the Old scene specification
Figure 7 and 8 show a strong relationship between configuration represented in the sky openings and both the reflected components of daylighting and the total daylighting levels in the case study. The figures also show that while reasonable correlations existed for the reflected energy component in both June and December, poor correlation is shown for the total daylighting energy levels during summer time. The sense of harmony and visual identity of the place can only be maintained throughout the year with a reduction of glare during summer time. The traditional temporary shading devices were therefore necessary not only for thermal considerations but also for visual comfort. The ‘re-introduction’ of high summer sun in Cairo in the renovation project distorted the delicate daylight balance achieved by the configuration of the alley in the absence of the traditional temporary canopies.

Another set of simulation is performed using data of the new applied materials due to restoration. The output of the comparative analysis of the two scenarios (i.e. the old and the recently restored scenes) is shown in Figure 9. The figure shows a noticeable increase in the reflected components during wintertime with as much as 30% at certain points. Such high proportion in the daylight profile would be sensitive to any slight change of facades’ materials reflective characteristics and hence visual experience of the visitors to the area. The increase in the reflective component might be welcomed during winter, as it improves daylighting levels within the surrounding buildings. A similar conclusion was reached in improving interiors of buildings in medieval fabric of the Southern Europe by the utilization of light coloured materials in the opposing external facades (Lam, 1986). The increase in reflected energy was also doubled during the summer time in Cairo. Such sharp increase in the Cairo environment led to complete change of the visual comfort and high levels of glare in the area.

The figure also shows that the narrower the space, the more impacts of the materials on daylighting levels occur. This result adds to the sensitivity of the old Cairo fabric to any changes in materials. There will be more change in the feelings of the place with slight change of the material in Old Cairo where the streets are narrow and winding.
5. CONCLUSION:

Old Cairo with its unique medieval value of Islamic heritage is going through major conservation and restoration project. Different scenarios for rehabilitation strategies have been employed to maintain such unique global heritage. The extent of the success of some of these projects in preserving the identity of the Cairene context is currently under scrutiny and created a debate among local residents, professionals, and politicians. The cultural debate has highlighted the need to review the preceding practices and to identify the ingredients of the original context in drawing the suitable regeneration strategy.

The rehabilitation scheme for Al-Darb al-Asfar, the focus of the debate, offered an excellent case to investigate the role of daylighting as an ingredient in preserving the place identity. Daylight is an essential contextual ingredient that characterises particular places from its counterparts. The role of daylighting in shaping the iconic fenestration features of the built environment in Old Cairo is well known. What is less evident is the peculiarity of daylight performance within the uniqueness of this urban pattern and hence its potential role in viewing the place identity. This paper investigates the complex relationship(s) between the daylight performance, the configuration (morphology) of space and the provision of identity in a built heritage context.

A combination of photogrammetric and 3D digital technique has been utilized in building up a digital model.

The dynamic performance of daylight's three components within the case under study has been examined using a lighting simulation tool. The simulation technique has been also used to identify the variability in the performance of reflected component due to the rehabilitation scheme. The performance of the reflected component is traced by stimulating the impact of the original and recently used materials based on two separate simulation exercises. The output of the simulation exercise is initially validated via conducting comparative analysis between the empirical and the stimulated data of daylight levels. A reasonable confidence has been identified in the simulation task.

Analysis of the different light energy components shows a close relation between the daylight performance and the compactable geometrical characteristics of the examined urban pattern. The results show that while daylight follows a harmonic pattern during wintertime, the absence of the traditional temporary canopies from the configuration has led to more dramatic changes of the daylight performance along the alleyway during summer time. These results provide insight of the relationship between the daylight performance in the alleyway and the sense of visual comfort due to the pattern of change; whether there is sudden or smooth leap from dark to strong daylight conditions. The results also highlight the usefulness of the traditional shading installations in harmonizing the visual experience during the summer time similar to the soft transition of daylighting in wintertime. The poor correlation between the sky opening factor, representing the compactness of space, and total daylighting energy levels in summer times has similarly highlighted the important role of these temporary shading devices in achieving similar daylighting conditions in both seasons. The linear relationship between the gained reflected components and the sky-opening factor, on the other hand, indicates the critical intervention of the materials on the sense on the ambiance of the place.

In old Cairo, where the fabric's features are narrow and winding, there will be more change in the ambiance of place as a result of any slight change in the materials. This might explain the feeling of ‘newness’ in this scheme while similar intervention in a nearby square has not received similar criticism. Analysis of the impact of reflected components also indicated the potential of the light coloured materials in improving the daylight levels during wintertime. Complete change of the visual comfort combining with a high levels of glare would however be obtained from increasing the reflected energy component in summer time. Once again, the utilization of the shading devices would ensure the desirable reduction of the reflected energy during summer time.

The investigations emphasized the impact of the configuration of the space as well as the role of the selected materials and the shading devices. The results of our study highlighted the conflict between the benefits obtained by residents of historic sites and the requirements of the tourist industry. In Cairo, the improvement in the winter daylight level, as a result of improving the reflectivity of the new materials, is strongly criticized by the romantic attitude of visitors as a loss of authenticity. This conflict would be less apparent in higher latitude locations where the low sun maintained constant light before and after the renovation because of the low contribution of the reflected component to the site’s total. Careful consideration for the performance of various daylighting components can be crucial in maintaining a sense of place at historic sites. Planners of intervention projects should carefully analyse how new facade materials affect daylighting. These results are refined further by investigating the effects on daylighting of changing ground materials at restored historic sites.

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