Modelling Daylight for Preserving Identity:

Simulation of daylight levels for successful intervention in historic buildings

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ABSTRACT: Historical listed buildings have their own unique cultural identity, which is one of the criteria used by decision mechanisms for their statutory protection. The identity of many of these buildings is often related to their tangible features/components, such as period characteristics (geometry, size, colour, form, and shape), materials and construction. Daylight is one of the in/tangible elements that have contributed to the distinctiveness of many historical buildings; yet when constructing preservation schemes of historical buildings, daylight is rarely introduced or considered as one of the components that shape the character of buildings. One of the reasons is the limited number of credible simulation studies that identify such interrelationships. As many of these buildings were originally designed to accommodate different activities to today's requirements, maintaining the quality of daylight that originally contributed to their visual identity can be a very challenging task; especially if the building is to be adapted to accommodate a different activity. In this paper we will discuss the conflict between maintaining the original visual identity of historical buildings and meeting the visual requirements of restored buildings. The paper discusses the visual performance of a traditional bathhouse (Hammam) in the city of Bursa in Turkey. The change in the visual performance of the selected case study will be discussed in terms of daylight conditions. The paper explores the possibility of maintaining the original daylight conditions of renovated historical buildings while meeting the visual requirements of the new use.
Keywords: Daylight, visual identity, renovation, minimum intervention, re-use, daylight requirements, historical buildings.

INTRODUCTION

Several rehabilitation projects of urban centres have been recently implemented in Bursa, the fourth largest city of Turkey. A number of the city's indigenous buildings were converted to museums, art galleries, cultural and community centres. Keeping and reusing historic buildings, a well-supported practice by the Turkish government, is often seen as a way not only to preserve the physical building fabric "as a tangible link with the past", but as an opportunity to preserve the intangible heritage such as traditional skills and craftsmanship. The intention is to provide new accommodations where these skills can thrive. Many of these buildings were originally designed to accommodate different activities to their new use. Preserving the quality of daylight that originally contributed to their visual identity can be a very challenging task. Furthermore, as most historical buildings were originally designed to be lit by daylight, maintaining the "daylit appearance" of a building can be problematic in terms of artefact conservation requirements. On the other hand, a successful utilisation of daylight can create a better visitor experience and museum environment as well as improve the energy efficiency of a building [1].

Of the various building types, museums and art galleries are well recognized for their challenging day/lighting criteria [2]. Whereas retrofitting of ordinary non-historical old buildings can offer a number of possibilities for improving the ambient conditions and energy efficiency of buildings [3], in a heritage building, a radical change to the original quality of daylight though an extensive use of artificial light or displacement of daylight can have a critical impact on the visual character and sense of place [4]. Although the conservation practice in general is clear about the importance of applying and adopting "minimal intervention" when developing a rehabilitation scheme, the practice of implementing "minimal intervention" is often understood by designers in terms of preserving the tangible aspects of a building. Indeed preserving the original tangible components of buildings such as their materials, fabric and fenestration features, is the key for preserving the physicality of the buildings. There are however many other facets of historical buildings that contribute to their distinctive quality and significance. Daylight is one of these in/tangible elements that have contributed to the distinctiveness of many historical buildings and settlements [5]. Yet when initiating preservation schemes of historical buildings daylight is rarely introduced or considered as one of the components that shape the character of buildings. A review of relevant documents also suggests that at present there is no clear recognition of the role of daylight in shaping the visual character of historical buildings [6]. Without a clear valuation and an understanding of the value of daylight in shaping the visual character of a historical building, it would be rather challenging to first establish whether daylight should be taken into account when developing a renovation scheme, and then what might be considered as "minimal intervention" in terms of preserving its ambient conditions.

This study explores the relationship between daylight, visual identity, and sense of comfort for the reuse of historical buildings in the city of Bursa (40◦11 latitude, 29◦04 longitude). The basis of the work is the belief that there is a large potential for preserving the ambient daylight conditions of reused historical buildings if the original daylight conditions are well understood and correctly used. It is argued that an understanding of the original ambient daylight conditions of a historical building and their role in the overall visual identity and perception of place can contribute to a better decision making and "adoptive reuse" strategy.

DAYLIGHTING REGULATIONS AND PRACTICE IN TURKEY

The role daylight can play in improving the energy efficiency in buildings has recently received much attention in energy performance regulations in Turkey. The value of daylight and the importance for maximising its effectiveness for illuminating building interiors, which were clearly stated in building performance legislations introduced in 2008, has been further emphasised recently with the latest introduction of the new Turkish Lighting Standard. As a candidate country for the European Union membership, Turkey has adopted the European Standard Lighting of Work Places (EN 12464-1:2011) in January 2012 as the Turkish Lighting Standard (TS EN12464-1:2011). Item 4.10 of this standard emphasises the role of daylight provision in buildings and provides in clause 5.4 the lighting requirements for retail premises, such as restaurants and hotels, theatres and concert halls, as well as exhibition halls and museums. All of these functions can be given to historical buildings for re-use. While recommended light levels for most of these public premises are given in the European guidelines, there are no values given for museums, where lighting requirements are mainly determined by the display classification. However, other reliable international guidelines such as those recommended by the Illuminating Engineering Society of North America (IESNA) or by the Charted Institution of Building Services Engineers (CIBSE) can be used to establish lighting requirements in a museum or gallery environment. As the recycling of old buildings is a practice well received and increasingly emerging in many other major cities in Turkey, the work reported in this study can be beneficial for those concerned with conservation practice and the reuse of historical buildings in the region.

DAYLIGHTING REQUIREMENTS IN MUSEUM BUILDINGS

Whilst the presence of natural light with its vibrant qualities is an attractive design feature in many building types, in a daylit museum environment certain preventive measures should be taken to minimise its "deleterious" effects on the museum collection. Daylight has always had (the most) desirable colour-rendering qualities for aesthetic reasons that are important to the museum function. However, the high energy in the Ultraviolet region (UV) of the spectrum can cause chemical and physical damage to the fragile objects in the collection, such as discolouration, fading, yellowing and surface cracking. Designing for successful daylight in a museum environment requires then an understanding on how the qualities and properties of light at different regions of the spectrum affect the museum objects. Natural light has specific spectral characteristics at different wavelengths which are usually classified into three regions: The ultraviolet region (UV) (300-400 nm), the visible region (400-700nm) and the Infrared (IR). Research indicated that the "relative damage factor" or the rate of deterioration as result of the action of light is inversely proportional to the log of the wavelength [1]. Thus the ultraviolet radiation which has the shortest wavelengths and the highest energy is the most damaging component to museum objects [8]. Unnecessary visual light can also pose a threat to certain types of museum objects. The "reciprocity law" states that the cumulative photochemical effect "is directly proportional to the illumination levels multiplied by the time of exposure" [8]. Thus 200 lux exposure for six months can cause as much damage as 100 lux exposure for one year. Reducing the exposure time is therefore another important measure to limit damage from light. On the other hand, the rate and extent of deterioration brought about by the amount of light and exposure time varies between the different types of objects depending on their material properties and chemical composition. Museum artefacts in general can be grouped into three categories based on sensitivity to light: Highly sensitive objects derived from organic origins, partially sensitive objects contain organic and inorganic substances and insensitive objects have geological origin.

The illuminating Engineering Society of North America (IESNA) (2000) established illuminance recommendations and annual exposure times for the various material–type categories found in a museum collection. As illustrated in Table (1), a maximum of 50 lux is recommend for highly sensitive objects and a range of 200 lux and 300 lux for partially sensitive and insensitive objects, respectively. Similar illuminance values are also given in the Charted Institution of Building Services Engineers (CIBSE) Lighting Guide LG8 [9]. In terms of the exposure time, the values given in the IESNA lighting handbook are relatively lower than those given in the CIBSE lighting guide (Table 1). These later values are based on the assumption that the lights will be either extinguished or maintained at a very low level outside museum opening hours. However, in a museum environment a minimum exposure to light is usually preferred for the preservation of particularly susceptible or precious materials, and therefore the cumulative exposure values given in IESNA lighting guides are adopted in this work. While the level of light is important in terms of conservation considerations, the pattern of its distribution within an interior is equally important in terms comfort and visibility. Large spatial variations in horizontal illuminance across an interior must be then avoided to prevent discomfort problems associated with uneven distribution of light. According to the CIBSE Code for Lighting [9] "the diversity of illuminance expressed as the ratio of the maximum illuminance to the minimum illuminance at any point in the [main area in the space] should not exceed 5 to 1". Hence, in a gallery space, the exhibit illuminance should be no more than five times the average ambient level. Finally, an ambient light level of 100- 200 lux is recommended for spaces where visual tasks are occasionally performed and an average of 300 lux for spaces with more demanding tasks (IESNA).

Table 1: maximum illuminance levels and cumulative exposure values given in the IESNA lighting handbook and the CIBSE lighting guide for various types of exhibits

Types of Objects	**Illuminance levels [Lux]**		**Annual exposure [lux-hours]**	
	CIBSE Guide	IESNA Handbook	CIBSE Guide	IESNA Handbook
Insensitive to light	Subject to heating effects	Depends on exhibition situation	-	Depends on exhibition situation
Moderately sensitive to light	200	200	600, 000	480,000
Highly sensitive to light	50	50	150, 000	50,000

METHODOLOGY

Several site visits to the selected heritage buildings in Bursa took place in May and August/September 2012, for this study. The first building is a small Turkish bath (hammam) located in a village in Bursa and currently under renovation (Fig. 1). At the time of the field work the decision regarding the new use of the building as a cultural centre or as museum has not been confirmed, although it is now proposed that a cultural centre where exhibitions can be organised will benefit the village's community. Therefore, this building offers an opportunity to test how understanding of its original ambient daylight conditions can inform the decision making process and contribute to a better adaptive reuse strategy. The other selected building is the Uluumay traditional clothing and Jewellery museum, one of the first ethnographical museums of Bursa. This building was originally a school (a madrasa) for teaching theology and religious law and recently becomes a museum. Key changes to the building, which were implemented as part of its recent reuse, included the transformation of the private study cells and the previously an opened archway into exhibition galleries, blocking up all windows in the cells, introducing an excessive internal shading system and electric lighting for illuminating the objects. Only the visual performance of the first case study is reported below, as this article (study) is part of an ongoing research project.

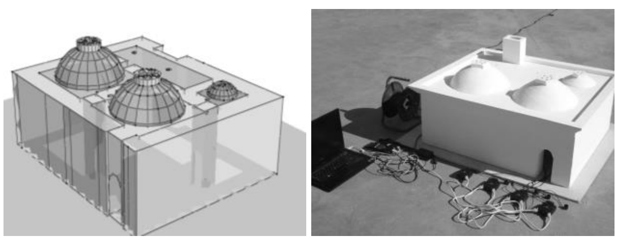
Figure 1: The Demirci Hammam- Bursa, internal view showing the toplit dome of the northern hot room (right)

The daylight simulation tool Radiance in the *IES Virtual Environment* is used to perform the analysis in the two selected buildings. Although the capacity of Radiance to predict realistic illuminance values in various sky conditions has been repeatedly validated [11], a literature review in this study suggests that there is no evidence of the use of this package within Turkey's climatic regions. A validation exercise was therefore necessary, which was designed and mainly implemented to provide the authors with more confidence in the simulation modelling of the examined context.

In 2011, Kim and Chung [2] have presented a daylight validation approach using a 1: 20 physical model of a museum building in South Korea and a multi- sensor lux meter. Five-day measurements in real sky conditions were conducted and a comparative analysis was then made between the measured and the simulated data. A validation exercise similar to Kim's and Chung work is adopted in this work.

A 1:20 physical model of the original part of the hammam building including the top-lit domes of the three hot rooms was created using high density modelling foam blocks. A three dimensional digital model of the hammam was also developed using the geometry model creator (Model IT) in the Virtual Environment (Fig. 2). Daylight illuminance values at certain points in the physical model were then measured using a Konica Minolta T-10 illuminance meter and four photosensors (see Fig. 5). Several phases of measurements were conducted at nine time intervals and a total of 144 measurements were recorded using the data management software (T-A30). The validation experiment was carried out on the roof of one of the multi-storey residential blocks near the actual site of the hammam and all of the measurements were conducted under clear sky with sunshine between August 30th and September 2nd.

Figure 2: Physical and digital Model of the Demirci Hammam



The results of the validation experiment were not entirely consistent, showing a close agreement as well as some discrepancy. Whereas the predicted illuminance values at the two main hot rooms (photosensors 1, 2 and 4) closely matched measured illuminance values, the values predicted in the middle of the private cell were much lower than the measured data. The absolute relative difference between simulated and measured illuminance values recorded at the two main rooms was in the range of -4.83 to 7.04 percent, as opposed to the 45.27 percent difference at the private cell (photosensor 3).

In previous work, Ng et al [12] presented an approach for improving simulation values generated by Radiance and hence reducing the discrepancy between predictions and measurements by adjusting the transmittance properties of the openings of their digital model through trial and error. Similar approach is used in this work, but instated of adjusting the transmittance properties of the model, the height of the dome sitting above the private cell is adjusted and slightly reduced through four attempts of trial and error. The results of the corrected model (Fig. 3) show a reasonable match between predicated and measured values, and suggest that adjusting the height of the dome helped significantly in reducing the relative error recorded previously at the private cell. The relative error recorded at the middle of this cell after correcting the dome height was 16.67 percent and the overall difference between the two models was 3.62 percent.

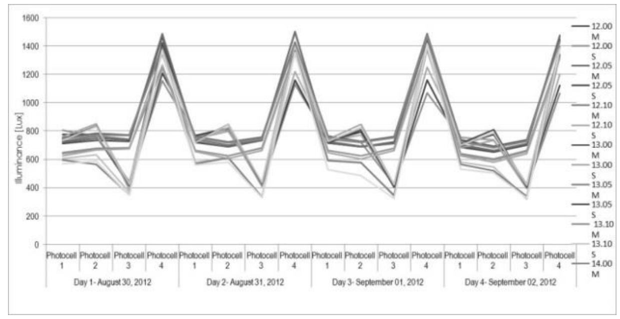


Figure 3: Scale model measurements versus the values generated by the radiance simulation for the three examined spaces - Corrected model

DAYLIGHT PERFORMANCE OF THE SELECTED BATHHOUSE: THE DEMIRCI HAMMAM

Public bathhouses or commonly known as "Turkish baths", hammams, are the product of a long bathing tradition dating back to prehistoric times. They evolved from the Roman and Byzantine public bath houses, and flourished under the Ottoman Empire to meet the washing requirements (and the ablution principles) of Islam. Hammams were important facilities in Islamic cities, providing not only a washing facility for the conduct of major ablutions necessary before praying, but also a venue for social interaction, celebrations [13] and for generating revenue to charitable foundations.

The case study building is the Demirci Hammam in the Nilufer District, Bursa. The elements of the plan follow the traditional layout of the Roman baths with a cold room, a warm or semi-hot room and a hot area. The cold room known as "frigidarium" is usually used as a transitional space between the changing rooms and the heated area. The semi-hot room known as "tepidarium" is the room where beauty treatments such as oiling and massaging of the body take place, while the actual bathing takes place in the hot room "caldarium" that is often considered the most important place in a bath building. A Turkish bath was usually a twin bath with one part dedicated to women being smaller, however in cases where there is not a twin bath or complex, the bath building was used by men and women on separate days. A bath house was both a "complex structure and an expensive enterprise" that was carefully designed and perforated to maintain certain ambient conditions necessary for the bathing requirements taking place. Hence there were no windows in a bath to avoid drafts, save and control steam and heat and daylight was provided by small glass openings studding the domes while allowing a minimum amount to filter through [14].Only the hot area of the Demirci Hammam has survived today, as the other two areas (the cold and semi-warm) were destroyed and rebuilt later. These later areas which are being demolished and rebuilt will be re-functioned along with the original hot complex as a cultural centre as stated before. The dimensions of the caldarium are 7.21 m x 8.77 m, including two hot rooms, a small cell for private bathing and the furnace room. The size and the quality of the bath in general is quite impressive for a village bath, which might suggest that these villages once stood on the route of the silk transport.

A system of reference points that were assembled on three main axes is used to measure daylight illuminance values in the two main rooms (the northern and southern room) in the hot zone. The values predicted at the target areas are shown in Figure 4. The analysis of the results on the summer solstice, the spring and fall equinoxes reveals that for most of the year, illuminance values received into the northern room is almost constant. Average illuminance values predicted before and after midday on the spring and fall equinoxes were nearly identical ranging between 127 and 130 lux in the morning and afternoon hours and less than 175 lux on midday (Fig. 4).

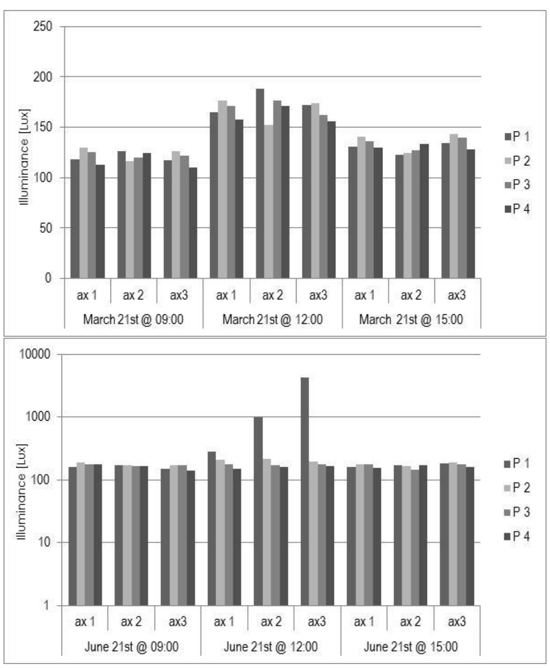


Figure 4: Illuminance values predicted for the northern hot room on the spring equinox and the summer solstice

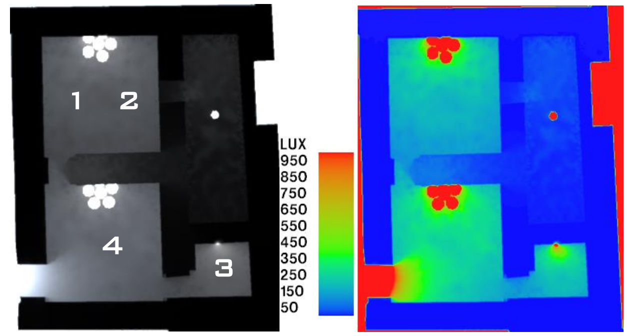


Figure 5: Illuminance values received into the Hot Area of the Hammam including: a – the northern room (upper left), b- the southern room (lower left), c- the private cell (lower right) on the summer solstice.

On the summer solstice, and apart from the few bright spots and (the high intensity of daylight) recorded in the room (see Fig. 5), the average values predicted for the space at the three tested times were also identical ranging between less than170 lux in the morning and afternoon hours and 188 lux on midday. These figures are the results of the complementary effects of the north location of the space, the circular configuration of the sky light openings and the shape of the dome that allows an equal reflection of diffuse light. Given the dynamic nature of daylight and the continuous change in its intensity over the course of the year, achieving a uniform level of illuminance within a daylit space can be quite challenging. Therefore, the uniform illuminance values reported in this space should be well understood and carefully restored and integrated with any supplementary lighting. Illuminance values predicted on the winter solstice were slightly low ranging between 48 lux on the morning and afternoon hours and over 105 lux on midday. As for the artefact conservation requirements, and apart from the two spots recorded at noon on the summer solstice (Fig. 4), all the illuminance values predicted fall comfortably within the IESNA recommended values for moderately susceptible objects. The values recorded on the morning and afternoon hours on the winter solstice fall even well within the recommendations for highly susceptible objects. However, in terms of visual comfort criteria, these later figures can be a bit problematic, well below the minimum recommended values for exhibition spaces. Therefore, an additional light intensity of 100 -150 lux is needed to meet the recommended illuminance values and compensate for the lack of daylight in winter. On the spring and fall equinoxes, a supplementary lighting of 25 - 70 lux should be enough to ensure more comfortable lighting conditions. This can be easily added and without creating a dramatic change to the original ambient conditions of the space through the design of the display containers, which can be provided with an artificial light source for illumination of the displayed objects. The other key concern in exhibit spaces is the artefact total exposure in terms of illuminance hours per year and the exposure to direct sunlight. The average illuminance values calculated for the space at noon on the four evaluated days was 159.7 lux. This gives a maximum annual exposure value of 466,388 lx - h per year or a total of 306,666 lx - h per year if the building/space is only to be opened five days a week. Both figures are well with the limit defined by the IESNA for moderately susceptible displayed materials, as shown in Table 1.

The uniform distribution of daylight predicted on the four tested days in the northern room is also evident in the southern hot room. At present, the southern room is illuminated by both the toplit glass openings in the dome and the external arch door on the west elevation; the presence of this side opening should explain the high intensity of daylight recorded at the lower western corner of the space, as shown in Figure 5. However, once the construction of the cold and semi warm rooms is complete and the original link between the cold and the hot rooms restored, the external door will become an internal opening, and the space (similar to the northern room) will be again mainly illuminated by the toplit dome. An analysis of the illuminance values predicted in the southern room with the toplit dome as the only opening/ daylight source has shown daylight levels and distribution patterns similar to those recorded in the northern room. Overall (and as for the new use of the hot complex), the analysis of the results suggests that with an additional light intensity of 100-150 lux the ambient daylight conditions in both spaces can be easily adopted to meet the visual comfort criteria for a museum environment. However, if these spaces are to be re functioned as workshops for the community centre, a much higher additional light intensity of 200-250 lux would be necessary to satisfy the visual requirements of their users. This suggest that the original ambient conditions of the studied spaces offer an ideal setting for a museum collection, but they are less convenient for working spaces with more demanding visual tasks.

CONCLUSION

Daylight is key ingredient for maintaining the identity of a cultural built heritage. In Bursa, intervention to adapt CBH to more contemporary use is essentials for their sustainability. Such intervention cannot just rely on the new Turkish lighting standards, particularly where museums are suggested as new functions for these buildings. The paper shows that simulation of daylight performance and careful distribution of activities, in a heritage building, not only maintain its ambience and character but also contribute to maximum use of daylight use in order to minimise the damaging use of excess artificial lighting.

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