

# Shop Window Lighting: the Use of Sun to Improve Visual Appeal and Reduce Energy Demand

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## ABSTRACT

*The present study deals with the potential reduction of energy consumption for the lighting of shop window displays. Urban commerce has a very high impact on economics and at the same time, it is a highly energy-consuming sector. Light has the power of attracting people's attention, which is one of the goals of the trading and selling activity and very high illuminance levels are usually recommended. In the Mediterranean areas, where daytime lasts for many hours, commercial activity takes place mainly under sunshine conditions and shop windows frequently fail to fulfil their main corporative goal, namely the unobstructed observation of the products exhibited. The necessary increase of artificial lighting illuminance levels to accent interior light conditions, due to extremely high-luminance urban surroundings, leads to an important increase of energy consumption, as a common solution. Nevertheless, the results are generally very poor, because reflections and other kinds of visual problems still defy solution and the final result is an economic and energy waste during daytime, especially in low latitude countries. The present study evaluates the visual and energetic benefits of an innovative passive design that obstructs solar rays and redirects them into the interior of the shop window scene. A scale model of this new design confirms the visual benefits produced by its use, via the different luminance maps tested. This new lighting passive system results in a very simple, effective and low cost solution that can be easily applied in economically emerging countries. The most important fact is that high illuminance levels are achieved and, simultaneously, there is important energy reduction, taking advantage of natural light instead of competing with sun power.*

## INTRODUCTION

Urban commerce and storefronts play a major role in the economy and the very image of a city, especially in climates that favour exterior human activities. Being a fundamental element of the commercial process, a proper visual presentation of shop windows is crucial. Lighting contributes to the creation of a corporate identity, ideally, it assists the production of the image desired by the trader and together with other components of the design it contributes to sales promotion (Rea, 2000). The present study analyzes the lighting requirements and visual inconveniences of window displays associated with the Mediterranean climate and how they are or should be dealt with, so that the aesthetic and commercial function of shop windows will not be inhibited.

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The complexity of light presentation of these everyday urban elements is linked to their exposure to varying light conditions in the outside environment. Being a part of the urban landscape, the illuminance levels in the interior of shop windows should be corresponding to the surrounding light, so that they would be able to stand up and yield good vision of the products on display. In Mediterranean climates, the temperature favours urban commerce, since duration of daily solar radiation is extensive and solar intensity is prevalent throughout the whole year. As a result of the very high level of exterior illuminance, though, the visual goals of window displays are often impeded.

### **High energy consumption yet poor visual outcome**

The lighting design of window displays is required to perform multiple visual tasks, most important of which are to attract clients and to provide visual comfort and good vision of the products exhibited. In order to do so, two basic factors, among others, must be secured: adequate illuminance levels and luminance contrast between the display objects and their background. A recommended value for luminance ratio between the illuminated object and its surrounding area is 3:1, although this ratio can reach values from 10:1 to 30:1 (Carillo, et al., 2010). Regarding illuminance values, they can be as high as 5.000 lx during night-time and 10.000 lx during daytime (Freyssinier, Frering, Taylor, Narendran, & Rizzo, 2006). Moreover, certain studies prove that a higher illuminance level implies that more passers-by are attracted by the shop windows (Carillo, et al., 2010). As a result, the consumption of energy for the lighting of window displays that remains on for at least 15 hours per day (Freyssinier, Frering, Taylor, Narendran, & Rizzo, 2006) is rather high.

In Catalonia, window display lighting constitutes 11.2% of the total energy consumption for the lighting of a typical store (Institut Catalá d'Energia, 2008). Nevertheless, despite the high energy consumption, visual inconveniences insist; during the research discussed in this paper, a study of a representative sample of shop windows of Barcelona has been performed in its natural opposing lighting conditions, day and night, analyzing their visual results. The basic tools of this analysis have been the luminance maps and evaluation, via computer application, of the odds of glare and its possible sources. The study has confirmed and identified the main inconveniences that can impair the visual result and, therefore, the commercial purposes, during daytime hours. Specifically, the most frequent problems are: penetration of exterior light into the scene, which affects the balance of the luminances projected, failure to reach the appropriate contrasts for the projection of exhibits, as well as glare and annoying reflections.

Among the analysed stores, **as shown in Figure 1**, the visual presentation of 65% of them failed to reach a contrast of 3:1 between all exhibits and their surroundings, as well as 65% of them failed to avoid annoying reflections. In addition, the conducted analysis confirms that the commercial storefronts mostly affected by such inconveniences, especially by the generation of glare, are those receiving direct solar incidence, even in cases that solar protection is provided. This effect can be generated not only by solar incidence in the actual presentation of the window, but also by the incidence in immediately adjacent areas, whether on the surrounding facade or the sidewalk that lies before it.

In order to help face these visual disadvantages resulting from very high levels of exterior illuminance, a remedy often applied is to increase artificial illuminance projected during the day, in contrast to the one projected overnight. However, the intensity of sunlight in low latitude areas is so high that artificial lighting can never compete with the natural one. The inability of artificial lighting to compete with high solar illuminance makes it vain for any power to increase during the day, along with the corresponding energy additional charge this practice entails.

This new study, instead, evaluates the benefits of the use of a passive design that takes advantage of the very solar ray incidence in order to increase interior illuminance effectively and at the same time reduce energy consumption.

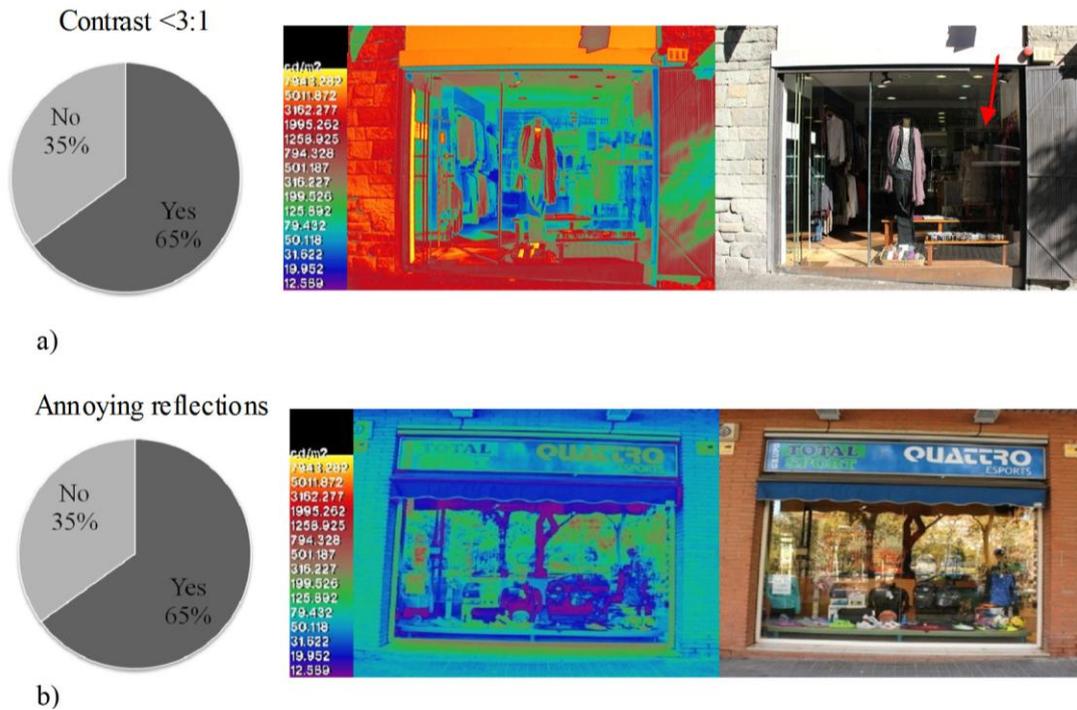


Figure 1 (a) Part of examined window displays that failed to reach contrast 3:1 between all exhibits and their surroundings, plus an example (b) Part of examined window displays with annoying reflections, plus an example.

## METHODOLOGY

The present research evaluates the visual and energetic benefits of an innovative passive design that obstructs solar rays and redirects them into the interior of the shop window scene. In fact, the improvement of the quality of the observation of exhibits during daytime is assessed, along with the possible reduction in energy consumption.

The research implementation is summarized in 4 main steps which are presented below and explained in the following subsections:

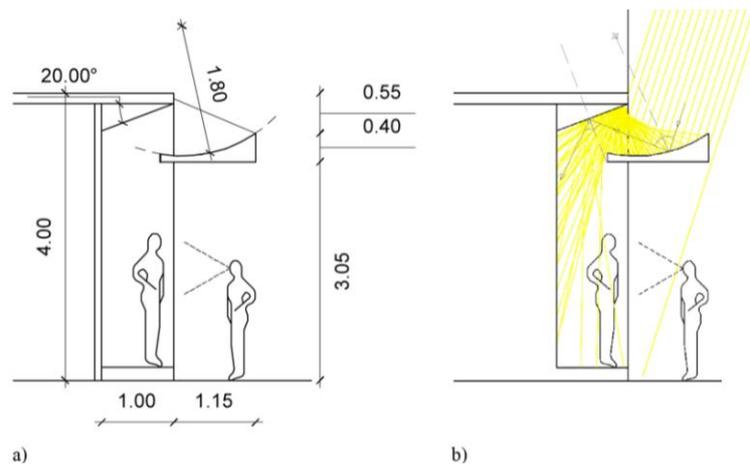
1. Design of a component that manages to obstruct solar radiation and re-direct it towards the interior of the scene.
2. Development of two scale models of the window analyzed, the one being independent of and the other one based on the proposed system.
3. Simulation of the unfavourable exterior light conditions.
4. Analysis of visual differentiation of the window display in the same lighting conditions, depending on the existence of the proposed system, or not.

### Development of the passive design component

A typical window display of Barcelona has been selected among the sample observed, that is about four meters high and one meter wide. Based on the solar diagram of the city, several design tests of a system of reflective surfaces have been performed in order that, when the latter is incorporated in a typical window facing south, it could make the most of the solar incidence during the most unfavourable conditions; these are produced during summer solstice, as it has been confirmed after analysis in a simulation program that incorporates solar trajectories (Heliodon). The possible contribution of both flat

and curved reflective surfaces was examined in various positions, with the purpose of introducing into the showcase as much light as possible, especially during summer.

The design finally proposed here, is based on two successive light reflections, **as shown in Figure 2**, where typical dimensions can also be appreciated. Rays that fall upon the curved surface will be reflected symmetrically around the axis joining the point of incidence and its centre of curvature (Peoglos, Raptis, & Christodoulides, 2004); subsequently, they will be cast on the plane surface and will be reflected towards the interior of the scene. Regarding the concave surface, in order to directly introduce as much light as possible, the use of a specular material is proposed. On the contrary, for avoiding intense reflections in the scene that, depending on sky conditions, may adversely affect the visual result, the use of a diffuse-reflection surface is proposed for the second reflection.



*Figure 2 (a) Geometry of the component proposed (b) Conduction of natural light in the interior of the scene.*

A vertical movable lamina should be placed in order to control the system and, depending on the solar height, to regulate the solar radiation introduced through the opening of the system. In addition, a fixed glass surface could help to avoid problems of water or dirt accumulation. In any case that this design is implemented, it will have to adjust to any special needs.

### Development of the scale models

Two scale models of the window analyzed, the one being independent of and the other one based on the proposed system, have been developed. As in the present study the effect of chromatic contrast is not analyzed, all the components of the scene have been chosen to be of soft and slightly contrasting colours. The dimensions of the models have been adjusted to the artificial lighting projected, giving special care so that both the area of the surfaces and the luminous flux they receive, would be correctly scaled.

In each one of the models two LED sources have been placed above two mannequins and 30cm of led stripe above the background of the scene, **as shown in Figure 3**. Because of their size and characteristics, the sources Prolight PM2B 3LxS-SD-3W Power LED have been chosen; in order to simulate the illuminance of the real window display, after measuring their luminous intensity and applying the basic laws of photometry, the appropriate scale of the model has been defined:

$$dM = 0,09 dR \quad (1)$$

For wall washing lighting simulation, a strip led of 40W type 3528 has been used in each model. A potentiometer has also been connected to it, so that its intensity could be dimmed and, in this manner, possible reduction of energy for vertical illumination could be evaluated.

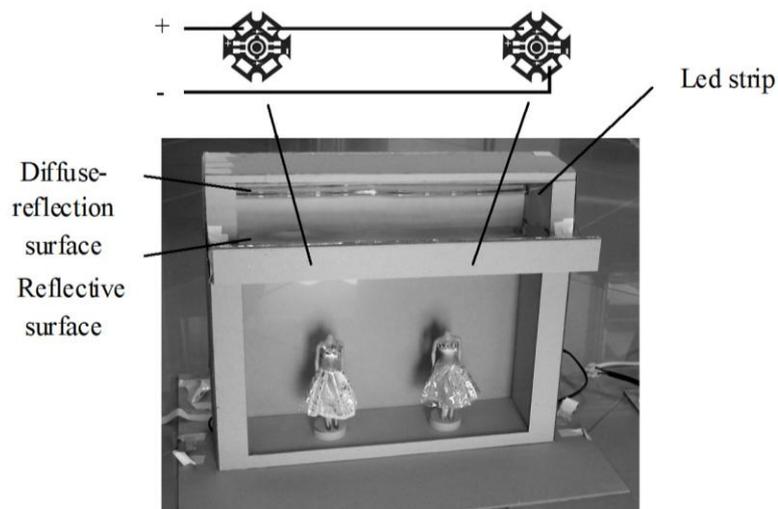


Figure 3 Model based on the system proposed.

### Simulation of the desired exterior light conditions

The study took place in Athens on December 10, during the time of zenith. In order to simulate the summer solstice in Barcelona ( $72^\circ$  during the zenith) the table where each model was placed has been rotated through  $43^\circ$ , as shown in Figure 4, equal to the difference of solar altitude on December 10 in Athens ( $29^\circ$  during the zenith). Furthermore, in order to obtain an overall assessment of the results for the entire year, a simulation of the equinox and winter solstice in Barcelona ( $49^\circ$  and  $26^\circ$  correspondingly during the zenith) were simulated rotating the table through  $20^\circ$ , and  $-3^\circ$  correspondingly.

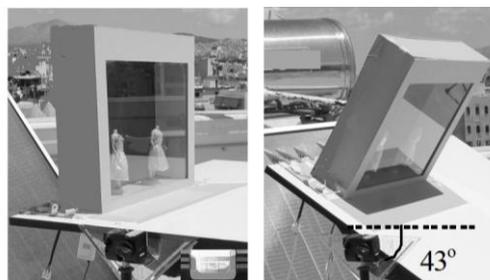


Figure 4 Simulation of the desired exterior lighting conditions by rotating through  $43^\circ$  the table where the model is placed.

### Evaluation of visual differentiation, depending on the existence of the proposed system

The comparison of the visual outcome of the two different models has been realized via the observation of photographs and their equivalent luminance maps, in addition to the observation in situ. The comparison took into account the following visual inconveniences:

1. Annoying reflections.
2. Achievement of 3:1 contrast between products and their surrounding area.
3. Glare.

In order to compare the possibility of glare in every situation, the Radiance based tool, called Evalglare, which evaluates that possibility through the daylight glare probability index, DGP (Wienold, 2009) has been used in addition to the luminance maps.

## RESULTS AND DISCUSSION

### Improvement of visual appeal

The comparison of the visual result of the two scenes, the one being independent of and the other one based on the proposed system, has resulted in the expected improvement. Via the observation of the photographs and the luminance maps deriving from them, the positive effect of the redirection of the sunlight into the scene is appreciated, **as shown in Figure 5**. Specifically, when comparing the two models, the following parameters are observed:

1. The annoying reflections on the glass of the scene, after the incorporation of the proposed system, are significantly moderated. Looking at the model without the system (on the left) one can see the reflection of the photographer's figure; however, looking at the model with the proposed design incorporated (on the right) this effect does no longer exist.
2. The desired contrast of 3:1 between the products and their surrounding area is achieved in the model where the proposed system has been incorporated, while simultaneously solar incidence upon products is avoided.
3. Large surfaces of high luminance that can dazzle there are in the model where the proposed design is not used; on the contrary, in the model based on the proposed system the area and luminance of these surfaces is moderated, thus glare is less probable. The comparison of the DGP index in the two cases is indicative of the improvement.

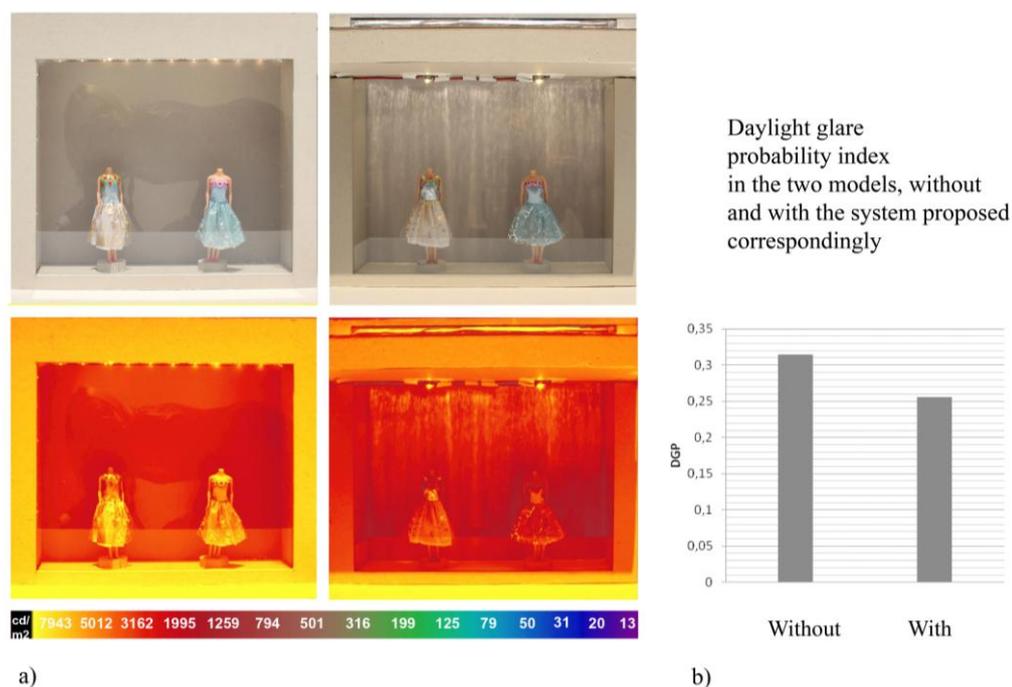


Figure 5 (a) Photograph and luminance map (b) DGP index. Comparison of the two models, without (left) and with (right) the system proposed.

Concerning the rest of the seasons, the design proposed has no negative effects. Instead, during the research discussed in this paper, the effect against the inconveniences of glare and annoying reflections has been examined and proven positive throughout the year.

### Energy demand reduction

As predicted, the visual result of the model, following the incorporation of the system proposed is significantly improved. That alone signifies that the frequently applied technique of increasing the power of the lighting of window displays, is a remedy that can be abandoned along with the useless energy charge it entails; therefore, energy consumption for the lighting of display windows can be reduced.

In addition, the possibility of further energy reduction has been verified with the help of the potentiometer connected to the vertical illumination of the model: The illuminance of the background lighting of the scene has been decreased, in the case of the design proposed, to the 1/3 of the illuminance projected before. Once again, when examined in the simulated lighting conditions, even with a drastic reduction of power applied the result has been positive, **as shown in Figure 6**. The comparison of the visual result of the two scenes, the one being independent of and the other one based on the proposed design with a power decrease to the 1/3 for vertical lighting, has resulted in improvement. Specifically, when comparing the two models, the following parameters are observed in the one based on the system proposed despite the power reduction:

1. The reflections of the glass of the scene are, once again, significantly moderated.
2. The desired contrast of 3:1 between the products and their surrounding area is achieved, while solar incidence upon them is avoided.
3. Fewer areas of high luminance that can dazzle are generated. The comparison of DGP index in the two cases is indicative of the improvement.

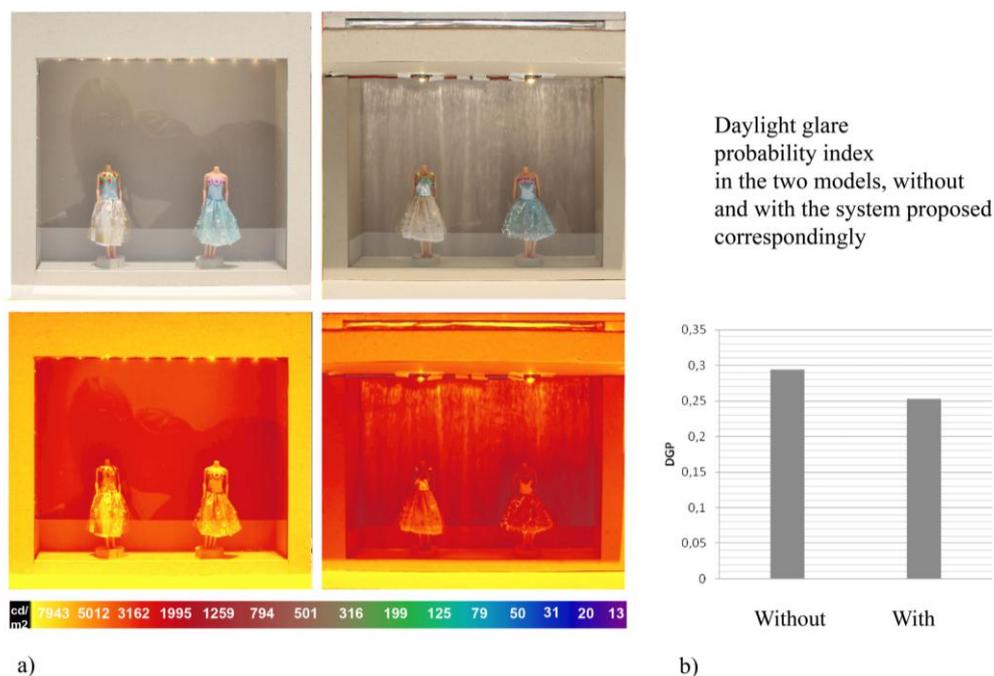


Figure 6 (a) Photograph and luminance map (b) DGP index. Comparison of the two models, without (left) and with (right) the system proposed when wall wash lighting is reduced to 1/3.

The effects observed above are the expected ones, since solar light intensity which is introduced in the scene, and not artificial lighting, is the one increasing significantly the illuminance in it. In that way, it is verified that under the most negative conditions for the visual result of shop windows, which arise during solar incidence, not only does the vertical lighting not have to be increased but, in contrast, it can be drastically reduced while, simultaneously, the visual outcome can be significantly improved.

## CONCLUSION

This paper results in a passive design proposal that can offer very positive effects on the visual result of shop windows, improving the quality of their observation, thus fulfilling their commercial visual goals during the day and, in addition, reducing energy consumption. In low latitude countries, the inability of artificial lighting to compete with high solar illuminance makes it vain for any power to increase during daytime, along with the corresponding energy charge this practice entails. Instead, the increase of interior illuminance levels of shop windows by using the very illuminance of the sun may improve the visual outcome and reduce energy consumption for the lighting of the scene.

The positioning of the proposed design of sunlight redirection, with the dual effect of both obstruction of its incidence and the benefit of its intensity to increase illuminance in the interior of the shop window, has very positive effects on its visual presentation, especially in terms of reducing annoying reflections and the possibility of glare. Moreover, these effects are valid even when reducing the installed power for the lighting of the background of the scene, thus making possible, in combination with the use of sensors and resistors, further reduction of energy consumption for the lighting of the display window. This new lighting passive system results in a very simple, effective and low cost solution that can be easily applied in economically emerging countries, with considerable environmental and economic benefits when incorporated in the highly energy-consuming display windows. Therefore, it is deduced that, instead of trying to compete with the sun, it is better for one to ally with it.

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## NOMENCLATURE

- $d_M$  = dimensions of the model
- $d_R$  = dimensions of the real window display
- DGP = Daylight Glare Probability

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