A case study on light and colour for monuments and cultural assets

Andrea Siniscalco[1]

[1]*Department of Design, Politecnico di Milano, Italy. andrea.siniscalco@polimi.it*

Corresponding author: Andrea Siniscalco (andrea.siniscalco@polimi.it)

ABSTRACT

The enhancement of monumental assets through lighting requires particular attention. The absence of specific laws (except those for the prevention of light pollution and the perishability of certain assets) results in installations whose sole purpose is to make them visible, without offering an effective valorisation at night. In this contribution, it'll be presented a concept experience for the monumental complex of Neptune in Bologna (Italy), where the choices made were aimed at satisfying specific requests of the client, which also included the use of different shades of white and coloured light.

KEYWORDS Cultural assets, Lighting, Colour, Concept

RECEIVED 14 October 2019; **REVISED** 24 November 2019; **ACCEPTED** 29 November 2019

1. Introduction

The lighting of cultural heritage is an activity of primary importance, especially in a country like Italy, one of the states with the highest concentration of world cultural heritage (UNESCO 2019). It is normal that, despite a not always appropriate conservation policy, the intention of the structures in charge (but also of the population, which every day enjoys these assets) is that of maximising the value of the heritage. The most effective method of making the works of our history usable is undoubtedly that of extending their usability even in the evening and at night with an illumination capable of maximising their value. Despite the relatively low costs of implementing lighting systems, cultural assets are made to last, and electrical consumption is a very significant expense item for municipalities. Due to the price of functioning and upkeep, often installations are kept switched off, or without proper maintenance. Fortunately, technology has been of fundamental help over time. Not only to simplify lighting design, but also to drastically reduce consumption, without having to sacrifice the final result. The light sources and the respective control systems guarantee a high flexibility, which however raises some doubts, especially when they're used on elements of historical-cultural interest. In this paper, I will present a case study focused on the monumental complex located in Piazza del Nettuno in Bologna, which, in occasion of the ongoing renovation of the site, had to be enhanced by paying attention not to distort its nature.

2. The monument and its context

The monumental complex protagonist of the case study is the Neptune fountain located in Bologna (Italy). Built between 1563 and 1567, it is a brilliant example of cooperation by a team of artisans, artists, architects and engineers (Tuttle 2015). The monumental complex is located at the confluence of two important squares in old Bologna and is surrounded by impressive historic facades. A squarish basin composes it with a pedestal and a statue that crowns the whole; marbles of two colours and elaborate figures and bronze finishes immediately give the idea of the importance and the magnificence that wanted to be transmitted by this work. Pope Pio IV (Giovanni Angelo 'De Medici) commissioned the fountain, and the work had the complete supervision of Pier Donato Cesi, a Roman governor who summoned the architect Tommaso Laureti (called "*il Siciliano*") and the Flemish sculptor Jean de Boulogne (known as "*Giambologna*"). Also, the gathering of an impressive international workgroup and a considerable amount of money made it clear right from the start that the aim was to create what was destined to be considered the most beautiful fountain in Italy.

Fig. 1. The Neptune monumental complex seen from Palazzo d'Accursio. Courtesy of VISTAvisuals.

Although not as popular as other cities of art, Bologna registers more than 1.5 million tourists per year (Municipality of Bologna 2019) and pedestrian transit in this square is considerable even in the evening hours. Visitors walk on two main routes around the complex; the path to the right and the one to the left of the fountain. Via Rizzoli (to the north) and piazza Maggiore (to the south) are connected by these pathways. The imposing buildings of Palazzo D'Accursio and Palazzo di Re Enzo frame the fountain; both are large brick facades enriched by many characterising elements. On the ground, we find pink granite, darker granite slabs and the presence of elements in white marble (Figure 1).

Concerning lighting, currently the only attention given to the monumental complex is provided by a single roto-symmetrical projector for metal halide lamp with opening (estimated by the relative position between the fixture and the statue) that concentrates the entire luminous flux (light emitted by the source) in a cone of 6°. The particularity of this single projector is given not only by the lateral lighting of the statue (which guarantees a proper modelling of the forms) but also by the presence of a sharp shadow (probably will of the designer), the shape of the statue,

projected on the building that houses the offices of the municipality of Bologna.

The remaining lighting on the monumental complex is given entirely by the light that indirectly comes from the reflection of the historical facades and the pavement. As a result, the elements of the fountain are illuminated flatly and uniformly, and the differences between light and dark are exclusively due to the reflection factor of the material and the layer of oxide or deposits that covers most of the elements of the fountain.

2.1. *The requests*

The client requested the Laboratorio LUCE of the Politecnico di Milano to produce three lighting concepts relating to the monumental complex and the surrounding spaces.

In formulating these concepts, a series of requests expressed by the client were taken into consideration, summarized in the following points:

- Minimise the consumption of electricity;
- Controlling diffused light;
- Contain the phenomena of discomfort glare towards passers-by;
- Enhance the monument of Neptune;
- Provide a clear legibility of the Fountain-Statue complex for the context, the surrounding buildings in the square, and its components;
- Use dynamic lighting solutions on special occasions, such as commemorations and anniversaries decided by the Municipality of Bologna;
- Lighting the Statue differently from the pedestal.

Initially, three concepts were formulated which, after several discussions with the client (who in turn interfaced with the municipality), were merged into a single preliminary proposal. The produced concept is not only intended to meet regulatory requirements, but also to interpret and enhance the space by mediating with communicative and functional requirements.

2.2. *The preliminary analysis*

Before starting to gather ideas on how to enhance the complex with light, the Laboratorio LUCE staff provided a complete lighting survey on the fountain and its surroundings.

The survey aimed to evaluate the current state of the lighting system; instrumental measurements, photographic sessions and visual inspections were carried out to characterise the luminous scenario of the statue and the immediate surrounding areas. The reference standards for the measurements were UNI 11248:2012 (now replaced by UNI 11248:2016) and the European harmonised standard EN 13201_02:2004.

The measured quantities taken into consideration are illuminance (amount of luminous flux per unit area) and luminance; photometric quantity correlated to the psychophysical sensation of luminance whose value depends on the position of the observer related to the surface itself (Fotios, & Gibbons 2018).

In addition to the lighting survey, a census was also made of the installed lighting fixtures and light sources (which will remain in good part even after a possible renewal intervention) in order to verify the functioning status of the systems but above all, the "quality" of the light present in terms of tonality and ability to reproduce colors.

After having carried out a census, it was possible to note that the light sources used are exclusively discharge lamps in traditional gases, of the two types (Rea, Bullough, & Akashi, 2009):

- High-Pressure Sodium Lamp - HPS
- Metal Halide Lamp - MH

The first type of lamp (HPS) is very efficient and is often used in urban lighting, where high colour rendering capacity is not required; in fact, this lamp emits a yellow-orange light, which offers a limited ability to distinguish colours, but allows the emanation of a considerable luminous flux with a modest electrical power consumption and consequently with reduced energy consumption.

Sodium lamps are mainly used to light the façades of buildings, i.e. in those parts of the space where yellow-green colours abound (part of the spectrum where this lamp is well-performing). In this way it is possible to obtain good results even if the Colour Rendering Index of the source is rather low. The colour rendering index (Ra) is a number between 0 and 100, used to express how much a light source can render the colours of a predefined set of colour samples (Guo & Houser 2004); that of the HPS lamp is about 20÷23.

The metal halide lamp, on the other hand, has a much higher colour rendering (Ra=65) but a lower efficiency than the HPS. Another factor is the colour temperature of the two sources, i.e. a parameter used to describe whether a white light source tends more towards a warm white shade (2000 K, typical of incandescent light sources) or a cool white shade (6500 K, characteristic of natural light with a clear sky). The MH lamps present are at a neutral colour temperature (about 4000 K).

These two combined characteristics are plausibly the reason why the MHs were chosen to illuminate the statue and some of the marble elements.

3. Coloured light for cultural heritage

The purpose of the proposal is certainly not to completely replace the luminaires of the area, of all the buildings and the monumental complex. The goal was to enhance the Neptune and its pedestal (the Castellum), and therefore, the current lighting on the areas not under consideration and will not be modified; however, following the lighting survey, we highlighted all the issues of the site.

Current technologies related to lighting sources allow us much greater flexibility, without compromising the efficiency of the sources. The LEDs, if appropriately combined, make it possible to obtain a very varied range of different white tones, also reducing consumption and guaranteeing control flexibility unthinkable with the sources currently installed.

This flexibility also allows you to enter a very thorny environment, that of coloured light on cultural heritage.

Time is not particularly lenient with colour pigments and history, often presents us colourless works of art; and we are used to this, to the point that thinking that once they were coloured leads us almost to feel uncomfortable. Many of the great Greek works like the Parthenon were not at white; the colours were saturated, and often materials like copper, silver and glass paste were used to make the finishes even more vivid.

Fig. 2. The coloured light projection simulates the appearance of ancient colour on the Ara Pacis in Rome (2008).

Even the Ara Pacis in Rome was colourful; in 2008 an experiment (Figure 2), sponsored by Martin Professional, a luminaire manufacturer, coloured the bas-reliefs with light, using a gobo (transmissive glass disk, in that case, coloured) for reproducing its ancestral appearance (Rossini 2010).

The attempt was rather coarse and not precise; however, it had the great merit of creating a particular resonance and of being a precursor to more recent reconstructions (with advanced technologies, such as augmented reality) that are still discussed today.

Piazza del Nettuno was surely not as colourful as the Ara Pacis was; however, the use of colour on cultural heritage has been used from time to time. Just think of the coloured lighting of the Castello Sforzesco in Milan (Figure 3) by Duilio Passariello, which caused many criticism (like the one of the Italian writer Umberto Eco) and then abandoned in favour of a more reassuring warm white light.

The radical modification of the colour of the lighting is a much-discussed topic, especially today that the more efficient solid-state systems are supplanting the old systems with discharge lamps. Even the only change in the colour temperature, perhaps accompanied by better Colour Rendering Index, is enough to trigger fierce criticism from the inhabitants and field experts (like the recent cases of Rome and Modica in Sicily).

Fortunately, however, the new control systems allow us to design a light that is still over time, allowing the possibility to use colour (even just change the shades of white) for certain occasions and for a specific time; to produce the so-called “wow-effect”, but to bring the situation back to normal, avoiding to definitively misrepresent the space.

Fig. 3. Lights at Castello Sforzesco in Milan (Italy). The installation received the critics (Colonnetti 2001) by many cultural figures such as Umberto Eco (writer), Arnaldo Pomodoro (sculptor), Emilio Tadini (painter and writer) and Carlo Bertelli (art historian).

4. The proposals

Already identified in the survey phase, the two privileged directions of observation coincide with the routes that tourists and users of the square usually follow: the first

route is the one that goes from Piazza Maggiore to Via Rizzoli, while the second is the one that goes from Via Rizzoli to Piazza Maggiore. The identification of these routes is essential both for the design of significant and visible lighting effects for most users, and for the evaluation of the parameters of quality of the system, such as containment of glare for the main directions of view of the observers.

4.1. *The lighting of the statue and the pedestal*

It was not possible to provide lighting from below (with submerged luminaires) due to the structural problems of the basin. Therefore, the first concepts presented all had an illumination from above (from the walls of the buildings), preserving the concept of projection of the shadow already existing. The connotation of the square given by this effect is such that it was thought to reinforce the concept, using three-point lighting and producing three sharp shadows (instead of one) on the surrounding walls. However, the municipality had the desire to remove the shadow to contain the glare and therefore, in the final concept, we agreed not to cast any shadows on the walls.

The lighting with three projectors (positioned on brackets mounted on the Palazzo D'Accursio and the Palazzo del Podestà) has nevertheless remained, to increase the luminance of the statue, but providing a system of custom barn doors to contain glare for those who look at the statue against the light.

Fig. 4. Digital photo-elaboration of a daytime picture of the complex to simulate the lighting in one of the early concepts (shadows were later eliminated).

Four warm-light projectors (Wide flood 50°, 24W / 3400lm COB LED with colour temperature of 3000 K) have also been proposed, which will be aimed at the pedestal (the *Castellum*); three of these projectors are mounted on the same structures that support the projectors of the statue, while the fourth will be positioned on the wall of the entrance courtyard of Palazzo di Re Enzo. The three projectors used to light the statue will have a cooler colour temperature (Narrow spot 10°, 35W / 5000lm COB LED with colour temperature of 5000 K), which will ensure greater prominence to the bronze structure. In this way, the contrast with the Castellum (in marble) will be even more marked. Cold light for the God of the sea and warm light for the earth on which he stands.

In addition to the regular white light, three RGB projectors (red, green and blue, 27.45W / 963lm) will be installed in the same position as the white light projectors that make up the Neptune's accent light, to provide temporary coloured lighting for events such as events:

- Blue lighting for World Diabetes Day in mid-November.
- Blue lighting for the World Autism Awareness Day at the beginning of April.
- Pink lighting for Komen Italia breast cancer day at the end of September.
- Red lighting for World Blood Donor Day in mid-June.
- Purple lighting for World Epilepsy Day at the beginning of February.

For the coloured light fixtures as well, we planned the installation of adjustable shielding systems for better control and definition of the beam related to the silhouette of the statue.

Fig. 5. 3D Simulation of the RGB Lighting of the complex. Digital reconstruction of the area was necessary to present the idea to the municipality.

Since some of the scenarios obtained with the coloured lights will lead the statue to have very low luminance levels compared to lighting with white light, it was decided that to make more visible the Neptune compared to the context, when using RGB projectors, the fixtures that illuminate the Castellum will be kept off, as visible in Figure 5.

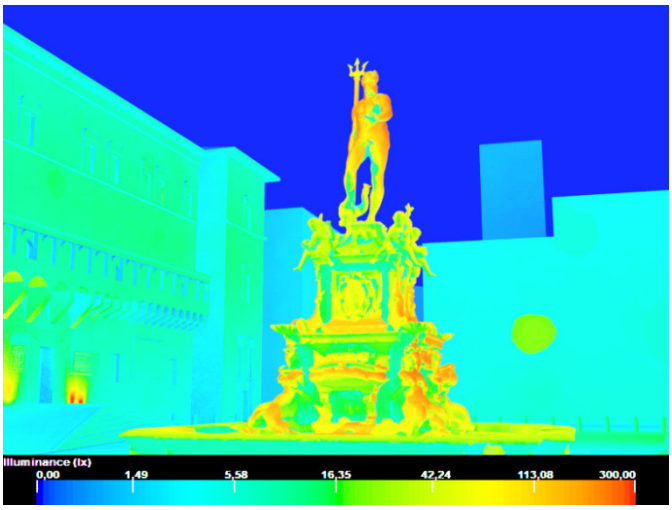

Fig. 6. 3D Simulation of the illuminance levels looking at the complex in the direction of via Rizzoli.

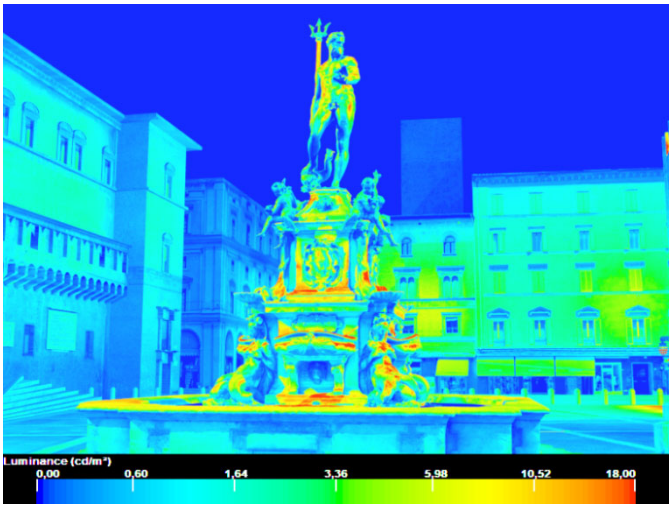

Fig. 7. 3D Simulation of the predicted luminance levels looking at the complex in the direction of via Rizzoli. The luminance levels of the actually installed luminaires average around 5 cd/m^2.

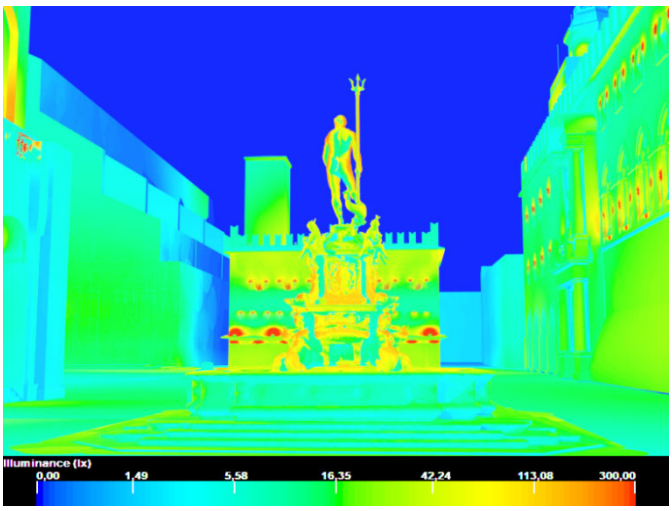

Fig. 8. 3D Simulation of the illuminance levels looking at the complex in the direction of piazza Maggiore.

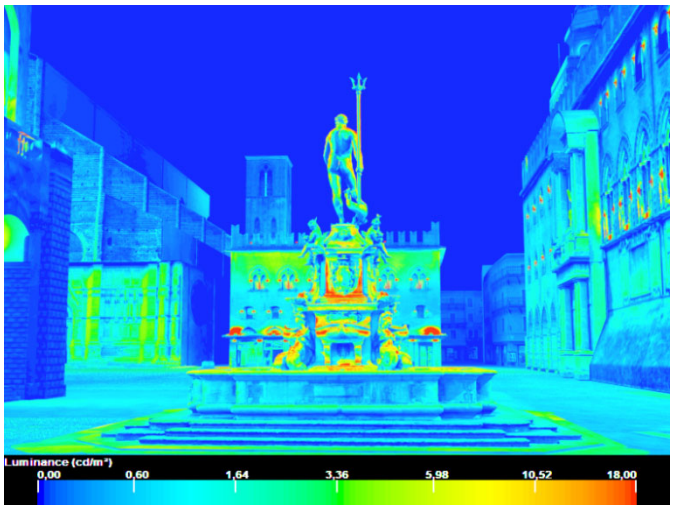

Fig. 9. 3D Simulation of the predicted luminance levels looking at the complex in the direction of piazza Maggiore. The luminance levels of the actually installed luminaires average around 5 cd/m^2.

4.2. *Additional lighting of the spaces surrounding the fountain*

In addition to restoring the functionality of the current lighting systems of buildings (projectors on the façades, light points on the windows, etc.) was also developed a proposal for the lighting of the spaces surrounding the fountain which consisted of a series of light signs placed on the floor in correspondence with the lines of white stone inserted in the flooring. These devices will emit a very controlled luminous flux (narrow blades of light 4,7W / 360lm), a sign of light to channel the attention of passers-by. The colour temperature chosen is neutral (4000 K). Some of the initial concepts provided for a large number of these light elements (and an RGB version of them) but, although these would guarantee great flexibility of use, in the end, we opted for a system of light lines that created a sort of corridor that ideally directs pedestrians towards Neptune. The aim is to create a dynamic perceptual context aimed at placing the complex at the centre of the hierarchies of visual perception of the area. In addition to the luminous signs on the walking surface, the windows of Palazzo D'Accursio (in correspondence with the Salaborsa Library) and the battlements of Palazzo di Re Enzo will also be lit. These additional lighting fixtures (narrow beam at 5.7W / 720lm, to illuminate only the profiles of the elements) will also, have a colour temperature of 4000 K.

Fig. 10. 3D Simulation of the Lighting of the complex. It is possible to observe the light hypothesised for the battlements.

4.3. *Lighting Management System*

The luminaires for the statue and the adjacent areas were all based on LED Technology; this allowed us to have maximum control over them. For the entire system, we hypothesised the installation of a management system capable of ensuring the achievement of the following objectives:

- Possibility of creating predefined lighting scenes that can be selected by the operator for events/recurrence;
- Dimming and partial shutdown of the system in the late hours of the night to contain operating costs;
- Possibility to create new light scenes in case of special needs, through the composition and regulation of the lighting of the individual elements of the fountain, statue or square.

For this application, the choice of the protocol for the management system leads to some possible options: DALI, DMX or a hybrid solution. A control system with a simplified interface (to make the programming of the scenes accessible) would guarantee additional and innovative functions for dynamic lighting, which would allow the Municipality to assign new and changing perceptual values to the context, depending on particular situations (Di Salvo 2014).

5. Conclusions

The main purpose of the work carried out was to provide the municipality of Bologna with ideas for enhancing the monumental complex, with contained costs and a low energy consumption. The designed sources have a much longer duration than those currently installed and, being easily controllable digitally, they allow programming of on and off cycles optimised with the time of day, the period of the year, and many other factors. With the new control systems and a specifically customised user interface, it is possible to offer the municipality a tool to make the monumental complex of Neptune, a veritable scenographic element, easily controllable and scalable for festivals and events that can take place on-site; all without sacrificing classic white lighting, designed to enhance colors, shapes and materials, limiting glare towards passers-by and guarantee a good usability of the cultural site.

6. Conflict of interest declaration

The author declares that nothing has affected his objectivity or independence in the production of this work. Neither the author nor his immediate family member has any financial interest in the people, topics or companies involved by this article. Neither the author nor his immediate family member had a professional relationship with the people and companies cited in this article. Neither the author nor his immediate family member is involved in a legal dispute with the people and the companies cited in this article. No conflict of interest including financial, personal or other relationship with other people and organization within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, this work.

7. Funding source declaration

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

8. Short biography of the author

Andrea Siniscalco - MSc in Industrial design in 2002. PhD in design and methods of Product development in 2007. Vice-director and teacher in the master in Lighting Design & LED Technology of Politecnico di Milano. Teacher of lighting theory at the School of Design. Vice president of GdC - Associazione Italiana Colore. Fields of interest are lighting design, visual perception and colour.

References

Colonetti, A. (2001) 'I limiti della città - Serve uno spazio per dare più visibilità al sistema design.', Corriere Design, 3, p. 1.

Comune di Bologna (2019) Turismo a Bologna, ecco com'è stato il 2018. Available at: http://www.comune.bologna.it/news/turismo-bologna-ecco-com-stato-il-2018 (Accessed: 11 October 2019).

Di Salvo, S. (2014) 'Innovation in lighting for enhancing the appreciation and preservation of archaeological heritage', Journal of Cultural Heritage, 15(2), pp. 209–212. doi: 10.1016/j.culher.2013.03.001.

EN 13201_02:2004 "Road lighting - Part 2: Performance requirements".

Fotios, S. and Gibbons, R. (2018) 'Road lighting research for drivers and pedestrians: The basis of luminance and illuminance recommendations', Lighting Research & Technology, 50(1), pp. 154–186. doi: 10.1177/1477153517739055.

Rea, M., Bullough, J. and Akashi, Y. (2009) 'Several views of metal halide and high-pressure sodium lighting for outdoor applications', Lighting Research & Technology, 41(4), pp. 297–320. doi: 10.1177/1477153509102342.

Richard J. Tuttle (2015) The Neptune Fountain in Bologna - Bronze, Marble, and Water in the Making of a Papal City. Turnhout, Belgium: Harvey Miller.

Rossini O. (2010). I colori dell'Ara Pacis. Storia di un esperimento. Archeomatica, 1(3), 20-25.

UNESCO (2019) World Heritage Center. Available at: https://whc.unesco.org (Accessed: 11 October 2019).

UNI 11248:2012 "Illuminazione stradale - Selezione delle categorie illuminotecniche".