LAYERED LIGHT: CREATIVE LIGHTING DESIGN TECHNIQUES FOR URBAN ENVIRONMENTS

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SUMMARY

Urban environments require careful consideration of numerous design factors in order to provide unique character, attractive settings and amenities, as well as safe surroundings. Appropriate lighting design is one of the factors contributing to successful urban environments. Wellington’s Civic Centre in the heart of New Zealand’s capital city serves as the setting for a case study exploring creative lighting design techniques to improve attractiveness, comfort and amenity in an area presently devoid of night-time social activity. Being unable to recognise people and architectural details or to make accurate colour judgments, as well as perceived lack of security or safety have been identified as significant problems in the Civic Centre. The proposed design solution takes a layered approach to lighting urban spaces and building facades, including their architectural details and three-dimensional articulation. The additive nature of layered light allows for unique opportunities in highlighting attractive features and improving visual comfort and safety while at the same time providing greater control of lighting scenarios and energy consumption. A comparison of photographs of the existing situation with virtual images rendered in Radiance formed the basis for testing these lighting techniques in a survey of public perception. Results from that survey indicate that three-quarters of the respondents judged the proposed lighting solution as solving the problems identified and significantly improving the commercial, social and recreational appeal of the Civic Centre during night hours.

LIGHTING REQUIREMENTS FOR CITIES

Attractive and vibrant cities are characterised by the unique beauty of their natural and built environment, combined with their cultural legacy and level of cultural or social engagement of the people who live in and visit them. City streets, public spaces and parks, bridges and buildings are all part of the urban environment and form the body of the city. Cities change over time with shifts in social and cultural values. That is clearly evident in architectural and urban design ideas and the resulting built form and human activity. Technological developments such as automobiles and aeroplanes have added another dimension to how we perceive and experience cities. Great cities allow us to experience them on a variety of levels, as visitors or as residents, as pedestrians or as user of various transport options. Most great cities are particularly wonderful on a warm and sunny day. Experiencing them at night requires light. Advances in lighting technology have offered new opportunities over the years. From petrol lanterns to modern street lighting, lighting systems have changed the night image of cities and generated new activities and life styles. Current technology allows for flexible and unique lighting solutions suitable to the particular characteristics of a city and the beautification of its environment (Sandoval 2000).

Human beings are phototropic, ie they are influenced by light, and respond to light physiologically and psychologically (Millett 1996, Loe and Rowlands 1996). Physiological responses to light, especially body rhythms and visual discomfort or disability reactions, are mainly influenced by light levels, colour, orientation and visibility. Psychological responses such as aesthetic or emotional reactions are linked to space sensation, atmosphere, comfort, safety, and security. Outdoor lighting systems have been developed in response to these characteristic human reactions. In more recent times, the importance of psychological factors has increased with expanding night-time activities that require different approaches to urban lighting. The lighting needs in a city are generally related to three main human activities: transport, commerce and recreation. As the oldest exterior lighting application, street lighting attempts to provide adequate illuminance levels for obstacle detection and orientation for drivers and pedestrians. But lighting applications in urban streets have been extended to other
Lighting has also been advocated as a tool for crime prevention, particularly in urban areas. Unfortunately, the relationship between public lighting and crime in cities has not proved effective as crime is also associated with other factors, especially social and economic ones. Researchers (Boyce and Gutkowski 1995, Fisher 1997, Nair et al 1997) investigated the relationship between light and crime but concluded that lights could not prevent crime and only decrease the sensation of fear in humans by eliminating dark zones. However, public lighting can be a powerful tool for crime detection, providing better illuminance levels for security cameras, decreasing the number of dark zones where illegal or undesired activities may happen, and facilitating police action. The sensation to feel safe and secure in an environment is associated with three main factors: person recognition, object detection and orientation. Person recognition is important because the sensation of fear is produced when, due to obstructions of facial expressions and movements, the intentions of other people cannot be predicted. Providing adequate lighting allows pedestrians to be aware of possible attacks or avoid dangerous areas. Lighting for object detection allows pedestrians to have an overview of an area and identify important structures and also possibly dangerous objects in their path. For good orientation, signs and other important information in an area should be visible in order to familiarise pedestrians with the layout of the area and allow them to easily identify entrance and exit paths.

Visual comfort is also a critical element in creating successful lighting solutions, including in the urban context. As visual comfort is more often a psychological rather than physiological human reaction it cannot be defined easily and requires some experience with a variety of lighting conditions and their effect on people. However, some parameters can be used to reduce uncomfortable sensations and provide visual amenities such as a pleasantly lit atmosphere which enhances the mood and interest of visitors to an area. These amenities can provide a sensation of welcome and safety. Appropriate colour rendering and colour temperature, glare and brightness (luminance) control, and adequate illuminance levels are all factors to consider when making decisions on creating luminous environments. However, assessing in advance which solutions will be successful is not as easy as one would hope and designers rely on a variety of tools to analyse existing conditions and test potential solutions.

WELLINGTON CASE STUDY

Due to its geographical location around a natural harbour and its topographical features which include a number of prominent vista points (eg Mt Victoria, Brooklyn and Tinakori Hills), Wellington, New Zealand’s capital city, is an ideal setting for creating urban lighting solutions that enhance visual appeal and amenities by identifying landmarks, improving general orientation and adding entertainment value for residents and tourists alike. While there is no equivalent of the Sydney Opera House, the Eiffel Tower or the Golden Gate Bridge, Wellington has a number of clearly identifiable landmarks. One of them is the Civic Centre in the heart of Wellington’s Central Business District. Visible from the harbour, from aircraft approaching Wellington International Airport and from all major vantage points, the Civic Centre includes four important cultural and administrative icons of the city, the new Wellington Central Library (1992), the City Gallery (1935-40, formerly the City Library), the Convention Centre – consisting of the Town Hall (1902-04) and the Michael Fowler Centre (1983) – and the City Council Building (1947, with additions from the early 1990s). These buildings share an open space, Civic Square, where social and cultural activities take place during the day but little or no activities occur during night hours. It is our hypothesis that the lack of night-time activity in Civic
Square results from the inadequate lighting conditions. Initially, existing lighting conditions in Wellington’s Civic Square were assessed in accordance with recommended outdoor lighting guidelines (e.g., CIBSE and ILE 1995, IESNA 1993, IES 1975) and on the basis of people’s reactions to the present lighting scheme. While the illuminance levels appear to be sufficient to fulfil basic street lighting requirements, pedestrians usually avoid Civic Square at night. When asked during a survey to tick the perceived night-time lighting problems in the Civic Square, the inability to identify people was selected by the respondents as the main lighting problem (77.5%), followed by problems with architectural detail recognition (72.5%), concerns with object colour recognition (57.5%), lack of security (47.5%) and low lighting levels (17.5%). Figures 1 and 2 illustrate some of the lighting-related problems identified in the survey.

The area is mainly illuminated by a few floodlights and luminaires built into the bases of planters, retaining walls and steps. Interior luminaires, especially the library’s, contribute to the overall illumination of Civic Square in the earlier hours of the evening (Fig 1). However, the high contrast between the library lights (acting as a large glare source) and the rest of the area does not allow pedestrians approaching Civic Square from the position of the photographer to identify other pedestrians walking towards them. Only a faint silhouette is visible and facial recognition is not possible. After the library lights are turned off (Fig 2), visual performance is further reduced and pedestrians generally feel very unsafe in Civic Square. Low vertical illuminance levels provide little light on the building façades and, therefore, architectural detail and colour recognition is severely impeded. Entry and exit points to and from the square are difficult to identify and even plants can barely be seen due to the low lighting levels.

**LAYERED LIGHT**

Appropriate lighting scenarios have been identified on the basis of recommended lighting guidelines for urban environments (e.g., CIBSE and ILE 1995, IESNA 1993, IES 1975). They address the provision of adequate illuminance levels on the ground and on building façades to allow for safe and efficient movement of pedestrians and visual hierarchy as well as for visual comfort and attraction. Visual orientation requires a hierarchy to emphasise some features and suppress others (Kemp and March 1996). Visual hierarchy, comfort and attraction are closely linked with the intensity, direction and distribution of light. It is therefore important that the lighting designer identifies critical features in the environment and ensures that those features receive special treatment, for instance through higher levels of illumination and/or colour accents. Uniform lighting may provide even illumination but cannot satisfy our need for orientation. Appropriate colour rendering also aids visual orientation, and the deliberate use of lamps of different colour temperature to accent certain elements of a space may create attractive features.

Because it is often difficult to solve the problem with one simple solution, we introduce the concept of *layered light*. To arrive at a final solution for lighting a particular urban space, several lighting layers are combined to create the overall luminous environment (Fig 3). Each layer fulfils one function of the overall lighting scheme. The luminaires needed to create each layer can be treated separately from those of other layers. If switched separately, these layers may be used in various combinations to provide very different lighting solutions.

Before starting to create a lighting composition, the designer needs to be clear about its objective. Architectural elements and features should be identified in order of importance for both visual
orientation and attraction. The overall and complete lighting solution is identified by the last or final layer. It incorporates all desired requirements: the maintained illuminance levels, overall colour rendering needs, lighting power density, initial installation and operating costs, etc. It is up to the designer to determine how many layers are needed to create an effective overall solution, but it is advisable that different requirements are treated as different layers. Simple lighting problems will likely not require more than one or two layers while complex lighting design problems may call for many different layers, especially when different lighting scenarios are desired at different times of the night or for different events. Energy management solutions and power distributions across the various layers can be tested and adjusted with an overall view using information from each layer. The information for each layer could be the number and types of lamps used, the associated power requirements for each type of lamp, their colour temperature, colour rendering index per layer, and type of luminaire.

The first layer will likely be defined by minimum requirements for the illumination of the main architectural features and important surfaces or objects. The buildings with less importance in the area should receive a lower illuminance, more important buildings should receive higher illuminances. At the same time, the dominant colour temperature of the complete installation should be selected according to the colour of building façades and other surfaces and in accordance with the colours of the surrounding environment. Just like the base colour on a painter's canvas, the first layer provides the starting point for the lighting designer's composition.

All other elements are built on this initial step. Because of this, the first layer requires special attention. The layer concept can be extended to area lighting to integrate separate spaces or areas within a larger space into a harmonious and pleasant environment. The layers in this case could be any structures found in the area, eg fountains or other features, and the ground level becomes a layer that must be analysed according to the minimum illuminance level required for safe pedestrian movement. Important considerations that need to be taken into account before starting the design process include the number of buildings involved in the area and in the project, the position of the buildings within the desired overall hierarchy, structures on the ground to be lit, the number of entrances and exits to and from the area, observation points, the colours of building façades and other surfaces, natural features, and cultural characteristics of the area.

The ground floor layer may be illuminated using the light reflected from the building façades in the area. Due to the reflection characteristics of the façades, the light distribution provides decreasing asymptotical illuminance levels forming a “dark valley” in the central part of the area (Fig 4). This dark valley allows the designer to illuminate central objects without light obstructions (Fig 5). In large plazas this method can provide the tool to reduce the number of decorative lanterns needed to satisfy the lighting requirements and, in the best case, even avoid their use.

Figure 3 Lighting composition and its basic elements

Figure 4 Asymptotic light distribution

Figure 5 Central object lighting solution
Figure 6  First lighting layer

Figure 7  Second lighting layer

Figure 8  Third lighting layer

Figure 9  Final lighting design result

Figure 10  Southern end of Civic Centre

Figure 11  Northern end of Civic Centre

Figure 12  Final illuminance levels

Figure 13  Civic Centre with central object
TESTING THE CONCEPT

Lighting simulation

As a proof of concept idea, the lighting solutions for the Convention Centre façade in Wellington’s Civic Square were designed using the layered light concept. The potential lighting design scenarios were modelled with the computer simulation program RADIANCE and the Rayfront user interface. For the final design presented here, three layers were chosen.

The first layer provides the initial lighting foundation (Fig 6). Note that in this first stage the shadows produced by the architectural details are not treated yet. The most important part of this layer is to provide enough light to make the façade visible at night-time. The second layer adds accent lighting and was selected to emphasise details at the bottom of the building (Fig 7). The third layer emphasises the repetitive details of the façade. Note that the shadows resulting from the first lighting layer have been treated adequately in this layer (Fig 8). The final lighting solution results from the combination of these three layers (Fig 9). Other layers have been added in a similar fashion to create the overall lighting design solution for the Civic Centre, including the City Council Buildings, the Central Library, the City Gallery, and Civic Square as the open space between these buildings.

Figures 10 and 11 illustrate the simulated images resulting from the application of this concept. It is possible to see clear details in the whole area on both vertical and horizontal planes. Figure 11 shows that the distribution of light in the area allows for a clear view to all buildings without light obstructions. Even the background area is visible. Figure 12 shows the illuminance level achieved in the area. Figure 13 shows how the lighting design might be developed if a central object, eg a fountain or sculpture, is placed in the centre of Civic Square.

Survey of people’s perception of existing and proposed lighting schemes

To test the lighting concept application against people’s perception, a statistical survey was designed. It focussed on impressions of perceived visual comfort, safety/security and overall lighting improvements and used a survey form with 13 statements. Respondents were shown a computer-generated image of the proposed lighting design (reproduced here as Fig 10) and a photograph of the present lighting conditions (reproduced here as Fig 2) for the Civic Centre. The targets were people over 20 years old. 40 people were interviewed, 40% were male and 60% were female. Survey contributors were lunch-time users of the Civic Centre area, library patrons, City Council technical staff, architectural students, and people walking in two main Wellington streets, Manners Mall and Lambton Quay. The survey was conducted showing respondents the simulated proposed lighting conditions and a photograph of the present lighting situation. The survey form was divided into two groups of statements according to a method described by Iwata et al (1994).

Some statements required making a direct judgement of the lighting design solution based on the images presented (eg, “The present lighting situation of the Civic Square is adequate”: strongly disagree – disagree – don’t know – agree – strongly agree). Others asked the respondents to indicate a more general feeling about the impact a lighting solution might have on an urban environment (eg, “This lighting solution improves the beauty of the city”: strongly disagree – disagree – don’t know – agree – strongly agree). Initially, all statements were analysed individually. A second step then combined the responses to selected statements (eg those directly referring to the proposed design solution for the area in question) and established an overall acceptance level of the proposed design solution.

Apart from the first three questions which related directly to one another, questions were presented in an order that made no connections between the individual statements. Statement 1 allowed for multiple ticks for a total of five identified lighting problems: person recognition, architectural details visibility, colour recognition, lighting levels, and security. The inability to identify people was selected by 77.5% of the respondents as the main lighting problem, followed by problems with architectural detail recognition (72.5%), concerns with object colour recognition (57.5%), lack of security (47.5%) and low lighting levels (17.5%). The five answers to Statement 1 have been expressed as overall percentages (Fig 14) to present a panoramic distribution of all respondents’ perceived lighting problems. Because respondents were able to provide more than one answer, the resulting
distribution reflects the total ticks per category (e.g., person recognition: ticked by 31 respondents) divided by the total number of ticks for all categories (109). The answers presented in Figure 14 clearly identify a lack of perceived safety or security in the area. The proposed lighting solution was compared in the survey with the present lighting situation in order to gauge the respondents' perception of the proposed lighting improvements regarding these five lighting problems. Approximately 72% of respondents indicated that the proposed lighting solution could solve the identified lighting problems (Fig 15). Nobody indicated strong disagreement.

Figure 14 Importance of the five lighting problems expressed as a percentage of all 109 responses to all five problems

Figure 15 New proposal addresses lighting problems

The development of one particular area depends on various factors such as location, transport, facilities, open space dimensions, attractions, etc. Lighting is one of those factors that could facilitate creating and being part of an attraction during night-time. Figures 16 and 17 indicate a growing necessity for areas to be beautified by lighting during the night in order to be more attractive. About 70% of respondents agree with this statement. The latter two answers are most important in terms of future possibilities, not only for the lighting concept proposed in this paper but also for other
improvements in the city. Combined responses to statements from the survey gave a final overview about the proposed lighting solution in terms of visual comfort perception and lighting improvements not only solving the five main lighting problems mentioned above but also in terms of the quality of proposed lighting solution. It is interesting to see that respondents thought that the proposed lighting solution would improve overall lighting and create a new night-time image for Wellington’s Civic Centre (Fig 18). The solution was also rated high with respect to anticipated overall visual comfort improvements (Fig 19).

CONCLUSIONS

On the basis of a relatively simple computer simulation and a survey we have established that it is possible to apply the layered light concept as a successful measure for improving the luminous environment of the Civic Centre area and provide one avenue towards the beautification of Wellington City. Other significant areas of Wellington City, including the Government District around Parliament and Lambton Harbour’s Waterfront, may be improved by similar design solutions. Ultimately, it would be desirable to use lighting design to create easily recognised landmarks within Wellington’s urban fabric while safety is enhanced at the same time.

The main goal at night is to provide an appropriate and safe environment for visual and other human activities, and to highlight the buildings and other structures that define the urban area. Luminaires do not need to be visible to achieve that goal. The details and structure of a beautiful lantern may be seen during the day but not during the night due to the brightness of its lamps. The lighting technique presented here avoids the intensive use of lanterns in open areas while achieving the required lighting levels. The additive nature of layered light allows for unique opportunities in highlighting those features and improving visual comfort and safety while at the same time providing greater control of lighting scenarios and energy consumption. Results from the survey indicate that three-quarters of the respondents judged the proposed lighting solution as solving the problems identified and significantly improving the commercial, social and recreational appeal of the Civic Centre during night hours.

The lighting layers concept can be applied to manage the electrical power required to provide a creative lighting design solution while emphasising the main features of the environment or a building façade. Layering the individual components of the overall lighting design allows for tighter control of these components. It also has the potential to reduce overall energy consumption as layers can be individually switched to provide higher levels of illumination when needed and lower levels when only lighting for safe movement is required. While this study has looked at the potential benefits of the layered light approach, the installation and operation costs as well as the potential energy reduction figures have not been analysed beyond some back-of-the-envelope calculations. The actual cost of this type of lighting solution will depend on the number of layers, the nature of the individual lighting details and the illumination levels a designer wants to create in the area in question. Further studies will attempt to address these concerns in more detail.

Additional research is needed on improving the computer simulation process. The assessment of the quality of a computer-mediated lighting design model during the design process is not always easy. The more detailed a model is, the more realistic the lighting effects can be portrayed by the model. Unfortunately, the only way to achieve a very close agreement between the results of a simulation and reality is by incorporating in the model as much detail about as many surfaces as possible in order to visualise potential lighting problems. Using AutoCAD to do this can be a time-consuming task and a disadvantage for the application of computer programs if the project requires fast answers. In this sense, this type of project and the corresponding lighting solutions should be considered primarily for medium to long-term term projects, at least for the time being.

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