

Simple Nomographs for Assessing Lighting in Urban Environments

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Abstract

Incorporating different technologies and lighting techniques in the illumination of structures has allowed us to portray fantastic night time vistas of our cities. However, the success of the selected technique or technology is frequently assessed based on what the lighting does to the overall environment.

At present, it is a common practice for the client or architect to require an illuminated night view of the building. These views are often used as part of the marketing strategy to promote building facilities. Alternatively, on a large scale, they can help promote buildings as city icons.

The illumination of building facades requires an appropriate selection of one or more floodlighting techniques and light sources to achieve the desired lighting effect. This selection, often driven by lighting standards and design considerations, will heavily influence the way in which that the overall lit environment will be portrayed at the end of the lighting project.

Currently, tables and floodlighting techniques exist to select the recommended quantity of light and the most suitable luminaire arrangement to illuminate a façade. There is however, no direct indication of how the surrounding area will be affected when the recommended light levels are achieved on the façade.

Despite the increased importance of the floodlighting technique, the design of a good illuminated façade does not have a tradition on

which to base parameters for the lighting design. This is often individually approached based on the knowledge, understanding, experience and proficiency of the lighting designer. Considering the diversity of buildings in urban environments, the selection of uncoordinated design parameters could have a significant impact on the area where the building is located. This could affect the occupant comfort and good energy management.

In light of the considerations presented above, it is only with a methodological approach that the lighting designer will be able to provide predictable and consistent results in any number of different situations. This presents an opportunity to develop a methodology to identify whether a façade is over-lit or if the proposed lighting solution is adequate for the area where it is situated.

The proposed methodology will provide a tool to estimate the potential lighting results while considering the effect on the overall environment where the building is located. When a façade is illuminated, the degree of the light experienced at street level is very much dependent upon the reflected light from the primary lit surface. This allows for a relationship based on light levels received at the surrounding street and the average illuminance level achieved on the façade.

Considering that lighting parameters such as lamp lumen output, the reflective qualities of the surface and the luminaire position are intrinsically connected to light reflections, a mathematical expression is formulated to link the relationship mentioned above with lighting design parameters through a set of nomographs.

This method provides a good foundation to systematically approach lighting designs with a comprehensive procedure to link the practical lighting considerations with the lighting requirements that will provide occupant comfort and good energy management. This method will help designers to compare different lighting alternatives by analysing the lighting impact of different lit facade options at the very early stage of the lighting design process.

1.0 Introduction

1.1 The Importance of Good Urban Lighting

The majority of the world's population lives and works in and around urban centres. There is no doubt that cities dominate the experience of modern humanity offering many benefits such as employment prospects and social or cultural activities. On the other hand, the higher the population density the more concerns arise about the urban facilities relating to the aesthetic of the city, safety and security, noise levels and reduced privacy. To counterbalance these concerns and to enhance the quality of life in the city, urban planners and designers consider a variety of aesthetic and functional possibilities. Appropriate lighting is one of those considerations that can provide significant benefits by enhancing the aesthetic value and perception of the urban environment.

Since efficient electrical lighting became a practical possibility, the illumination of building façades has contributed to enhancing nighttime activities through the provision of attractive settings as well as highlighting the unique character of the respective environment (Phillips, 2001). Good lighting has the potential for transforming neglected neighbourhoods into attractive urban showpieces while at

the same time creating a sense of safety for people moving about at night. This frequently results in extended hours for commercial and social activities.

Examples of buildings or structures where lighting has added aesthetic value to the night scene are widely published in professional lighting journals. Even though these journals usually do not show detailed indications as to how much people enjoy lit urban environments, and how this improves city activities, it is suggested that people prefer areas where lighting provides a variety of visual alternatives (Osterhaus and Sandoval, 2002).

1.2 Lighting Design Methods

Many designers have experimented with the use of lighting to showcase buildings – both historic and modern – as well as pieces of art to the public at night. At present, architects and designers certainly consider lighting a building at night as an integral part of the entire design process (Gardner, 2001). In professional practice, when designers develop a concept for the illumination of a façade, they often review available publications and look at how similar projects were undertaken.

Appropriate information is often found by consulting guidelines, standards, manuals, and recommendations from institutions such as the Illuminating Engineering Society – UK (IES), the Illuminating Engineering Society of North America (IESNA), the International Lighting Commission (CIE) or the Chartered Institution of Building Services Engineers (CIBSE), as well as the catalogues of suitable lamp and luminaire manufacturers.

Although there is vast information provided by the institutions mentioned above, the development of a good façade lighting concept can still pose a considerable challenge for lighting designers. The design of building facades often requires the input from other members of the design team such as architects, engineers and landscape designers who may have different and potentially conflicting goals. Information on the various aspects of a facade – such as colour or the visual impact desired for the area – is often a matter of interpretation among these different players (Holland, 1997).

A lighting designer can enhance the feeling of well-being for both residents and visitors through the use of appropriate lighting solutions. However, care needs to be taken to arrive at a solution, which considers both functional lighting aspects (including desirable lighting levels, energy use, operation and maintenance strategies), as well as

the impact of the proposed lighting scheme on the overall environment in which it is situated.

Less successful façade lighting design solutions might result in undesired side effects such as light spill onto neighbouring properties, excessive contrasts between buildings, visual discomfort, or unnecessarily high energy use. Lighting designers are especially vulnerable when they treat the lighting concept for their building in isolation from the surrounding physical environment.

Considering the vast number of buildings in urban environments, the repetitive application of poor lighting design techniques could lead to the destruction of what might have otherwise been a well-designed nighttime environment.

For many years, the most common approach for lighting the exteriors of buildings, monuments and other public displays has been floodlighting. But as Bean (2004) points out, there is an inherent danger in the name of this lighting technique: “Good exterior lighting needs to be more than simply “flooding” the façade or object with light”. Care needs to be taken in assessing the lighting requirements and the desired effects. There is a temptation to portray the building or object in similar lighting conditions as during the daytime when

diffuse light from the sky and direct sunlight interact in various ways with the surfaces. While this may be appropriate at times, other lighting approaches might produce more suitable results.

Uniform lighting across the frontages of several adjacent buildings, for example, creates a homogenous image, but makes differentiation of individual buildings and architectural elements more difficult (Fig 1.1). When used in conjunction with high light levels, it may also create unwanted spill light possibly resulting in glare or other visual discomfort. Spill light is light which spills or trespasses onto neighbouring properties and creates unwanted side or after effects. Residents living in the floors above street level might be kept awake by the bright illumination of the upper sections of the façades in Fig 1.1.



Figure 1.1 Nighttime view of the Rue de la Republique in Lyon – France (International Lighting Review, 003)

Differentiated approaches to lighting individual buildings in a defined area, combined with lower overall light levels, allow each building to be visible in its own right and reduce the chance of light trespass. Such approaches might include the application of different light colours to emphasise specific buildings or elements (Fig 1.2).



Figure 1.2. Integrated public lighting installations – Place du Sanitas, Nantes – France (International Lighting Review, 003)

Guidelines and recommendations provided by reputable professional organisations and lighting experts usually provide indications for typical ranges of façade illuminance levels. These recommendations vary depending on the reflective properties of the surfaces to be lit, the overall brightness of the surrounding environment, and the desired effect. However, these values have been considerably reduced from their initial recommended values. Two example recommendations from the Illuminating Engineering Society of North America are provided here for illustrative purposes (Tables 1.1 and 1.2).

Surface material	Reflectance in percentage	Surround	
		Bright	Dark
		Recommended level in Lux	
Light Marble, white or cream terracotta, white plaster	70 – 85	150	50
Concrete, tinted stucco, light gray and buff limestone, buff face brick	45 – 70	200	100
Medium gray limestone, common tan brick, sandstone	20 – 45	300	150
Common red brick, brown stone, stained wood shingles, dark gray brick	10 – 20	500	200

Table 1.1 Recommended illuminance for floodlighting (IESNA–1997)

Area description	Average target illuminance (vertical) (lux)
Bright surrounding and light surface	50
Bright surroundings and medium light surfaces	70
Bright surroundings and medium dark surface	100
Bright surroundings and dark surface	150
Dark surrounding and light surface	20
Dark surroundings and medium light surface	30
Dark surroundings and medium dark surfaces	40
Dark surroundings and dark surfaces	50

Table 1.2 Illuminance for floodlighting buildings and monuments (IESNA–2000)

From the comparison of these two tables, for instance, it is possible to see that values over 150 lux are no longer recommended in the 2000 Illuminating Engineering Society of North America document.

These reductions indicate that other considerations such as energy use and “the satisfactory practice” have possibly been considered in setting the new recommended illuminance values. A satisfactory

practice table provided by Bean (2004) suggests illuminance levels are categorised according to the area where the lighting will be provided, as shown in table 1.3. This table suggests considerable reduction of the recommended illuminance level for rural and suburban areas.

R (Building reflectance)	Rural (Lux)	Suburban (Lux)	Town centre (Lux)
0.8	15	25	40
0.6	20	35	60
0.4	30	50	85
0.3	40	65	110
0.2	60	100	170

Table 1.3 Average illuminance (lux) found satisfactory in practice (Bean, 2004)

While these façade illuminance recommendations provide a starting point for the lighting designer, many other considerations play important roles in the design process. As lighting of public places and building exteriors increases, concerns arise about never ending spirals. In order to make one building stand out among a group of buildings, higher light levels are typically selected to achieve sufficient contrast with the already lit façades.

The International Dark Sky Association (<http://www.darksky.org>), for example, publishes a considerable amount of information about the effects of lighting pollution on our environment and highlights the need for more moderate and better controlled use of lighting. In many

lighting applications it would appear not too difficult to reduce the light levels on the façade without affecting the overall success of the solution.

At present, the visualisation using lighting software of a proposed lighting concept prior to completion helps to identify all the potential problems mentioned above. Lighting simulation software enables the designers to develop 3D images of the proposed lighting solution. Such software is gaining importance in the context of architectural design practice and is increasingly being perceived as advantageous by designers.

Advances in rendering technology, especially related to simulation speed, have been significant in recent years. It is now possible to perform simulations of light interactions for moderately complex environments, yielding images of impressive realism. As realistic simulated images receive more attention, new potential applications for lighting simulations appear, especially in the context of urban design.

Using this technology, the lighting distribution and effects can be modelled to graphically visualise the overall lit environment proposed by the designer. Software can model complex lighting inter-reflections

between building façades, the street or landscape, prominent objects and many other elements, but the results depend strongly on the degree of detail incorporated into the model. However, a realistic simulation requires many hours of computer time. Time is needed constructing a three-dimensional model in a suitable Computer-Aided Design (CAD) package, importing the model into an appropriate lighting simulation program, selecting the desired light sources, luminaries and surface properties, and finally rendering selected solutions to establish comparative performance assessments.

The application of lighting simulation programs requires that the designer has some experience with and a reasonable understanding of the lighting techniques and available lighting technologies in order to select appropriate data for entry into the simulation program.

Most designers have developed their own methods to achieve successful lighting design outcomes through trial and error. They are typically guided by approaches which have worked in previous projects. To solve a new lighting task, the designers frequently apply variations on the basis of already known solutions.

Decisions still need to be made about how much light is desired on a building façade and its individual elements, about how much reflected

light from a façade is desired at street level and about how the light will be distributed across the façade and across the space which is delineated by the façade. The designer might also want to consider whether the lighting systems for the façade and the street could be integrated, for example to reduce overall installation costs and energy use.

Even though the visualisation using lighting simulation software helps to define and refine the desired solution, it has still not solved the problem of deciding upon the quantity and quality of light required without previously establishing references in order to avoid many and expensive computer rendering hours.

Lighting design often involves many considerations which vary from project to project and make it complicated to visualise the desired outcome. This complication arises from the constraints that façades impose on light spread, inter-reflections, energy savings and overall lighting requirements (Phillips, 2001). Moreover, as lighting solutions are frequently calculated independently and separately for each object or zone, the establishment of adequate light levels on a façade is not a simple process. This is especially true when also considering all the other architectural and/or landscape features in the adjacent area that the designer wants to include in the overall lighting concept.

On the other hand, examples similar to that shown in figure 1.2 published in different lighting journals suggest that good lighting solutions are nevertheless produced. Currently, simple tables exist to select typical illumination levels for a façade. From these, and in conjunction with the most common method to light a façade — the floodlighting technique — the number of luminaires likely to be required can be estimated. But the absence of a reliable more detailed method to arrive at a suitable solution for each specific application often results in a random process of trial and error, rather than in a systematic approach to the design problem.

1.3 Opportunities for a New Method

As already mentioned above, floodlighting is the predominant approach for lighting the exteriors of buildings. Its effectiveness depends largely on the reflective properties of the façade. Darker and less shiny materials require more illumination to achieve the same brightness appearance as a lighter more reflective façade. However, more light also means a higher potential for light trespass and unwanted spill. While floodlights can be supplied with accessories to avoid light spill to other buildings, some of the light directed at a façade will always be reflected into the surroundings and can, for example, be measured at street level.

In order to give all buildings their special place and, if appropriate, establish a visual hierarchy between them, there needs to be an area of lower illumination against which these buildings can be seen. This lower illumination can be estimated based on the analysis of the impact that the reflected light from lit façades has on the surrounding street.

This opens an opportunity to develop a systematic method to estimate how much light is required to illuminate a façade in environments where various façades with opposing or varying orientation, for example façades around a plaza or square, need to be illuminated at the same time.

Overall, such an approach can assist designers with the selection and analysis of the quantity of light, as well as the arrangement of luminaires for the area under design.

1.4 The Hypothesis

The light reflected off a lit façade provides an illuminated area at the surrounding street, thus light levels can be measured. Based on these measurements, it should be possible to develop a tool which can be used to estimate the lighting effect that lit façade would have on the overall environment in which it is situated with reasonable accuracy.

The light received at street level depends largely on the reflective properties of the façade, the amount of light directed at the façade and the position of the lamp(s) and luminaire(s) producing that light. To a small extent it also depends on the reflective properties of other surfaces in the environment which contribute to the illumination at street level through interreflection. For the purpose of initial estimates, this contribution can probably be ignored as in urban environments surrounding façades are often situated on each side or opposite to the illuminated building.

None of the currently available methods includes the determination of illuminance at street level due to the light reflected off a façade. This thesis project attempts to develop such a method for use in the early stages of an exterior lighting design task.

Figure 1.3 illustrates an example computer simulation of the illuminance at street level resulting from floodlighting of a building façade of 50% average reflectance with three ground-mounted floodlights with symmetrical reflectors and 150 W lamps producing 12000 lumens. As would be expected, with increasing distance from the façade the illuminance at street level decreases.

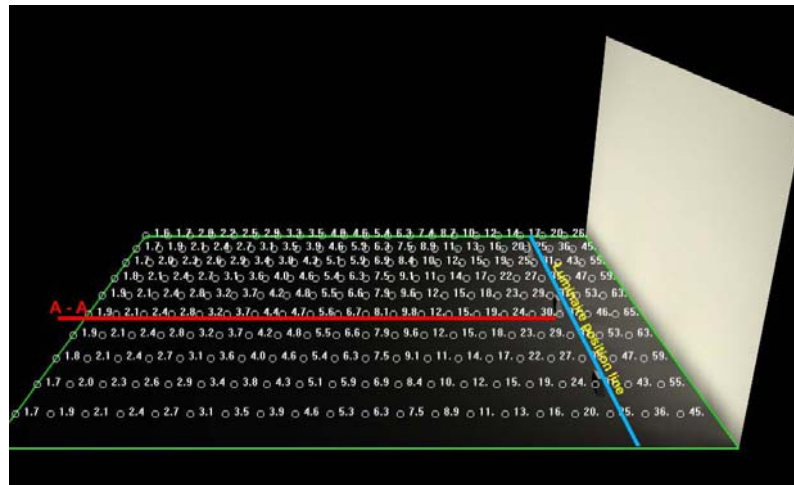


Figure 1.3 The figure shows an illuminated building façade. The numbers presented on the horizontal surface represent received illuminance levels (Lux) resulting from light reflected from the building façade.

Plotting the illuminance values at the horizontal line A-A against the distance from the façade, the resulting graph shows a trend that could be a characteristic of this type of lighting application (figure1.4).

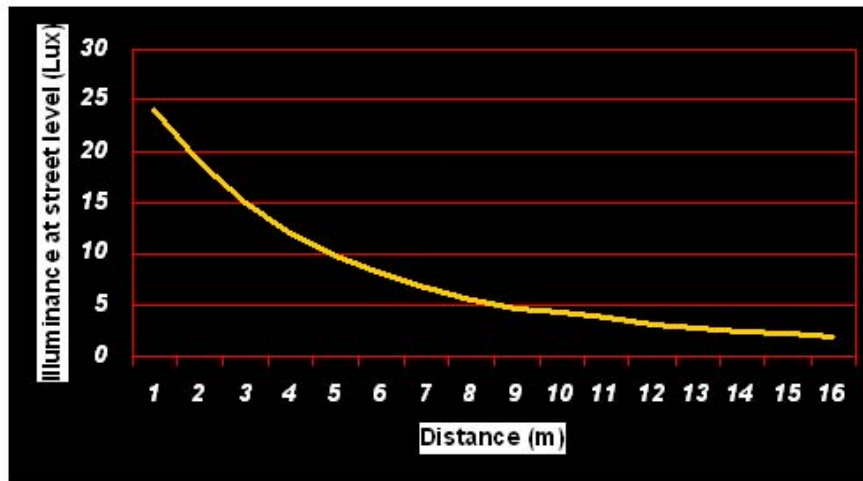


Figure 1.4 The graph depicts the illuminance levels (Lux) measured along the horizontal line in the centre of the light spread at street level (Y-axis) against the distance (X-axis)

When analysing many such simulations, it appears likely that common patterns are exhibited which could be displayed through a set of closely matching or congruent curves. If that is indeed the case, then it should be possible to construct a set of nomographs on the basis of these curves for different lighting design approaches, for example different mounting positions of the luminaries, different façade reflectances and different lamps. This would allow the lighting designer to work out the likely impact of a façade lighting solution on the illuminance at street level. This in turn, can then be applied in the selection of a suitable street lighting system complementing the already available light reflected off the façade and thus altering the equipment and energy requirements for the street lighting system. As long as building floodlighting and street lighting operate at the same times, one would expect a reduction in energy use.

Alternatively, if a city ordinance, code or bylaw sets limits as to how much light can be reflected off a façade onto the street, the tool could be employed to establish the maximum permissible average illuminance on the façade of a building.

The hypothesis of this thesis is thus as follows:

Hypothesis

It is possible to create a set of nomographs to predict the horizontal street illuminance (within a set of variables) generated as a result of light reflected from an illuminated building façade.

1.5 Synopsis

The development of this thesis starts in Chapter 2 and ends in Chapter 4 with the provision of the nomograph and a formula that integrates the values from the nomographs. Chapter 5 is dedicated to show a step-by-step procedure of the lighting technique presented. Chapter 6 has been prepared for the general conclusions and finally, Chapter 7 provides a brief description of possible further work. Each chapter is preceded by a brief introduction.

The thesis is arranged as follows:

Chapter 2 – Background

This chapter briefly reviews current lighting techniques and lighting requirements for outdoor applications. This chapter also establishes the main characteristics of artificial light sources.

Advantages and disadvantages are shown to establish the main lighting parameters such as photometrics, lamp light output, distances between luminaires as well as the luminaire position and distances from the façade often recommended when a façade is illuminated.

Chapter 3 – Methodology and Data Collection

This chapter describes the methodology followed in this thesis. Based on the previous chapter, this chapter reviews the lighting requirements for exterior applications and defines the lighting arrangements to be tested. This also includes the collection and preparation of the data for analysis.

Chapter 4 - Analysis

This chapter shows evidence that it is possible to use nomographs to simplify the façade lighting design process. This is analysed based on the data gathered from lighting arrangements defined in the previous chapter.

A detailed development of the nomographs is shown in this chapter. A mathematical expression to estimate the illuminance levels at street level based on nomograph variables is also developed.

Chapter 5 - Step-by-Step Lighting Design

An open virtual public space is created, analysed and illuminated to show the Step-by-Step procedure. The area is designed following the

suggested method stated in the thesis and complemented with a simple suggested design process for designers.

Chapter 6 – Conclusions

General conclusions of this work are provided in this chapter along with a summary of the parameters required when using this method.

These conclusions also indicate potential for energy savings and the integration of combined lighting techniques in urban applications such as plazas or civic squares.

Chapter 7 – Future Research Recommendations

This Chapter describes recommended future work that could be carried out based on the results presented in this thesis for those potential lighting applications.

2.0 Background

It is indubitable that exterior lighting is playing an important role in the urban planning process. Strongly influenced by the introduction of the new lighting concepts and technologies, the implementation of exterior lighting is providing illumination not only for safety and security but also for the latest city identification, spectacle and promotion concepts (Loe & Rowland, 1996).

From candles and petrol-gas lanterns mainly used in the 18th and 19th centuries to today's electric light, the continuous experiments with and implementation of these technologies have provided the flexibility to incorporate electric lights as part of the city environment.

From the basic illuminated façade to the architectural lighting solutions, exterior illumination for building façades requires thorough considerations to provide acceptable lighting schemes.

To help designers with the lighting conceptualisation, organisations such as the Illuminating Engineering Society – UK (IES), the Commission Internationale de L'Éclairage (CIE) and Chartered Institution of Building Services Engineers (CIBSE) have provided guidelines highlighting important recommendations. These recommendations, often overlooked during the decision making process, assist designers with the application of, amongst other considerations, the most suitable lighting technique, recommended lighting levels and location of light sources.

This section deals with these recommendations to approach this type of lighting design in relation to the most used light sources, concepts, terminology and units of the floodlighting technique. A brief description of the most important characteristics of floodlighting and its effects is also provided in this chapter.

2.1 Light Source and Luminaire Characteristics

The invention of electric lamps at the end of the 19th Century made practical the implementation of street lighting in cities. However, it was not until the introduction of discharge lamps at the beginning of the last century that this implementation was possible on a large scale. This was due to a technical break-through that allowed these lamps to provide more light output and reduced power consumption.

Along side the lamp development, luminaires that initially were used to protect lamps from the environment were fitted with optic systems and diffusers to distribute and control the light spread received on a surface. At present, luminaires play an important role to optimise lighting designs. The selection of the luminaire characteristics such as light distribution and dimensions often become critical in the achievement of the desired lighting effects.

This section highlights the appropriate selection of these lighting components and available technologies that have made possible the illumination of cities by reducing the number of luminaires and power consumption.

2.1.1 Lamp

Considering that the success of a lighting design for exterior applications strongly depends on the achievement of desired light

levels on a façade, the selection of a lamp is not a trivial task. Generally classified by the way the light is produced, this selection responds to numerous factors such as operating characteristics, light characteristics and lamp shape that need to be considered to suit the lighting project requirements.

2.1.1.1 Lamp Operating Characteristics

Lamps are, among other factors, identified by the power measured in Watts (W). However, the most remarkable characteristic is the quantity of light emitted by the lamp. This is measured in lumen and is defined as the luminous flux emitted from a light source in a unit solid angle (Henderson & Marsden, 1975).

With a ratio based on these two characteristics the luminous efficacy of a lamp can be established. This ratio refers to the quantity of light emitted by a lamp and the wattage of electrical power (Lumen/Watt). The higher the value of this ratio the better the luminous efficacy. The importance of this ratio roots in the provision of the required information to determine if the proposed lighting solution will lead to an energy efficient installation. Currently, the selection of lamps always requires the analysis of the luminous efficacy. This constitutes one of the most important information requiring careful attention when a lamp is specified for an exterior lighting project.

The evaluation of the luminous efficacy of the main lamp types existing in the market reveals that incandescent lamps are situated at the bottom of the list showing the lowest efficacy values. For the reason that the light produced by this type of lamp is based on heating a filament, a large part of energy is wasted through heat instead of light. This makes this lamp type less effective.

On the other hand, since the first electric discharge lamp was introduced in the market, important improvements with relation to the efficacy of the lamp have been made. From these, discharge lamps such as high-pressure sodium, metal halide and mercury lamps have continuously benefited from these improvements and made them the preferred lamps for exterior applications.

Latest lamps technologies suggest the utilisation of LED lamps in exterior lighting applications. The advantage of these lamps can be seen in terms of dimensions and energy consumption. However and despite successful projects portrayed in international magazines, these lamps are in an early development stage and do not provide the required light output to efficiently “wash” a façade yet.

From these lamps, discharge lamps are still the preferred lamp for outdoor applications. However, discharge lamp selection depends on the colour of buildings and objects in the designed area. Colours could be altered under these types of lamps; and in the worst case scenario, they could create visual discomfort. For this reason, these lamps require careful consideration of two important lamp characteristics: colour temperature and colour rendering index.

2.1.1.2 Lamp Colour Temperature

Light is popularly classified from warm to cool colours (Table 2.1). To enable an object comparison of the colour impressions from various light sources a scale is required. This scale is given by the “correlated colour temperature”. ‘The correlated colour temperature’ is the colour gradation of the light compared with the light emitted by an intensely heated iron bar (black body radiator) of which the temperature is

known; this is specified by a value in Kelvin (K)' (Henderson and Marsdem, 1975). From the table below, the lower the colour temperature the warmer the light colour.

Light colour	Colour temperature
Daylight	6000K
Cool White	5000K
Neutral white	4000K
“Crisp” warm white	3000K
“Cosy” warm white	2500K
Very warm white	2000K

Table 2.1 Colour temperature chart. The table approximately indicates how different Kelvin values would be perceived in an environment.

The visual impression of the lit environment could be distorted by how material colours would appear under the light emitted from the selected lamp source.

2.1.1.3 Lamp Colour Rendering Index

Discharge lamps provide the required lumen output needed for exterior applications, but the true colour of objects is strongly affected under the light produced by these lamps, thus the environment will be perceived differently and maybe unpleasant. They require careful consideration in the selections of colour rendering characteristics.

The colour-rendering index is a standardised percentage number from zero to one-hundred percent that is provided by lamp manufacturers. These numbers indicate how much of the natural colour can be

rendered when illuminated by an electric lamp and can be generally classified as follows:

Colour Rendering Group	General Colour Rendering Index Range (C.R.I.)
1A	$Ra \geq 90$
1B	$80 \leq Ra < 90$
2	$60 \leq Ra < 80$
3	$40 \leq Ra < 60$
4	$20 \leq Ra < 40$

Table 2.2 Colour Rendering Index (CRI) indicative values (AS/NZS 1680.1:2006)

These numbers indicate that colours are best shown under a light source with the highest colour-rendering index. For instance, a high-pressure sodium discharge lamp can cause uncomfortable environments due to its colour temperature (2000K) and colour-rendering index (23%). It changes the colour perception in an area washing the area with a yellowish hue as well as a poor colour rendition for colour such as green or blue for example.

Main manufacturers provide a large range of lamps in catalogues. They often show these characteristics along with the lamp power, lamp holder required and dimensions. Comprehensive lamp manuals from manufacturers such as Philips or Osram are available on line for those researchers interested in the lamp colour topics.

2.1.1.3 Shape and Dimension of Lamps

Since the first electric lamp was created, new materials and technologies applied in manufacturing have allowed the reduction of lamp dimensions and the exploration of new shapes. For instance,

figure 2.1 shows two different lamp shapes. These two lamps are designed to operate under the same lamp power (100W); however, they provide a different lumen output.

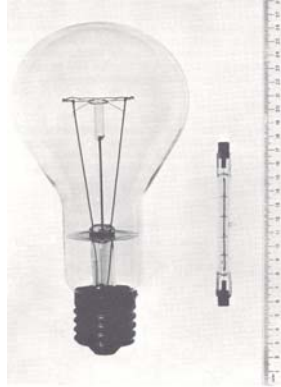


Figure 2.1 - GLS pear bulb lamp - 100W, 1360 lumen - vs. double ended linear lamp - 100W, 1600 lumen - University of Arizona (www.optics.arizona.edu/Palmer/opti506/lectures)

Significant to the implementation of exterior lighting, apart from the reduction of lamp dimensions, was the exploration of new lamp shapes for discharge lamps. This resulted in the development of three basic lamp shapes: tubular, pear bulb and tubular with two terminals (Figures 2.2).



Figure 2.2 Latest technologies in HID lamps provide a new range of compact lamps for outdoor applications (Osram ceramic lamp CDM-T – Catalogue of Lamps 2005-2006)

Reduced lamp dimensions and new lamp shapes, e.g. tubular lamps, allowed the introduction of small floodlights that enable the illumination of small details or ornaments on façades.

2.1.2 Luminaire

It is evident that lamps play an important role in satisfying exterior lighting. However, the achievement of lighting effects strongly depends on how the light is directed onto a surface. The reflector of the luminaire defines this. It was not until 1765 when David Garrick introduced an innovative way to light a stage using light sources behind the proscenium arch and across the apron (Williams, 1999), that the control of light output turned into a real opportunity to illuminate objects. This innovation introduced the idea to control the light output by using a reflector behind the lamp to direct the light flux to a surface. At present, manufacturers provide reflectors inside a housing that also contains all electrical components and accessories to protect the lamp against solids and water as well as to facilitate the installation. This housing is known as a luminaire. In exterior lighting, the most common luminaires are called floodlights.

Developments in floodlighting luminaire design have made it practical to employ equipment with different reflector or optical systems. This was also facilitated by the reduction of lamp dimensions. This allows lighting designers to reduce the visual impact of equipment used on façades as well as to provide innovative and efficient approaches.

2.1.2.1 Photometrics

Optical systems allow floodlights to deliver the light in different beam angles. These are classified as wide, medium and narrow spread

(Illuminating Engineering Society of North America, 1999). Wide spread luminaires are often used to evenly distribute the light provided onto the façade while medium and narrow spread are mostly used to provide accent lighting effects (Stranks & Berry, 1995). This imposes a new importance on closely examining how the light output of the lamp behaves when placed inside an optic system. This examining can be done through the analysis of the photometric characteristics of luminaires. Photometric information is presented graphically as polar curves or in a numerical arrangement suitable for application in lighting software. At present, the most often used numerical arrangement is that proposed by the Illuminating Engineering Society of North America, the IES file (See figure 2.3).

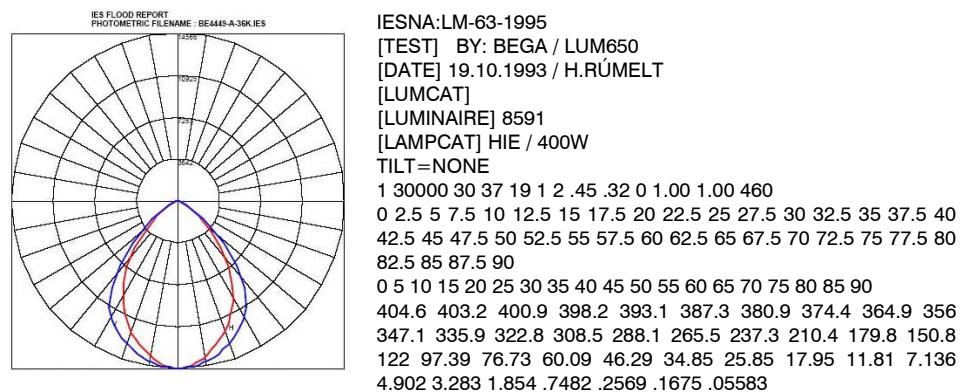


Figure 2.3 Photometric file – Bega Floodlight polar curve and its corresponding IES file

Polar curves and IES files are prepared by certified laboratories who apply the standards established by international lighting institutions. One of the requirements from the standards is that the data have to be collected based on candelas per 1000 lumens of the lamp as universal value of reference (Illuminating Engineering Society of North America ED-100.4, 1999). IES files built with this reference allow the use of the same light distribution of the luminaire whether the lumen output of the lamp is increased or decreased, as long as the shape and size of the

lamp are identical. This information, either in polar curves or IES files, allows the calculation and prediction of the quantity of light received on a surface.

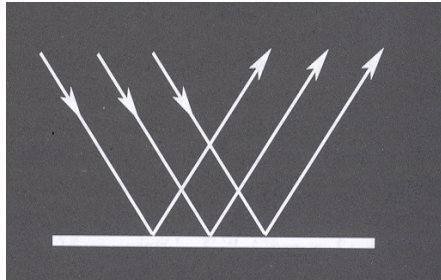
At present, manufacturers produce aesthetic and small luminaires with a very flexible light distribution. This allows architects and designers to select products with appropriate photometric performance within their expected aesthetic luminaire considerations. However, it is important to have a good understanding of the overall definition of luminaires for a successful façade lighting design, as the selection of luminaires does not occur in isolation from the lamp or reflector. The selection of a lamp and most suitable optic system from the initial concept stage of any project is essential. The prime consideration must be the overall photometric performance including light intensity values at different angles to define the type of luminaire required for the desired lighting effect.

2.2 Façade Characteristics Affecting Light Reflections

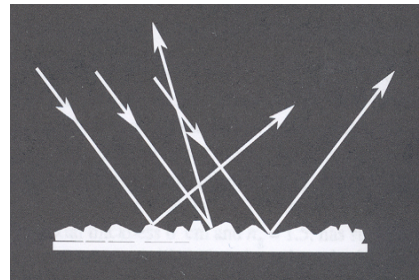
The lighting design of building facades often requires detailed attention to the material and colour of the building façade at the design concept stage. As light may be absorbed, transmitted and/or reflected by the affected surface, lighting effects strongly depend on the type of surface from which the light will be reflected.

Reflections from a surface are identified as specular and diffuse (Tunnacliffe & Hirst, 2000). The specular reflection occurs when light is reflected from an ideal polished surface (See figure 2.4) where all incident light is reflected at the mirror angle. However, surfaces on exterior structures are not ideal polished surfaces; therefore, the incident ray of light is reflected according to the normal of every

tangent formed by any irregularity of the surface creating a predominantly diffuse reflection (Figure 2.5).



**Figure 2.4 - Specular reflection
(Henderson & Marsden, 1975)**



**Figure 2.5 - Diffuse reflection
(Henderson & Marsden, 1975)**

Rough surfaces as shown in figure 2.5 will reflect the light rays and diffuse them in many different directions. Roughness of the material means that each individual ray meets a different surface orientation. Consequently, when the individual rays reflect according to the law of reflection, they scatter in different directions. The result of this effect is that the concentrated bundle of rays incident upon the surface will be diffused upon reflection.

Despite this, the light reflected can be predicted by the law of reflection, but the problem is complicated when a second surface is affected by light already reflected. This could be the case when light is reflected off a façade onto the street for instance, and this calculation is not simple. In such a case, the calculation of the amount of light due to these reflections is based on the flux transfer and the inter-reflection between surfaces (Figure 2.6) given by the equation known as the Mutual Exchange Coefficient indicated in equation 1 (Henderson & Marsden, 1975).

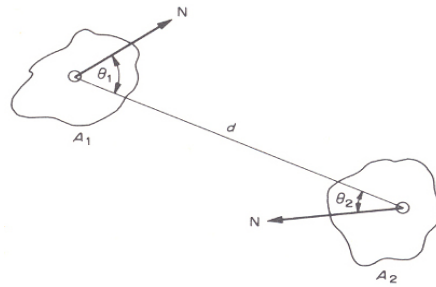


Figure 2.6 Light provided from one light source can be reflected from one surface and received in another surface (Henderson & Marsden, 1975)

The equation considers that the incident light reflected at the mirror angle per unit area of the first surface will affect smaller areas of the second surface. Therefore the result of the received light flux at the second surface will be the addition of all light flux incident per unit area hitting the second surface.

$$\frac{\Phi_2}{M_1} = \frac{\cos \theta_1 * \cos \theta_2 * \Delta A_1 * \Delta A_2}{\pi * d^2} \quad \text{Equation 1}$$

Where:

Φ_2	Flux of the light source
A_1, A_2	Area of a surface
d	Distance from one surface to another
θ_1, θ_2	Angles between surfaces' normal and the incident ray
M_1	Luminous exitance of surface A_1

According to Hirata, Gama and Nakurama (2001) “this method provides one of the most accurate lighting analysis methods for inter-reflected surfaces”, but because of its complexity, this equation requires computational calculations.

Another factor affecting the reflections is the façade's colour. Colours reflect light differently due to the reflectance properties, and these could also be influenced by the colour of the light sources themselves. 'For instance, a neutral coloured surface will reflect a proportion of all

spectral colours of the light incident upon it, while a coloured surface will reflect only some of the spectral colours' (Lighting Guide 11, 2001). This means for instance, that if a white lamp illuminates a red coloured surface, its reflectance properties could be lower than if the same surface were illuminated with a red coloured lamp (Illuminating Engineering Society, 1999). In relation to the previous information, façade colours and lamp light colours are integrated in one single term: reflectance, expressed as a percentage value of reflected over incident light.

Reflectance is used to calculate general lighting situations regardless of colours of surfaces and the incident light upon it.

2.3 Façade Illumination and the Most Common Luminaire Arrangements

An effective façade painted with light utilises common floodlighting techniques. As its name suggests, floodlighting is a lighting technique which uses a direct beam to “flood” the object with light. This often attempts to achieve a uniform light level based on the provision of light distributed by the optical system of the luminaire onto the façade until the required illuminance level is reached.

Despite the fact that its purpose is largely the provision of general illumination for open spaces, floodlighting techniques can also be used to provide lighting effects when focused on architectural features. However, the lighting effect could vary according to the direction of the luminaire's main light beam.

2.3.1 Luminaire Arrangements

To achieve different lighting solutions using floodlights, lighting recommendations provided by institutions such as the Illuminating Engineering Society (IES) and The Commission Internationale de L'Eclairage (CIE) suggest common methods to light different building geometries. These recommendations predominantly suggest the use of floodlights in front of and at the bottom of the façade as shown in figures 2.7 (Illuminating Engineering Society of North America, 1999). These recommended luminaire locations provide advantages and disadvantages that the lighting designer should take into consideration along with the corresponding recommendations for application of the selected technique.

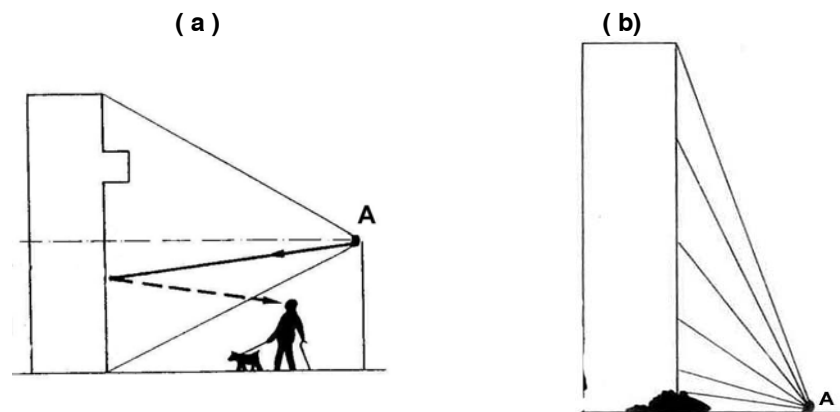


Figure 2.7 Most common floodlighting techniques to illuminate a façade where A indicates the position of the luminaire (IESNA Lighting Handbook, 1995)

The first lighting technique refers to luminaires in front of the façade as shown on the left in figure 2.7(a). This usually spills the light on the entire façade providing a very evenly lit surface. This technique allows efficient illumination using a limited amount of fittings. Lighting designers can see this as an advantage. However, the final aesthetic result could be questioned on the basis of lack of contrast. For instance, Figure 2.8 shows a typically floodlit façade achieved by the

method described above. This provides sufficient light levels to make the entire building visible, but this solution provides a monotonous illumination as all building details look like they were in the same vertical plane.

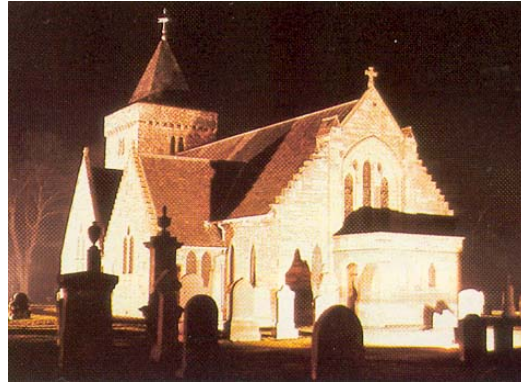


**Figure 2.8 Saint Michel, Brussels
(International Lighting Review, 79/4)**

The second lighting technique refers to a luminaire located at ground level with the light beam directed upwards as displayed in figure 2.7(b). Using this lighting technique, the light reaching the façade is strong at the base of the building and fades towards the top of the building. Lighting designs based on this technique characteristically project distorted shadows in the direction of the light beam. The size of these shadows often depends on the features and geometry of the building as illustrated in figure 2.9.

In this case, the building has been typically illuminated by using floodlights in an upward position. The features of the building project shadows to the roof and the second level of the front façade. This lighting technique often requires complementary light sources to avoid

the strong contrasts that shadows can create. However, sometimes designers conceive these shadows as a design advantage as projected shadows can be used to dramatise the nighttime vista.



**Figure 2.9 Aberlady Parish Church, Great Britain
(International Lighting Review, 79/4)**

An extension of these lighting techniques can be observed when the two lighting techniques are concurrently applied by using floodlights in different positions and intentionally directed. This lighting combines a set of floodlights in front of the façade along with dedicated uplights located at different points of the building to illuminate other features of the building. With this combined technique, the façade as well as the whole building can be lit to achieve a three-dimensional lighting distribution such as shown in Figure 2.10.



**Figure 2.10 Main Plaza in Cusco, Peru – 2000
(International Lighting Review, 00/1)**

With the now increasing need to improve the nighttime vista, the control of unwanted lighting effects needs to be effectively handled. In figure 2.11, the lighting solution achieved by using floodlights in an upward position provides a “good” illuminated building; however, the excessive light levels may create the most common undesired lighting effect - light pollution. The term light ‘pollution’ includes all the light spill around an illuminated building that causes visual discomfort and directs light at surfaces or the sky that is neither needed nor wanted.



**Figure 2.11 - Dayabumi Complex Jalan Sultan Hishamuddin
(International Lighting Review, 92/3)**

Despite that the identification lighting concept suggests that icons of a city can be used to capture the attention of visitors and residents’ (CIBSE: Lighting the environment, 1995), it is clear though that when a building is excessively illuminated, this will not necessarily provide the desired effect for people. More than often it creates a contrary effect. With thoughtful lighting design, such as the illumination of the building shown in figure 2.12, a reduction in lighting load can produce a

dramatic increase in visual effect. This effect highlights the building with less impact for the environment.



**Figure 2.12 – A new landmark on the Singapore skyline
(International Lighting Review 96/4)**

From the information, it can be concluded that more than often design considerations along with carefully specified light levels and characteristics of luminaires increase the visual effect and greatly increase the overall effectiveness of the installation for energy savings.

2.3.2 Building Height and Luminaire Distances from the Façade

Most modern cities have grown from an existing infrastructure and urban distribution. From historic and traditional to modern buildings, cities show a variety of architectural design tendencies and building geometries applied over time. However, important from the lighting

design point of view is that when they are being illuminated, the ratio of the required distance from the façade to the position of the luminaires is a value that considers the height of the building.

This value is provided by lighting institutions such as the Illuminating Engineering Society (IES) as a ratio between the height of the building and the distance of the luminaire from the façade in a ratio of 2 to 1 as shown in figure 2.13.

Height of the building (h) / distance position of the luminaire (D) = 2/1

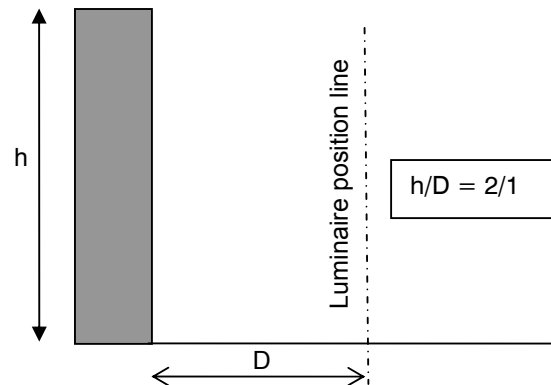


Figure 2.13 Luminaire location based on the relationship between a building's height and the luminaire distance from the façade (IES Lighting Guide, 1975)

'This ratio gives an approximate ideal distance from a façade of luminaires based on wide beam angle luminaires' (Illuminating Engineering Society of North America, 1999).

From this ratio, it is possible to observe that the higher the building the larger the distance required for the luminaire to illuminate the façade, however, in a city environment the luminaire distance has limitations due to the physical width of a street, the luminaire pole height, and the area available for mounting the luminaires.

2.3.3 Pole Height

In general, cities have limitations on the heights of poles allowed for lighting applications. 'Specified through either lighting codes or design standards they have two intentions: to reduce the visual impact within the landscape and to avoid the spread of the light into surrounding areas' (International Dark-Sky Association, 2002).

The first intention refers to the number of poles used to illuminate a façade or area that might block the view and disrupt the surrounding environment. The second intention refers to the mounting height of the luminaire on the poles. The mounting height of the luminaire goes some way to determining the light trespass and pollution into a surrounding urban environment. These two limitations mean that a careful selection of the pole height and the type of luminaire is required. Commonly, for an urban environment, city codes and standards often suggest poles from three to seven metres high for those city areas where the street width is not more than eight metres and the street is not a highway. For those streets classified as highways, they often recommend poles from nine to fifteen metres as the required illuminance and uniformity levels are often higher than for secondary streets or pedestrian areas and can more easily be achieved at this height (e.g. Standards Australia - New Zealand – AS/NZS1158.3.1- Road Lighting Part 3.1, 2005).

2.3.4 Distance Between Luminaires

The literature reviewed shows that there is no specific recommendation for distances between luminaires. What is indicated however, is that the distances between luminaires are basically

defined by the illuminance uniformity and the light levels desired on the façade (Henderson & Marsden, 1975). Often designers will include a minimum number of luminaires for aesthetic purposes. Under all considerations, the distance between luminaires will depend on the selection of a luminaire able to provide an appropriate photometric distribution. This distribution normally takes different shapes according to the geometry of the optic system. For example, a round luminaire with a specular symmetric optic installed at ground level provides an oval light distribution on the façade as shown in figure 2.14.

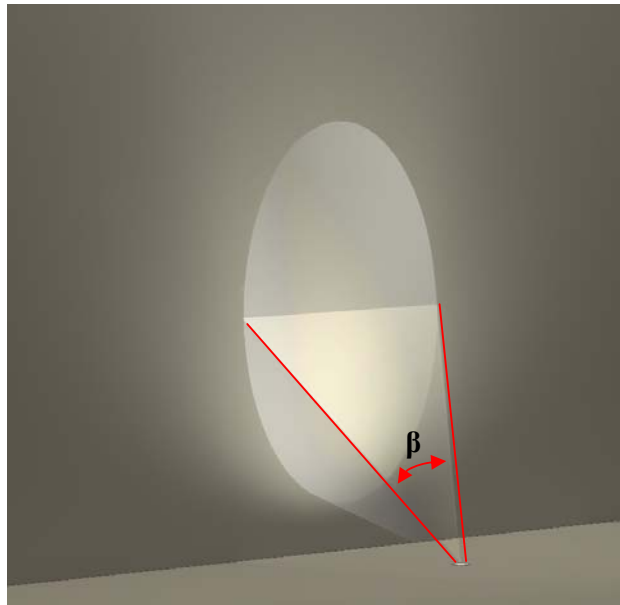


Figure 2.14 Typical light spread on a faced from a floodlight. The angle β indicates the horizontal aperture of the light beam.

The light distribution also varies according to the selected beam angle of the luminaire indicated as β in figure 2.14. Luminaires with narrow beam angles will provide less light spread in comparison to a wide beam luminaire. Manufacturers provide this information indicating the beam angle of the light output. However, the selection of the type of beam angle also depends on the required mounting distance from the

façade. The further the distance the wider the light spread required for the same number of luminaires.

Characteristically, when the light output of a lamp is distributed by an optic system, the strongest light incident is often provided at the centre of the light spread decreasing while the light beam reaches the maximum aperture of the optic system. Because of this characteristic, when two luminaires are used to provide illuminance uniformity, they require to be collocated at a distance that allows overlapping their corresponding light spread as shown in figure 2.15.

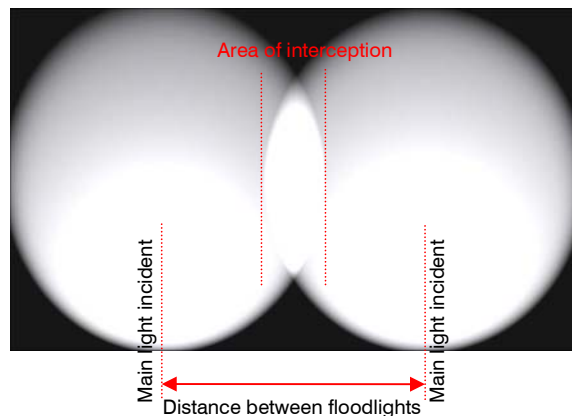


Figure 2.15 Typical interception of the light spread provided by two light sources. The uniformity and light levels reached on the façade vary depending on the luminaire location from the façade and the distance between luminaires.

The optimal distance between these two luminaires is obtained when the interception of their corresponding light spread satisfies the illuminance levels and uniformity required on the façade. This distance varies depending on the light levels desired, luminaire distance from the façade, luminaire properties and lumen output of the lamp.

On the other hand, when a set of luminaires is used to illuminate a façade, the achievement of the illuminance uniformity is often reached by equally spacing the luminaires at the required optimal distance (X)

which satisfies the illuminance uniformity and light levels, and along a parallel line to the façade as indicated in figure 2.16.

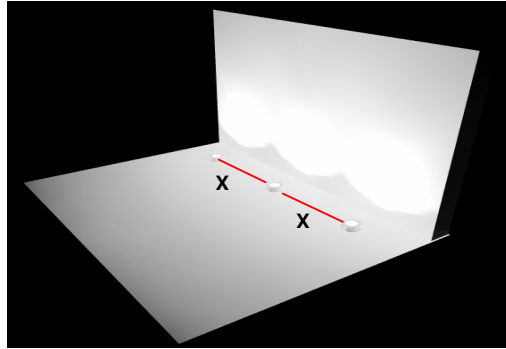


Figure 2.16 Typical illumination using floodlights from the bottom of the building where luminaires have been equally spaced.

As a general rule, it is possible to say that the wider the beam angle the bigger the distances between luminaires. However, if the required illuminance level is higher than this rule of thumb achieves, and the same lamp is specified, the ideal distance between luminaires may need to be smaller.

3.0 Methodology

In order to ascertain whether the various parameters described in the background section indeed displayed the suggested similarities and thus allowed for the development of simple nomographs, it was critical to set up suitable scenarios for which the essential parameters could easily be varied. In addition, the factors tested required that they related closely to situations commonly found in real floodlighting applications.

These considerations suggested that a number of factors needed to be investigated, preferably by systematic parametric modelling. They included the following:

1. Determination of parameters for building modelling
 - Building façade dimensions
 - Building façade surface properties

2. Determination of parameters for lighting system
 - Luminaire position relative to building façade
 - Luminaire aiming angle
 - Luminaire intensity distribution
 - Lamp characteristics

3. Measurements
4. Physical versus digital model
5. Calculation and data display arrangement
6. Data analysis procedure
7. Nomograph construction

These factors were assessed for their importance and relevance for the research project. To provide useful information to lighting designers, common scenarios have been selected for this study.

3.1 Determination of Parameters for Modeling

3.1.1 Building Façade Dimensions

The dimensions of a building façade obviously have a significant impact on the selection of an appropriate lighting system. Building height especially is a critical dimension as it will influence where the luminaires applied to light the façade can be mounted. The higher a building the more difficult it will be to provide suitable mounting positions for floodlighting techniques, especially when pole-mounted luminaires are to be used in front of the façade. For the purpose of this thesis, building heights have been limited to fourteen metres, or approximately four to five stories.

3.1.2 Building Façade Surface Properties

When considering what might influence the surface properties of a building façade a number of factors come to mind. The selected building materials, their surface textures and geometries, the architectural articulation of the façade (e.g. protruding and receding elements), potential paint applications, and any dirt which might have accumulated on the façade, and many others will all have an impact on how light is interacting with the building façade. Individual surface areas of the façade typically might have different reflective properties which affect how light is reflected back into the environment.

For this thesis it would be too difficult to test all the possible combinations of these factors. Instead, the cumulative effect of these

individual factors was expressed as an average surface reflectance factor across the whole of the façade.

3.1.2.1 Surface Reflectance Factor

It may seem strange to establish the “surface reflectance” first at this part of the thesis, but it will be valuable as the façade surface in fact plays an important role in determining the final lighting effect.

As indicated in the background section, there is more than one surface parameter that affects the reflections of light when a surface is illuminated. A theoretical approach to the study of reflection properties of surfaces has led to a workable system for describing these properties in quantitative terms. This is possible due to a simplified description provided by the surface reflectance factor that is provided from no reflection to full reflection level of the light expressed in percentage from zero to one-hundred, respectively. This thesis uses this factor as one of the variables of the façade model that is affecting the reflected light received at street level.

The reflectance factors used in the calculations were established having considered that reflectance values from 90 percent to 100 percent are usually impossible to achieve even with mirror glasses as the façades are normally affected by dust and pollution that reduce the reflectance properties. On the other hand, reflectance values under 10 percent are difficult to reach as these values belong to very dark colours that are not often used in façades.

In this study, reflectance values from 10 percent to 90 percent in steps of 20 percent were used as any smaller increment will not reveal any more details.

3.2 Lighting System

As introduced in the background section, the light levels received on a façade depend directly on the luminaire and lamp selection. The luminaire distributes the light from the lamp according to the geometry of its optic system. This lighting distribution is provided by manufacturers as the photometrics of the luminaire.

3.2.1 Luminaires and their Photometric Properties

The photometrics, commonly provided by a numerical arrangement to be used with lighting software (The IES file, see Chapter 2 figure 2.1), is built considering that the peak of light of a floodlight occurs in the direction of the beam axis and is generally specified in candelas per 1000 lumens of the light output of the lamp as a universal value. This facilitates the incorporation of different lumen output of lamps by using the same IES file. This is possible because the numbers that define the light distribution of the luminaire are adjusted by an appropriate multiplier placed at the third position of the eighth row of the IES file.

For instance, the floodlight BEGA series 8591 (figure 3.1) shows different photometrics for the series 8591400W metal halide lamp (HIE) and 8591 – 400W high-pressure sodium lamp (HSE) despite the fact that they are based on the same IES matrix arrangement.

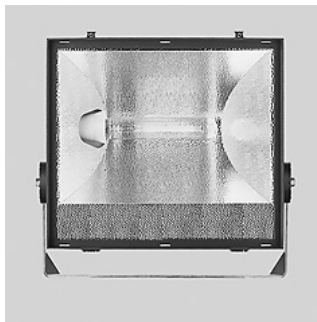


Figure 3.1 Bega floodlight model 8591

The differences between these two photometrics can be noted at the second and third position of the eighth row of the IES file where the lumen output of the lamp and the multipliers are indicated in blue in figures 3.2 and 3.3. In this case, the constants are 30 for 30000 lumens and 47 for 47000 lumens, where the lumen output of the lamp places the second number and the constant the third number beginning from left. Because these constants are proportionally affecting the light values indicated in *Italic* in figures 3.2 and 3.3, the photometric curve keeps the same shape as found under laboratory conditions. This property can be used to calculate the reflected light levels for different types of lamp light output based on the same lighting distribution on the façade.

```

IESNA:LM-63-1995
[TEST] BY: BEGA / LUM650
[DATE] 19.10.1993 / H.RÜMELT
[LUMCAT]
[LUMINAIRE] 8591
[LAMPCAT] HIE / 400W
TILT=NONE
1 30000 30 37 19 1 2 .45 .32 0 1.00 1.00 460
0 2.5 5 7.5 10 12.5 15 17.5 20 22.5 25 27.5 30 32.5 35 37.5 40 42.5 45 47.5 50 52.5 55 57.5 60 62.5 65
67.5 70 72.5 75 77.5 80 82.5 85 87.5 90
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
404.6 403.2 400.9 398.2 393.1 387.3 380.9 374.4 364.9 356 347.1 335.9 322.8 308.5 288.1 265.5 237.3
210.4 179.8 150.8 122 97.39 76.73 60.09 46.29 34.85 25.85 17.95 11.81 7.136 4.902 3.283 1.854 .7482
.2569 .1675 .05583

```

Figure 3.2 BEGA 8591-400W HIE IES file
(<http://www.bega.de/index.php?sprache=en>)

```

ESNA:LM-63-1995
[TEST] BY: BEGA / LUM650
[DATE] 19.10.1993 / H.RÜMELT
[LUMCAT]
[LUMINAIRE] 8591
[LAMPCAT] HSE / 400W
TILT=NONE
1 47000 47 37 19 1 2 .45 .32 0 1.00 1.00 440
0 2.5 5 7.5 10 12.5 15 17.5 20 22.5 25 27.5 30 32.5 35 37.5 40 42.5 45 47.5 50 52.5 55 57.5 60 62.5 65
67.5 70 72.5 75 77.5 80 82.5 85 87.5 90
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
404.6 403.2 400.9 398.2 393.1 387.3 380.9 374.4 364.9 356 347.1 335.9 322.8 308.5 288.1 265.5 237.3
210.4 179.8 150.8 122 97.39 76.73 60.09 46.29 34.85 25.85 17.95 11.81 7.136 4.902 3.283 1.854 .7482
.2569 .1675 .05583

```

Figure 3.3 BEGA 8591-400W HSE IES file
(<http://www.bega.de/index.php?sprache=en>)

Luminaire models from the main flood lighting manufacturers - Bega, Philips Lighting, Ruud Lighting, Thorn Lighting and GE Lighting - tested for the purpose of this thesis showed that the same luminaire model may be fitted with different lamp types.

According to this, the light spreading into the environment from a luminaire can then be increased or decreased using the same photometric data but altering the lumen output of lamps.

3.2.2 Luminaire Aiming Angle

Most successful exterior lighting designs are based on determining the correct light beam angle of the chosen luminaire. Although the resultant beam is simply a function of the lamp and the luminaire reflector, to be really successful one must go further than simply discriminating between floodlights' geometries, lamp types or lumen output of lamps.

The light beam resulting from the lamp comprises two components. The principal beam component is a controlled beam produced by the reflector, and the secondary is the direct luminous flux from the lamp that is not controlled. This uncontrolled component tends to produce light outside of the main beam. This can reach such a level that it will create unwanted glare. To solve this problem luminaire manufacturers often add accessories or modify the geometry of reflectors. These alterations have direct impact on the polar curves of the luminaire. From these, manufacturers group floodlights into three distinct generic categories: narrow, medium and wide beam. As explained in the background section, the wide beam is the most suitable to provide illuminance uniformity. Considering that it is desirable to evenly light a façade, the wide spread luminaire was selected in this thesis.

3.2.3 Lamps and their Lumen Output

The lamp lumen outputs selected to calculate the illuminance levels per luminaire arrangement were based on the four most common lamps on the market:

400W Sodium lamp : 56000 Lumens

400W Metal halide lamp : 36000 Lumens

250W Metal halide lamp : 22000 Lumens

150W Metal halide lamp : 12000 Lumens

3.2.4 Geometric Relationship Between Façade and Lighting System

As shown in Section 2, general recommendations exist for the establishment of an appropriate geometric relationship between a lighting system and the façade that it will illuminate.

3.2.4.1 Luminaire Mounting Distance from Façade

The IESNA Lighting Guide (1999) suggests, for example, that the horizontal distance between a vertical façade and the mounting positions of the luminaires illuminating that façade should be half of the building façade height. A façade of six metres height would thus suggest that the luminaires would be mounted at a horizontal distance of three metres away from the façade. However, there are some practical limitations as to how far away luminaires can be mounted from a particular building façade. Some of the limitations might result from building regulations and ordinances, others might be the result of limited street width. Typically, luminaire mounting positions, either on

poles, on the ground, or attached to the façade, need to be located within the site boundaries for the building in question. Occasionally, it might be possible to position luminaires on structures located across the street from the façade to be lit. For the purpose of this thesis, horizontal distances between three and seven metres have been selected, corresponding to building façade heights of between six and fourteen metres (Figure 3.4)

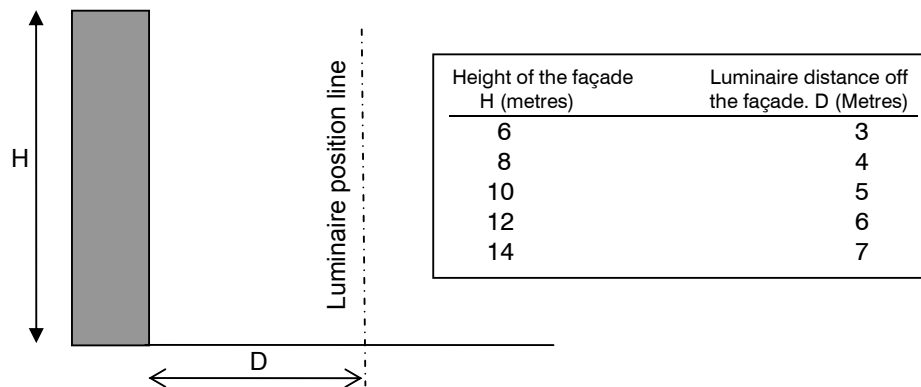


Figure 3.4 Luminaire location based on the relationship between building height and luminaire distance off the façade (IES Lighting Guide, 1975)

3.2.4.2 Luminaire Mounting Height Relative to Ground

If one assumes common recommendations for urban areas where the street is not a highway, one would typically select luminaire pole heights between three and seven metres. These heights are both reasonable and practical, as they do not require specialised equipment for maintenance and lamp replacements. For this study, pole heights of three, five and seven metres have been used.

3.2.4.3 Luminaire Spacing

Spacing between luminaires obviously depends on the intensity distribution curves of the individual luminaires used and whether or

not it is desirable to achieve good illuminance uniformity across the building façade. Luminaire manufacturers typically provide appropriate spacing criteria. The scenarios and luminaires chosen here resulted in luminaire spacings of between five and seven metres.

3.3 Measurement Positions

Another important issue required was the number of measurement points at street level. Considering that the standard width of a city roadway typically varies from approximately seven to twenty metres from edge to edge, to calculate and measure the light levels at street levels, the width of the street used in this study was limited to twenty metres maximum. The first measurement location for each arrangement was placed at one metre behind the position of the luminaire at street level perpendicular to the façade. Other measurement points were taken at the same line away from the façade in one metre intervals. The maximum number of measurement points was sixteen for those luminaire arrangements situated at three metres from the façade and the minimum twelve for those luminaire arrangements situated at seven metres from the façade as shown in figure 3.5.

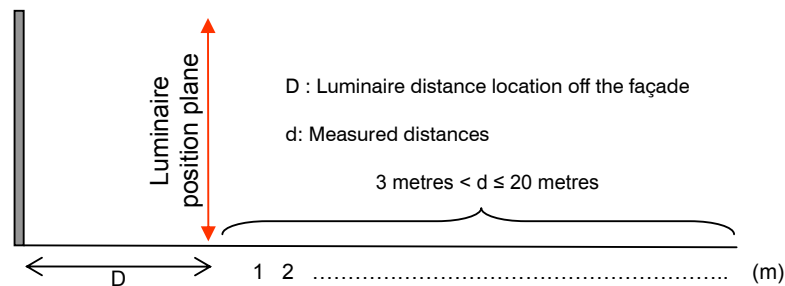


Figure 3.5 Position of the measured points. The number of the points to be measured varies according to the light source position from 16 points for those arrangements at three meter from the facade to 12 points for those at seven metres from the façade.

3.4 Physical Versus Digital Modelling

Initially, both physical and digital models were considered for this investigation. Physical models were eventually discarded as a viable option due to the significant costs associated with the construction of building façades of sufficient size required to match the physical characteristics of floodlighting luminaires for appropriate scaling of the light distribution and intensity.

In addition, digital models were thought to significantly simplify the parametric modelling, as parameters could be modified consistently without inaccuracies that could easily have been introduced in physical modifications of the physical test environment. In digital models, for example, it is significantly easier to alter the aiming angle of a luminaire and be consistent with its aiming throughout many different façade scenarios. Physical movements of actual luminaires would have required reasonably complex steps to ensure that a luminaire aimed was consistently at the same spot, for example to test the impact of different façade surface reflectances.

On the other hand, reliance on digital models required that the software used for the construction of such digital test cases was capable of producing reliable and repeatable results that could be confirmed in physical tests. This suggested that only software that had been rigorously tested for the accuracy of its computing algorithms under various scenarios could be applied in this research.

To establish a suitable software program for this project, several options were explored, including a literature search of recent lighting software reviews and tests conducted by professional lighting designers and organisations (IESNA Software Survey, 2001).

Lightscape® was eventually chosen as the most appropriate program. It was found to produce very realistic results in a wide range of professional applications and also offered a simple user-interface for easily modifying modelling parameters, reasonably fast computing times, and good data display and transfer options.

3.4.1 Construction of the Computer Model

To construct the digital model of the environment to be lit, AutoCAD® was used. From the information provided and described previously, the models were defined according to the two most recommended lighting arrangements as shown in section 2.0. To floodlight a façade then, these arrangements recommend luminaires situated at ground level, “UPLIGHT” model (see figure 3.6), or luminaires situated at a determined mounting height, “FRONTLIGHT” model (see figure 3.7).

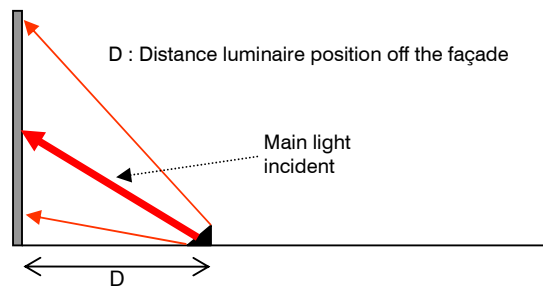


Figure 3.6 “UPLIGHT” arrangement. The lighting arrangement was defined for those luminaires situated at ground level and pointing in an upward direction.

Additionally, the “FRONTLIGHT” model also includes the height of the pole as a variable. As indicated in the background section, the pole heights used in city environments are often limited to a maximum of seven metres to avoid disrupting the landscape of the area and to simplify maintenance access. According to the background

information, the height of the poles was selected as 3 metres, 5 metres and 7 metres to present realistic scenarios for this thesis.

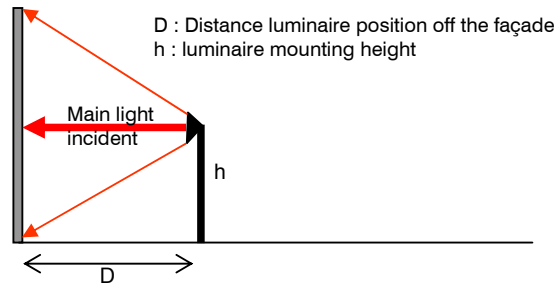


Figure 3.7 “FRONTLIGHT” arrangement: The lighting arrangement was defined for those luminaires situated in front of the façade and placed at specific mounting height.

To explore the variation of the light output of the lamps and the surface reflectance factors in the computer models, luminaires were required to be located at different distances off the façade and mounted at different heights. These two models required the construction of individual models to respond to the variables of distance of the luminaire from the façade versus height of the façade defined by the height/distance ratio ($H/D=2/1$). For instance, considering that a two-storey building is being illuminated and assuming a typical ceiling height per floor as three metres, the height of the building would be six meters and the distance from the façade at which to install the luminaires three metres.

Even though there is no indication of restrictions of distances between a façade and poles, these can be established by considering that certain limitations of pole installations in cities exist. These limitations are often based on the width of the street that could include the roadway, footpath, grass strip and ornaments or street furniture. For instance, it is often found that poles are requested to be installed in

the inner part of the footpath or inside the property limits to facilitate the street cleaning and repairs. Considering that the illumination of a four-storey building would require poles located at approximately seven metres from the façade according to the relationship. This distance is often not available in a context of a city environment, therefore, seven metres maybe considered as the maximum luminaire installation distance from the façade and fourteen metres the maximum building height.

Consequently, the heights of the façade and their corresponding luminaire installation distance from the façade required to be built into the models for the purpose of this thesis were defined as shown in figure 3.4, where the luminaire distances from the façade were defined from three metres to seven metres in steps of one metre. The model arrangements were constructed considering the relationship $H/D=2/1$ resulting in height of the façades from six metres to fourteen metres respectively.

From the information provided above, the luminaires' position for each model arrangements can be summarised as follows:

“UPLIGHT” arrangements: luminaires situated at ground level at three, four, five, six and seven metres from the façade.

“FRONTLIGHT” arrangement; Luminaires situated as in the previous arrangement but including the mounting heights at three, five, and seven metres as defined previously.

3.5 Calculation and Data Display Arrangement

As mentioned in the introductory section, the desired data to be gathered from the models were the illuminance values at the horizontal line in the centre of the light spread at street level as shown by the red arrow in figure 3.8.

These light levels at street level were calculated for each luminaire position varying the light output of the lamps, and for each variation of the lamp lumen output as well as the surface reflectance factors. The resulting light levels were expressed in lux.

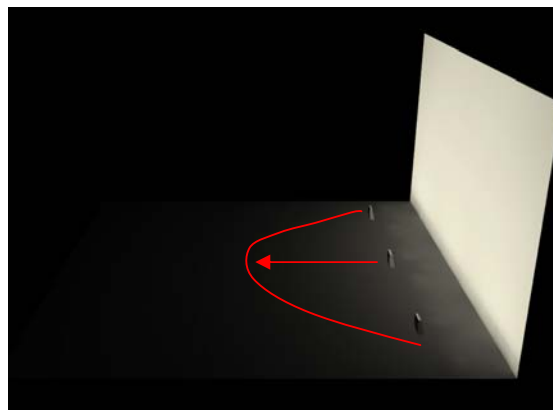


Figure 3.8 Reflected light from a lit façade at street level. The strongest light incident is observed at the centre of the street area as indicated by the red arrow.

Using the luminaire arrangement located at three metres off the wall as an example, the calculations would start with the luminaire situated at ground level. The first set of data would be gathered setting up the lumen output of the lamp with 12000 lumen and the surface reflectance factor with ten percent. These parameters were set up in the lighting software and calculated. The resulting light levels were placed in an arrangement as indicated in bold in table 3.1.

		Arrangement Xm : Ym																			
		12k					22K					36k					56K				
d (m)		10	30	50	70	90	10	30	50	70	90	10	30	50	70	90	10	30	50	70	90
1		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
....																				

Measured illuminance values (Lux)

Where:

Xm :Ym : luminaire distance from façade (m) : Luminaire mounting height (m).

d : Measured distances from the luminaire position

12K, 22K, 36K, 56K : 12000, 22000, 36000 and 56000 lumens

10, 30, 50, 70, 90 : 10%, 30%, 50%, 70%, 90% façade reflectance

Table 3.1 Data arrangement display. This table also considers the variation of the mounting height of the luminaire.

The second set of data was taken changing the surface reflectance factor to thirty percent but keeping the lumen output of the lamp at 12000 lumens. This procedure was repeated for 50, 70 and 90 percent surface reflectance factors. Then the lumen output of the lamp was changed to 22000 lumens and the process repeated again for the different reflectance factors, and then for the rest of the lamp lumen outputs as indicated in the table 3.1. Following the example, the procedure continued by changing the luminaire arrangement position, this time keeping the same distance off the façade but locating the luminaire arrangement at three metres off the ground level. With this new arrangement, the light values were calculated as above. The next ones were locating the luminaire arrangement at five metres and seven metres off the ground level.

The simulated data were recorded varying the luminaire location off the façade from three meter to seven metres in steps of one meter according to the previous defined luminaire location against the distance off the façade. The data from the calculations were recorded as illuminance values (lux). Please see Appendix A for the complete data set.

3.6 Data Analysis Procedure

The analysis of the data was done in two parts. The driver of these two parts was the provision of arguments to conclude that the curve shown in the introductory section is a characteristic trait of the floodlighting technique and can be used to estimate light levels of different lighting conditions.

The first part looked for similarities between curves and the deviation range for each tested arrangement. The luminaire arrangements were tested using different light output of lamps to the same arrangement and, as expected, the illuminance levels measured at street level showed different values at each measured point. To compare the curves generated from these values, it was required to draw them under the same scale. This was done transforming the data into normalised dimensionless numbers from zero to one. From this, all the normalised data corresponding to the same lighting arrangement were plotted and portrayed in the same view for comparison. These plots facilitated a general overview to compare the characteristic trait of the curves as well as to provide the deviation between individual data and an average for each analysed arrangement.

The second part was the evaluation of those deviations. This analysis was based on how closely the calculated illuminance values obtained from the models were to light values calculated based on a referenced data. The referenced data were selected as a set of illuminance values corresponding to one lighting arrangement and one lighting condition. This process affected the referenced data by two numbers. The first number was the result of the division between the lumen output of the new lighting condition and the lumen output of the reference. The second was the result of the division between the new surface

reflectance factor and the surface reflectance factor of the selected reference. This last number affected the values obtained with the previous procedure. The differences between these estimations and the data gathered from the models were expressed in illuminance.

Important from this procedure was the visualisation of how big were these deviations in illuminance levels. The achievement of smallest differences would indicate that maybe they could be considered not relevant when light levels were estimated from a reference characteristic curve; therefore validate the construction of the nomographs.

3.6.1 Normalisation of Data

To facilitate the comparison and interpretation of this information, the data were transformed into normalised values using a dimensionless range of values from zero to one.

The normalisation was achieved by dividing each corresponding illuminance value from a defined light output and surface characteristic by the first value of each arrangement. To explain the normalisation process, the “5m : 3m” “FRONTLIGHT” arrangement will be used as an example.

The table 3.2 shows at the left side the light values corresponding to a 36000 lumen output of the lamp for each reflectance factor. The normalised values were obtained dividing the first value of each column by the values of the corresponding column, as shown in the centre of the table. The result of this operation gives the normalised values that can be seen at the right side of the table.

Distance \ Reflectance						→					→					
	10	30	50	70	90	10	30	50	70	90	10	30	50	70	90	
1	6.92	20.9	35	50.6	66.1	6.92	6.92	20.9	35	50.6	66.1	1	1	1	1	1
2	5.63	17.6	29.6	42.9	55.4	5.63	5.63	17.6	29.6	42.9	55.4	0.8136	0.842	0.846	0.848	0.838
3	4.57	14.8	24.9	36.1	46.7	4.57	4.57	14.8	24.9	36.1	46.7	0.66	0.708	0.712	0.713	0.707
4	3.82	12.5	20.9	30.4	39.3	3.82	3.82	12.5	20.9	30.4	39.3	0.552	0.598	0.597	0.601	0.595
5	3.21	10.5	17.6	25.1	33.1	3.21	3.21	10.5	17.6	25.1	33.1	0.464	0.502	0.503	0.496	0.501
6	2.71	8.8	14.9	21	28	2.71	2.71	8.8	14.9	21	28	0.392	0.421	0.426	0.415	0.424
7	2.36	7.56	12.7	17.9	23.9	2.36	2.36	7.56	12.7	17.9	23.9	0.341	0.362	0.363	0.354	0.362
8	2.09	5.94	10.2	14.4	18.9	2.09	2.09	5.94	10.2	14.4	18.9	0.302	0.284	0.291	0.285	0.286
9	1.83	5.11	8.97	12.4	16.1	1.83	1.83	5.11	8.97	12.4	16.1	0.264	0.244	0.256	0.245	0.244
10	1.62	4.41	7.55	10.7	13.9	1.62	1.62	4.41	7.55	10.7	13.9	0.234	0.211	0.216	0.211	0.21
11	1.43	3.82	6.42	9.83	12.7	1.43	1.43	3.82	6.42	9.83	12.7	0.207	0.183	0.183	0.194	0.192
12	1.27	3.34	5.61	8.59	11.1	1.27	1.27	3.34	5.61	8.59	11.1	0.184	0.16	0.16	0.17	0.168
13	1.13	2.92	4.91	6.94	9.74	1.13	1.13	2.92	4.91	6.94	9.74	0.163	0.14	0.14	0.137	0.147
14	1	2.57	4.32	6.11	8.56	1	1	2.57	4.32	6.11	8.56	0.145	0.123	0.123	0.121	0.13
15	0.897	2.27	3.82	5.4	7	0.897	0.897	2.27	3.82	5.4	7	0.13	0.109	0.109	0.107	0.106
16	0.804	2.01	3.39	4.79	6.21	0.804	0.804	2.01	3.39	4.79	6.21	0.116	0.096	0.097	0.095	0.094

Table 3.2 “5m:3m” 36000 lamp lumen output “FRONTLIGHT” arrangement normalisation process. As an example, the second normalised value belonging to 10 percent façade surface reflectance was calculated as follows: 5.63 ÷ 6.92 = 0.8136 as indicated in bold at the right side of the table.

The complete normalised values for the “5m : 3m - FRONTLIGHT” model arrangement were obtained following the same procedure explained previously and shown in table 3.3.

Distance (m)	Lumen output of the lamp : 12000					Lumen output of the lamp : 22000					Lumen output of the lamp : 36000					Lumen output of the lamp : 56000					
	Surface reflectance factors					Surface reflectance factors					Surface reflectance factors					Surface reflectance factors					
	10	30	50	70	90	10	30	50	70	90	10	30	50	70	90	10	30	50	70	90	
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.8750	0.8113	0.8414	0.8466	0.8483	0.8250	0.8504	0.8411	0.8439	0.8458	0.8136	0.8421	0.8457	0.8478	0.8381	0.8417	0.7784	0.8462	0.8426	0.8437	0.8437
3	0.7614	0.6575	0.7060	0.7117	0.7109	0.6750	0.7110	0.7103	0.7076	0.7095	0.6604	0.7081	0.7114	0.7134	0.7065	0.7065	0.6534	0.7138	0.7065	0.7078	0.7078
4	0.6648	0.5501	0.5940	0.5963	0.5972	0.5500	0.5984	0.5935	0.5980	0.5964	0.5520	0.5981	0.5971	0.6008	0.5946	0.5759	0.5511	0.5993	0.5945	0.5951	0.5951
5	0.5795	0.4630	0.4621	0.5031	0.5024	0.4750	0.4898	0.5093	0.5050	0.5039	0.4639	0.5024	0.5029	0.4960	0.5008	0.4620	0.4631	0.5045	0.5013	0.4961	0.4961
6	0.5045	0.3904	0.3897	0.4080	0.4218	0.4250	0.3858	0.4248	0.4252	0.4267	0.3916	0.4211	0.4257	0.4150	0.4236	0.3898	0.3693	0.4204	0.4232	0.4223	0.4223
7	0.4420	0.3396	0.3319	0.3337	0.3626	0.3500	0.3339	0.3617	0.3621	0.3625	0.3410	0.3617	0.3629	0.3538	0.3616	0.3324	0.3381	0.3524	0.3589	0.3583	0.3583
8	0.3875	0.3004	0.2836	0.2847	0.2853	0.3250	0.2850	0.2846	0.2927	0.2931	0.3020	0.2842	0.2914	0.2846	0.2859	0.2824	0.2690	0.2844	0.3060	0.3058	0.3058
9	0.3409	0.2642	0.2431	0.2448	0.2455	0.2750	0.2449	0.2444	0.2512	0.2519	0.2645	0.2445	0.2563	0.2451	0.2436	0.2426	0.2310	0.2451	0.2506	0.2621	0.2621
10	0.3006	0.2337	0.2103	0.2117	0.2118	0.2475	0.2118	0.2112	0.2116	0.2177	0.2341	0.2110	0.2157	0.2115	0.2103	0.2102	0.1977	0.2129	0.2128	0.2252	0.2252
11	0.2653	0.2061	0.2052	0.1834	0.1839	0.2175	0.1835	0.1827	0.1837	0.1920	0.2066	0.1828	0.1834	0.1943	0.1921	0.2056	0.1688	0.1932	0.1927	0.1951	0.1951
12	0.2352	0.1829	0.1826	0.1601	0.1607	0.1925	0.1740	0.1598	0.1605	0.1609	0.1835	0.1598	0.1603	0.1698	0.1679	0.1824	0.1474	0.1691	0.1675	0.1699	0.1699
13	0.2091	0.1626	0.1629	0.1405	0.1408	0.1700	0.1630	0.1397	0.1405	0.1411	0.1633	0.1397	0.1403	0.1372	0.1474	0.1620	0.1290	0.1458	0.1474	0.1466	0.1466
14	0.1864	0.1446	0.1457	0.1350	0.1237	0.1525	0.1457	0.1229	0.1236	0.1242	0.1445	0.1230	0.1234	0.1208	0.1295	0.1444	0.1134	0.1200	0.1297	0.1291	0.1291
15	0.1665	0.1293	0.1293	0.1301	0.1095	0.1375	0.1299	0.1089	0.1093	0.1098	0.1296	0.1086	0.1091	0.1067	0.1059	0.1287	0.1003	0.1063	0.1142	0.1155	0.1155
16	0.1494	0.1158	0.1155	0.1160	0.0972	0.1225	0.1102	0.0963	0.0970	0.0972	0.1162	0.0962	0.0969	0.0947	0.0939	0.1157	0.0889	0.0941	0.0936	0.101	0.101

Table 3.3 Complete normalised data of “5m:3m” 36000 lamp lumen output “FRONTLIGHT” arrangement. These values were grouped and plotted for each position behind the luminaire. An average of these values was plotted.

Please see Appendix B for complete set of normalised data.

3.6.2 Curve Construction and Comparison

To prepare the data for analysis, the normalised values belonging to the same row were plotted against the distances. As a result of these plots, combined normalised values of different light output and surface reflectance factors were vertically grouped for each distance from the luminaire mounting location. These arrangements provide an indicative deviation range (red vertical lines in figure 3.9) for the same row to display the similarity between the normalised values at the same measured distance.

To measure the range of this deviation, the average of the normalised values for each row were also calculated and plotted taking the distances on the X- axis and the average normalised values on the Y- axis as shown in Figure 3.9. As can be seen in Figure 3.9 the curve was plotted based on the averages of each measured distance. The table next to the graph indicates the minimum and maximum normalised values and the deviation from the average.

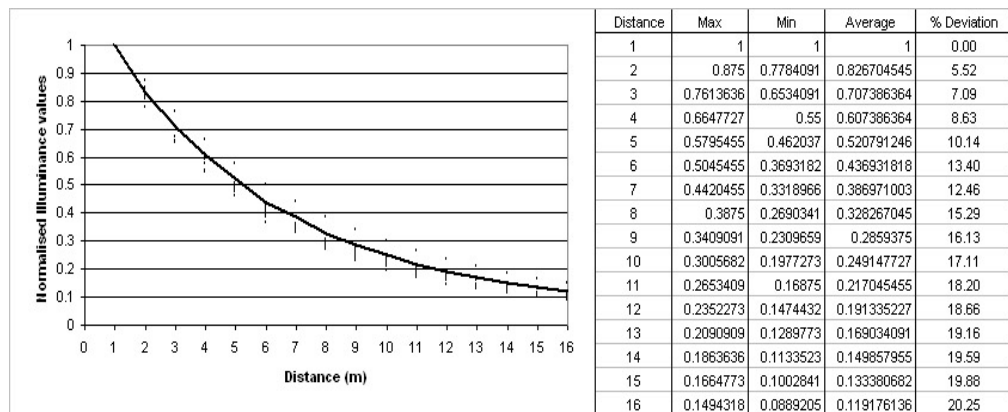


Figure 3.9 “5m:3m” 36000 lamp lumen output “FRONTLIGHT” characteristic curve

With this procedure it was expected to achieve a clear image of the deviation range between normalised values for each arrangement and measured distance. This information will be used to analyse and establish if the proposed curve can be generalised for the recommended lighting arrangements as well as to provide the considerations that this assumption will require to estimate the lighting levels at street level.

Please see Appendix C for complete set of curves from the normalised data.

3.7 Nomograph Construction Method

Suggested from the analysis section, a direct suggestion would be the construction of characteristic curves per lighting arrangement. However, they required to be based on the normalised data as these values are expressed in the same scale and format.

On the other hand, from the second part of the analysis section, different lighting conditions of the same lighting arrangement can be estimated using reference data. Based on this argument, it was possible to replicate the second part of the analysis using referenced normalised data. Hence, curves were plotted based on the normalised data belonging to the reference for each lighting arrangement. Curves corresponding to the same luminaire distance from the façade were plotted displaying the distance on the X-axis and the normalised values on the Y-axis regardless their mounting position.

Because these curves expressed one lighting condition, to make them general required to introduce two factors. These factors were defined considering that different lighting conditions result from the variation of lamps lumen output and surface reflectance factors. As the procedure also followed from the second part of the analysis section, these factors must be multiplied with the normalised value gathered from the normalised curves. This procedure is expressed in a general equation that is extensively explained in the next chapter.

4.0 Data Analysis and Construction of the Nomograph

The previous section provided the information to compare and analyse light levels measured at the surrounding street as result of the illumination of a façade. This information was gathered from the various models and luminaire arrangements described in the methodology section. Plotting these light levels against the distance as indicated in the methodology section, made it possible to see that the curves indeed display similar shapes. This opened the possibility that a single curve or a set of curves could be used to describe a multitude of different lighting solutions.

In order to develop the nomographs, it was critical to analyse the magnitude of the deviation between curves plotted from the models. To explore more results that could have potential similarities to the luminaire arrangements described in the methodology section, two extra arrangements were included. These extra arrangements were based on two common extensions from the defined models. These considerations suggested the following procedure:

- 1 Comparison of the curves. From all resultant light level curves were plotted on the same graph to investigate if they displayed a similar shape according to following:
 - The first analysis investigated the characteristic curve keeping the luminaire distance from the façade constant and varying the luminaire mounting height.

- This was followed by a second analysis fixing the same luminaire position (not varying mounting height or distance from the illuminated façade) but varying the surface reflectances and lamp lumen output.

These two procedures were complemented by two additional tests. The first one tested the use of an asymmetric luminaire mounted at three, five and seven metre poles. The second one tested an attachment of a luminaire on a canopy.

- 2 Comparison of the magnitude of the deviation against the average for each arrangement.
- 3 Monograph construction and mathematical equation formulation.

This chapter provides the evidence for the conclusion that the construction of the nomographs and the formulation of a relationship to estimate light levels at street as result of an illuminated façade is possible. Based on that conclusion, nomographs are constructed and the relationship for the estimation of light levels formulated.

4.1 Comparing the Curves

Using the two arrangements described in Section 3.2 (“UPLIGHT” and “FRONTLIGHT”), a graph was created with every different resulting light level curve plotted using the normalised values. This analysis revealed that the curves were very similar and displayed the same characteristic shape as illustrated in Figure 4.1.

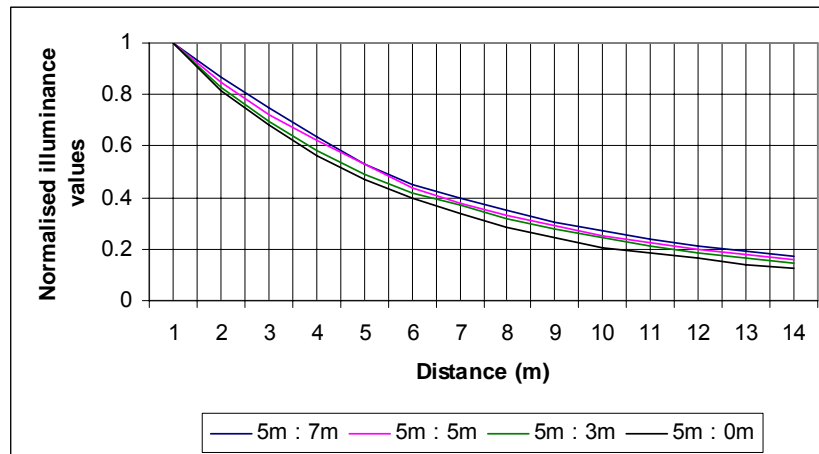


Figure 4.1 Characteristic curves obtained from lighting arrangements at five metres from the wall showing similar responses whether the luminaires were mounted at ground level or on a pole.

Figure 4.1 shows the curves drawn from the luminaire arrangement at five metres off the façade. The graphic shows the results when the luminaire mounting height varies from zero to seven metres. As can be seen in the figure above, all lighting arrangements show the same characteristic shape. These curves have in common the highest illuminance level closer to the façade, dropping off in a negative exponential form with distance from the façade. These curves are essentially the same regardless of the illuminance on the façade, luminaire position and luminaire distance from the façade.

4.1.1 Testing the Lighting Arrangements

The next step was to test two extra potential solutions. The first one was to see if using a different type of luminaire to light the façade would alter the results. The second one altered the building configuration attaching a canopy onto the façade as is common in many urban environments.

4.1.1.1 Asymmetric Lighting Arrangements

This test used an asymmetric floodlight which illuminated the upper two thirds of the façade using the “FRONTLIGHT” luminaire arrangement, as seen in Figure 4.2.

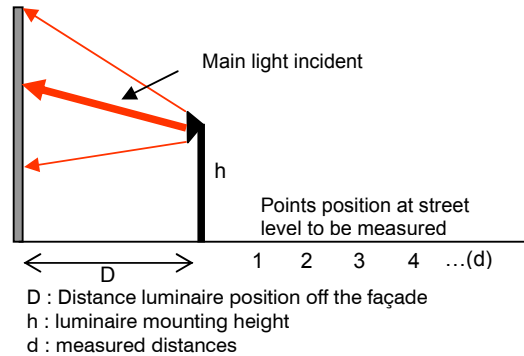


Figure 4.2 – Floodlight arrangement using a luminaire with asymmetric light distribution

This lighting arrangement was tested and the values normalised with the results shown below in Figure 4.3. The blue line (3m-3m) in this curve indicates similarities with “FRONTLIGHT” arrangement results. However, curves corresponding to 5m-3m and 7m-3m show a negative inflexion between the second and fourth measured points. This negative inflexion is more prominent in the seven metres luminaire arrangements (yellow lines) and is indicated by the red arrow.

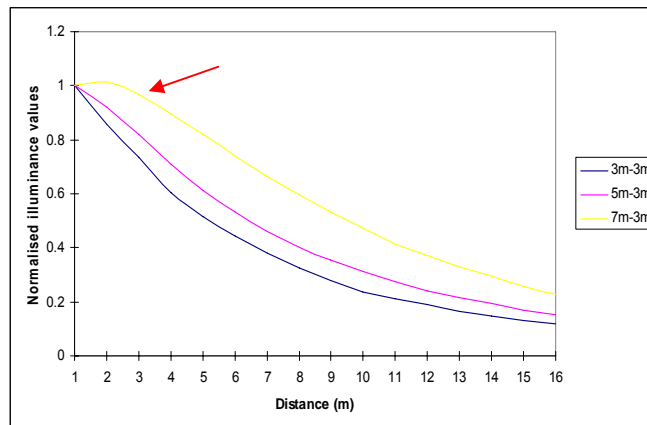


Figure 4.3 – Graph of four different lighting arrangements

Despite that one curve of this test shows similarity with “FRONTLIGHT” arrangement, as can be seen in the graph, varying the mounting position produced significantly different results at five and seven metres arrangements.

4.1.1.2 Canopy Attachment

The second variation attached to the façade a five-metre deep canopy mounted at three metres off the ground. The façade was illuminated using the uplighting technique with luminaire arrangements mounted over the canopy and situated at three and five metres from the façade, as seen in Figure 4.4.

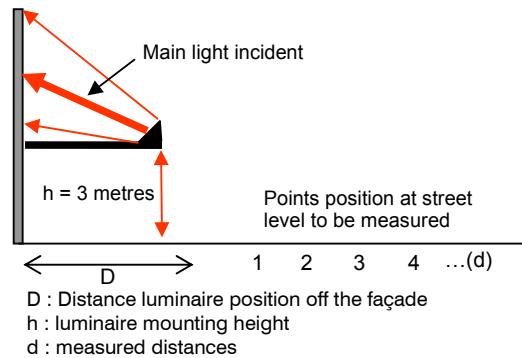


Figure 4.4 – Canopy Lighting Arrangement

The resulting illuminance values were normalised and the result plotted in the graph shown below in Figure 4.5. As can be seen in the graph, varying the mounting position produced significantly different results. Furthermore, this lighting arrangement did not present any similarities to the asymmetric floodlighting arrangement nor to the luminaire arrangements described in the methodology section.

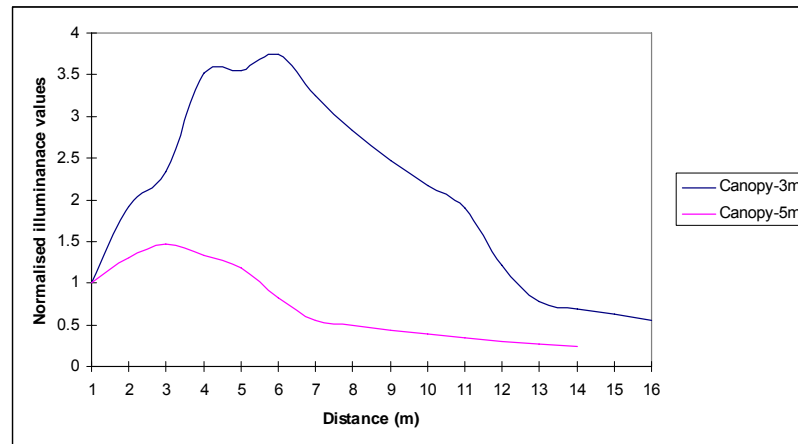


Figure 4.5 Canopy Luminaire Arrangement

Therefore, from the result seen in Figures 4.3 and 4.5 it is clear that one general curve could not be created for all lighting scenarios, but that there was a possibility of creating a single curve for the “UPLIGHT” and “FRONTLIGHT” scenarios as shown in Figure 4.1.

4.2 Comparing the Deviations: Generalisation of the Curves

Section 4.1 showed that there is evidence to suggest that the curves that are most likely related are just those ones belonging to the predefined arrangements: “UPLIGHT” and “FRONTLIGHT”.

To establish whether one single curve could be used or a group of curves was needed, the deviation from the average was investigated more closely. This was tested firstly by maintaining the distance between the luminaire and the façade, but varying the luminaire mounting height and secondly by keeping the luminaire position constant and varying the lamp lumen output and façade surface reflectance.

4.2.1 Maintaining the Luminaire to Façade Distance Constant

This test was conducted to investigate whether one single or a multitude of curves could be required to describe the same lighting distribution. The luminaire to façade distance was maintained, but the luminaire mounting height changed. This procedure is explained using the example below.

For instance, a lamp lumen output of 36000 lumens was chosen, the luminaire was mounted three metres from a façade with a surface reflectance of 50 percent. The luminaire mounting height was varied from zero to seven metres off the ground. The results were then normalised and plotted as shown in Figure 4.6. In the graph, it is clear that by changing the luminaire mounting height, the resultant normalised illuminance values differ.

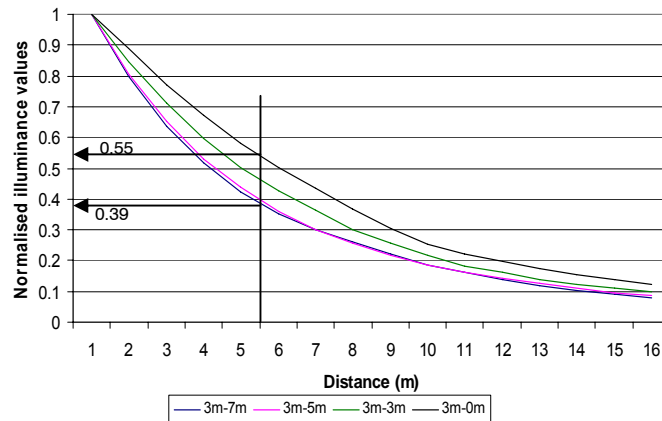


Figure 4.6 Characteristic responses from arrangements at three metres off the façade

As can be seen from the figure 4.6, the normalised values corresponding to luminaire mounted at five metres off the ground indicated that the normalised illuminance value was higher at zero metres off the floor, 0.55 approximately. These values decreased for the arrangements at three, five, and seven metres, with the minimum

occurring when the luminaires were mounted at seven metres off the floor, 0.39 approximately.

Therefore, and despite the similarities shown in some of the luminaire arrangements, these divergences suggest that each luminaire position requires one curve.

4.2.2. Varying the Lumen Output and Reflectance Values

From the above analysis, it was determined that each lighting arrangement needed its own curve. It was necessary to find out if varying the lumen output of the lamps or changing the surface reflectance values of the facades would alter the curve.

The “UPLIGHT” arrangement was chosen with luminaires mounted on the ground, at three metres from the façade. All normalised values corresponding to this arrangement were plotted regardless of the lamp lumen output or façade surface reflectance variations.

A curve based on the average of each measured distance was drawn as shown in Figure 4.7. The table next to the graph indicates the minimum and maximum normalised values and their deviation from the average.

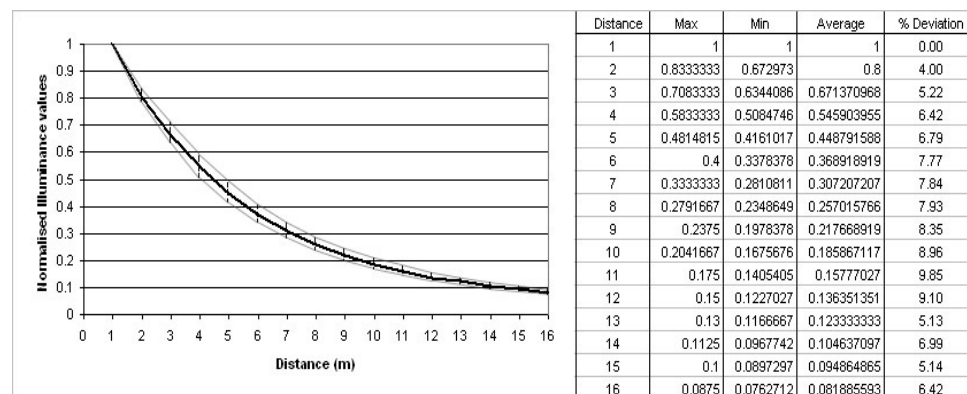


Figure 4.7 “3m : 0m” “UPLIGHT” characteristic curve.

The Figure above shows that a deviation range does exist, in this example the range was from 4.0 to 9.85 percent.

It had been ascertained that it was necessary to have one graph per luminaire arrangement, but it was still not clear if a separate graph was needed for each lamp lumen output or façade surface reflectance.

4.2.3. Testing Deviations Using Reference Street Illuminance Values

As the goal of this thesis was to create a set of generalised curves, it was necessary to test the effect of this deviation on estimating the illuminance levels for different luminaire arrangements.

In order to test this, reference illuminance values (which were calculated earlier in Section 3.0) were used to calculate different lighting conditions for the same lighting arrangements. The façade surface reflectance values were varied along with the lamp lumen output and the results compared with the lighting levels calculated earlier by the software.

To illustrate this process, a set of illuminance values corresponding to the “5m:3m” “FRONTLIGHT” model arrangement was used to manually estimate the different illuminance values that can be obtained varying the lumen output of the lamp and reflectance factors respectively. These manual estimations were based on multiplying the reference illuminance values by the lamp lumen output of the desired new lighting conditions and dividing by the lamp lumen output of the reference. This operation provided estimated illuminance values of a new lighting condition with the same reflectance factor. To estimate lighting conditions for different reflectance factors, the values

calculated previously were multiplied by the new surface reflectance factor and divided by the surface reflectance factors of the reference.

These manual estimations were then compared with the calculated illuminance values from the lighting software. The deviation between the calculated and estimated values was expressed in illuminance levels to provide a clear image of how big the deviation was and if it was significant. An example of these calculations can be seen in Table 4.1.

	illuminance from lighting software	Estimated illuminance values	Differences in percentage	Differences in Lux	illuminance from lighting software	Estimated illuminance values	Differences in percentage	Differences in Lux
	22000 lumens				22000 lumens			
	50 % surface reflectance				70 % surface reflectance			
	21.4	21.38889	0.05	0.011111	30.1	29.94444	0.52	0.155556
	18	18.08889	-0.49	-0.08889	25.4	25.32444	0.30	0.075556
	15.2	15.21667	-0.11	-0.01667	21.3	21.30333	-0.02	-0.00333
	12.7	12.77222	-0.57	-0.07222	18	17.88111	0.66	0.118889
	10.9	10.75556	1.33	0.144444	15.2	15.05778	0.94	0.142222
	9.09	9.105556	-0.17	-0.01556	12.8	12.74778	0.41	0.052222
	7.74	7.761111	-0.27	-0.02111	10.9	10.86556	0.32	0.034444
	6.09	6.233333	-2.35	-0.14333	8.81	8.726667	0.95	0.083333
	5.23	5.481667	-4.81	-0.25167	7.56	7.674333	-1.51	-0.11433
	4.52	4.613889	-2.08	-0.09389	6.37	6.459444	-1.40	-0.08944
	3.91	3.923333	-0.34	-0.01333	5.53	5.492667	0.68	0.037333
	3.42	3.428333	-0.24	-0.00833	4.83	4.799667	0.63	0.030333
	2.99	3.000556	-0.35	-0.01056	4.23	4.200778	0.69	0.029222
	2.63	2.64	-0.38	-0.01	3.72	3.696	0.65	0.024
	2.33	2.334444	-0.19	-0.00444	3.29	3.268222	0.66	0.021778
	2.06	2.071667	-0.57	-0.01167	2.92	2.900333	0.67	0.019667
	Reference: 36000 lumens				36000 lumens			
	50 % surface reflectance				70 % surface reflectance			
	35				50.6	49	3.16	1.6
	29.6				42.9	41.44	3.40	1.46
	24.9				36.1	34.86	3.43	1.24
	20.9				30.4	29.26	3.75	1.14
	17.6				25.1	24.64	1.83	0.46
	14.9				21	20.86	0.67	0.14
	12.7				17.9	17.78	0.67	0.12
	10.2				14.4	14.28	0.83	0.12
	8.97				12.4	12.558	-1.27	-0.158
	7.55				10.7	10.57	1.21	0.13
	6.42				9.83	8.988	8.57	0.842
	5.61				8.59	7.854	8.57	0.736
	4.91				6.94	6.874	0.95	0.066
	4.32				6.11	6.048	1.01	0.062
	3.82				5.4	5.348	0.96	0.052
	3.39				4.79	4.746	0.92	0.044

Table 4.1 Illuminance values for the 5m-3m “FRONTLIGHT” arrangement. The table shows the comparison between the illuminance levels calculated from the model using the computer software and the illuminance values manually estimated from the reference.

The key to the table above is that the illuminance values calculated from the lighting software can be used to estimate the illuminance levels for all of the different lamp lumen outputs and façade surface reflectance values.

In the example shown in Table 4.1, using a lamp with a lumen output of 36000 lumens and a façade surface reflectance factor of 50 percent as the reference (highlighted blue in the table); illuminance values for lamp lumen output and façade surface reflectance factor variations were estimated. Thus, to estimate the first illuminance values for a 22000 lumen output lamp and 50 percent surface reflectance factors, the first number of the reference, 35, is multiplied by 22000 lumens and divided by 36000 lumens; the result of this operation gives a value of 21.39 lux. The comparison between the estimated value and the value calculated by the software results in a 0.011 lux difference.

As another example to estimate the first illuminance value at 70 percent of surface reflectance factor for the same 22000 lumens, the 21.39 lux value is multiplied by 70 and divided by 50. The result gives a value of 29.94 lux that compared with the value calculated by the software results in a difference of 0.1555 lux.

As can be seen in the table, the percentage differences between the calculated values and the estimated values show varying levels of deviation. However, these percentages do not mean large differences when the calculated values by the software and the manual estimations are compared against the illuminance levels they represent in a real situation. For example, using 36000 lumens with a façade surface reflectance of 70 percent, the deviation between the estimated and calculated values is 1.6 lux, which means that the

estimated value is 50.6 ± 1.6 lux. This can be seen as a very minor deviation and would have little effect on the resulting lighting scenario.

Furthermore, in the majority of the cases, these values show that these differences between the estimated and calculated values are less than one lux, which is virtually imperceptible in an outdoor lit environment.

Subsequently, a general curve (nomographs) describing the same luminaire placement (that is not moving the luminaire position in relation to the distance off the façade) and the same luminaire configuration (that is either the “UPLIGHT” or the “FRONTLIGHT” arrangement) can be constructed using the reference method described above. Please see Appendix D for the complete data set.

4.3 Constructing the Nomographs

A set of general curves (nomographs) was established based on the luminaire arrangement for each different luminaire distance from the façade and were constructed based on the normalised reference illuminance values. These values were plotted showing the normalised illuminance values on the Y-axis and the measured distances on the X-axis (metres).

Because the curves are based on dimensionless values (normalised), to estimate the illuminance levels at ground for each arrangement and different lighting situations, the values taken from the normalised graph required to be adjusted by certain factors. These factors are the links between the data gathered from the curves and the illuminance values.

Therefore, the equation to estimate different lighting conditions was expressed as follows:

$$E_x = K \cdot (\text{Normalised value at "X" distance}) \cdot \text{Factor 1} \cdot \text{Factor 2} \quad \text{Equation A}$$

Where

- E_x = Illuminance level at "X" distance from the luminaire
- Factor 1 would relate to different surface characteristics of the facade
- Factor 2 would relate to the different light output of the lamps
- K is a value to be described further (Section 4.3.3)

4.3.1 Normalised Illuminance Values (N)

To construct a set of normalised illuminance values, referenced values were set up for 50 percent façade surface reflectance and a lamp of 36000 lumens as these values are situated in the average range of the data of the two different luminaire arrangements ("UPLIGHT" and "FRONTLIGHT").

To build the curves, the normalised values belonging to the referenced luminaire's arrangement from "UPLIGHT" and "FRONTLIGHT" models were plotted based on the luminaire position, where the measurement points were situated on the "X-axis" expressed in metres and the normalised illuminance values at the "Y-axis" (N).

The first set of curves displays the data for luminaires at three metres from the façade with their corresponding normalised values at ground level, three, five and seven metres luminaire mounting height respectively.

The second set of curves were constructed for luminaires at four metres from the façade, the third at five metres from the façade, the fourth at six metres from the façade and the fifth at seven metres from the façade respectively (see figure 4.8 on following page).

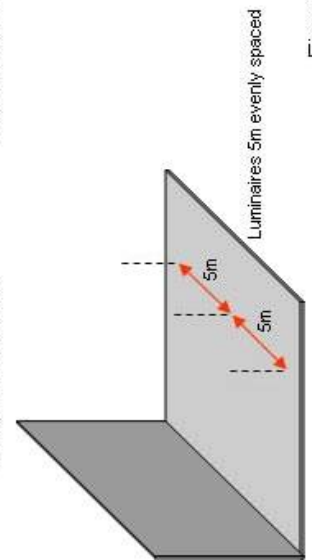
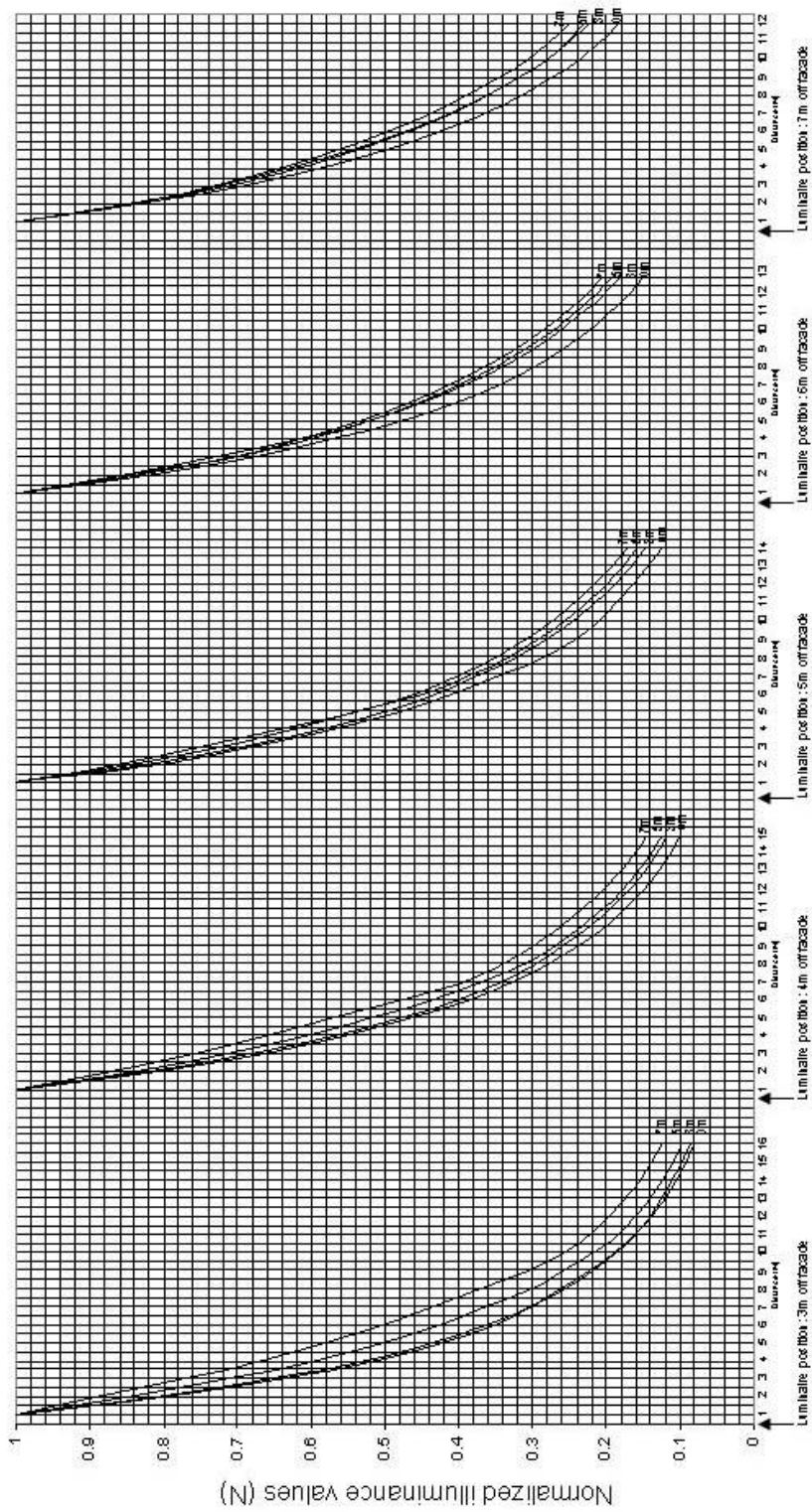


Figure 4.8 Normalised illuminance values for various distances and arrangements

Therefore, the equation A can now be expressed as follows:

$$E_x = K \cdot N \cdot \text{Factor 1} \cdot \text{Factor 2} \quad \text{Equation B}$$

4.3.2 Factor 1: Surface Reflectance Ratio (SRR)

As described previously, the surface reflectance factors (SRR) are those expressing the reflectance properties of a façade surface, and for this thesis, they were taken as 10, 30, 50, 70 and 90 percent for calculations. The reference surface reflectance factor was set as 50 percent. This value was selected according to IES Lighting Guide (2001) which refers to this value as the middle of the reflectance properties range and the most commonly occurring value in an exterior lighting design.

To relate different surface reflectance factors based on the referenced value, a linear relationship was constructed based on expressing the other surface reflectance factors as a fraction of the reference value (50%) as shown in table 4.2.

SRF (Percentage)	Conversion	(SRR)
10	10 / 50	0.2
30	30 / 50	0.6
50 (REFERENCE)	50 / 50	1.0
70	70 / 50	1.4
90	90 / 50	1.8

Table 4.2 Surface reflectance factors values and their corresponding conversion to a surface reflectance ratios

Plotting these values with surface reflectance on the Y- axis and the fraction of the reflectance on the X-axis (SRR), a linear relationship with a positive gradient is shown (figure 4.9). The SRR values are one of the factors that will affect the values read from the normalised illuminance curve (N).

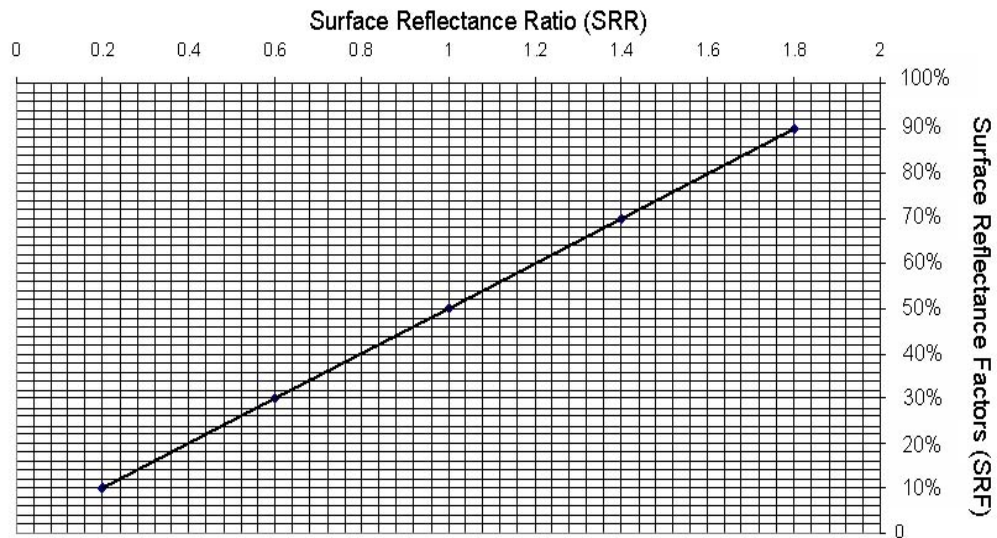


Figure 4.9 Surface Reflectance Ratios (SRR) curve

Equation A can now be expressed as follows:

$$E_x = K \cdot N \cdot SRR \cdot \text{Factor 2}$$

Equation C

4.3.3 Factor 2: Light Multiplier (LM)

To provide the illuminance levels at street level using the normalised curve (N), the values obtained from the normalised curve are affected by the SRR ratios and another factor that in this thesis will be called Light Multiplier (LM).

The Light Multiplier was defined as a value that will bring back the normalised values to illuminance (lux). As explained in the data normalisation process in chapter 3: 3.4, the normalised illuminance values were the result of dividing the maximum illuminance value against the other values belonging to the same luminaire

arrangement. These maximum illuminance values (lux) were then the first illuminance levels of each reference model's arrangement. They are summarised in table 4.3

Distance from façade \ Luminaire mounting height	3m	4m	5m	6m	7m
0m	9.3	7.6	5.3	5.22	3.88
3m	34.1	23.4	16.9	12.4	9.03
5m	35	24.9	17.9	13.1	9.69
7m	32.5	24.2	17.9	13.1	9.52

Table 4.3 Set of values corresponding to the first referenced illuminance values

To construct the Light Multiplier curve, the values from table 4.3 were multiplied by the number of luminaires (3) used to illuminate the façade, divided by the reference lumen output, and finally, multiplied by 1000 lumen to enlarge the scale to facilitate the readings (table 4.4).

Distance from façade \ Luminaire mounting height	3m	4m	5m	6m	7m
0m	0.775	0.633	0.442	0.435	0.323
3m	2.842	1.950	1.408	1.033	0.752
5m	2.917	2.077	1.492	1.092	0.807
7m	2.708	2.017	1.492	1.092	0.793

Table 4.4 Set of values converted to Light Multiplier values (lux) corresponding to the first referenced illuminance values

The Light Multiplier values were plotted with the luminaire mounting height on the "X-axis" in metres, and the calculated light ratios on the "Y-axis" as shown in figure 4.10. This factor is carrying the dimension to convert the values from Equation C to illuminance values.

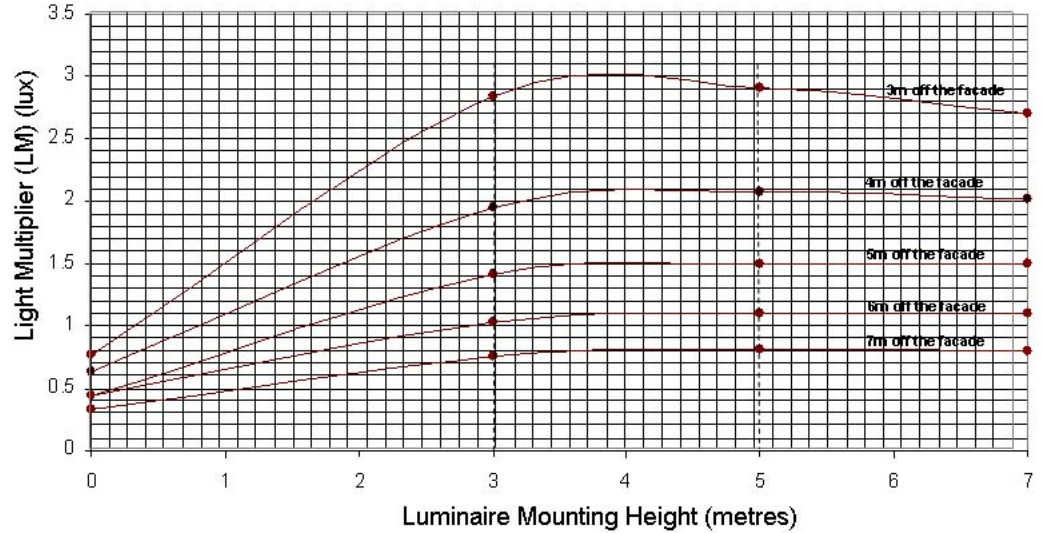


Figure 4.10 Light multiplier (LM) curve

As a result of the previous procedure, the value K was defined as the relationship between the lamp lumen output (LLO), the number of luminaires used for simulations in this thesis (3), and 1000 used to enlarge the scale for readings as follows:

$$K = LLO / (3 \cdot 1000) = LLO / 3000$$

Finally, the equation to estimate the illuminance levels can be expressed as follows:

$$E_x (\text{Lux}) = K \cdot (N \cdot \text{SRR} \cdot \text{LM}) \quad \text{Equation D}$$

Where:

- E_x = illuminance level in lux at "x" distance from the luminaire position
- K = LLO/3000
- LLO = Lumen output of the lamp
- N = Normalised illuminance values
- SRR = Surface Reflectance ratio
- LM = Light multiplier (lux)

5.0 Example: Application of the Curves Based on a Virtual Urban Environment

This chapter provides a general example of how nomographs can be employed when an urban lighting design is proposed. This is based on the provision of a realistic night-time lighting scenario where more than one façade of the same environment requires illumination. Since there is often a certain interaction between adjacent lighting installations, the achievement of harmonic lighting integration of these façades is featured in the example. This is demonstrated in such a way as to show how the nomographs (figures 4.8 and 4.11) facilitate the choice of the best-suited illuminance distribution for the area.

Although this example indicates realistic lighting scenarios, for the purpose of the thesis the successful use of luminaires in an urban area will be assumed considering that this example is prepared to show the application of this method and is not evaluating standards or lighting recommendations.

In general, this example will offer a useful overview and provide design guidelines to urban lighting specifiers. This example is starting with the well-known information often provided in practice and then moving on to the lighting planning.

5.1 The Virtual Urban Model

The area selected for simulations was a virtual Plaza with three main buildings and a central park with a water feature in the centre of the park. The level of complexity of the selected buildings in the area is

emphasised to highlight the applicability of this method for different floodlighting schemes and building geometries.

Despite the fact that the illumination of central objects as the fountain included in this example has not been part of the scope of this thesis, this might seem perfect to show that the illumination of central objects can be facilitated by this method. Considering that central objects are often illuminated to capture the attention of pedestrians, a successful illumination is often recognised when the observer is able to see the object in his/her view path with the minimum of effort (Moeck, 2000).

Therefore, the identification of the zones with low illuminance level in the area will help to provide the information required to incorporate central lit objects as shown in figure 5.1.

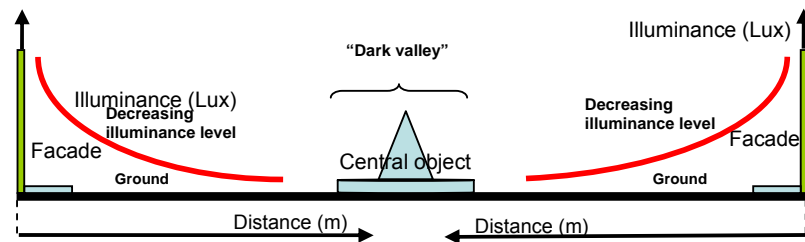


Figure 5.1 Typical “dark valley” created by reflected light from illuminated buildings. The decreasing illuminance levels create a suitable ambience for lighting a central object.

5.1.1 Model Description

The buildings here have been intentionally selected with different geometries and complexities. To facilitate the description of the model used in this example, the “selected” plaza was sketched as

shown in figure 5.2. Marked with capital letters A, B, C and D respectively are the buildings and the central feature that will be lit.

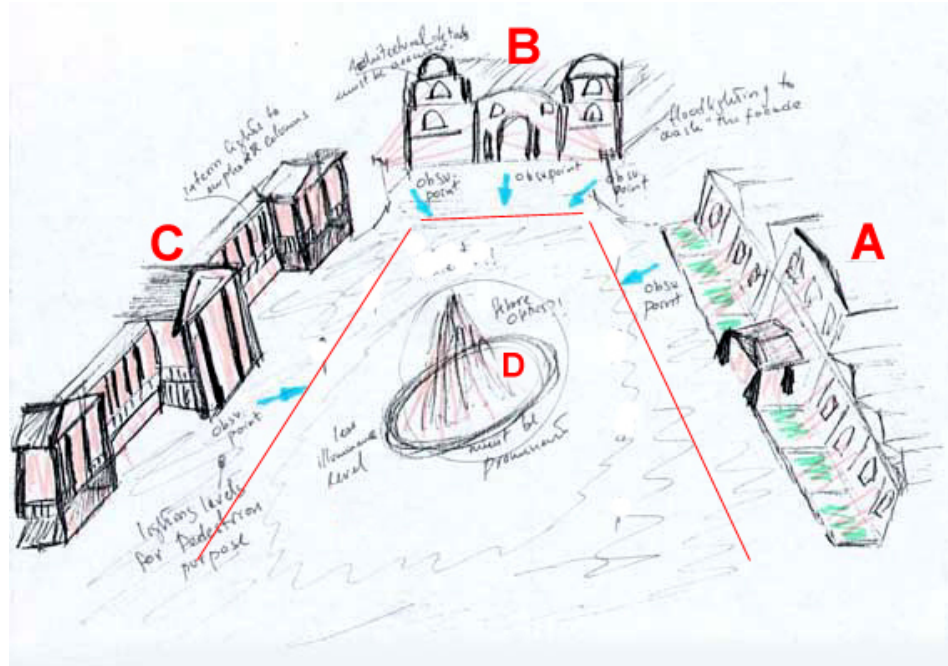


Figure 5.2 – Sketch of the public area to be lit involving three different buildings and a central object in the middle of the area.

The façade of the building A is divided into three sections, one central part that reaches a height of eight metres and two symmetrical and identical modules on each side of the central façade. The two symmetrical sections reach a height of six metres. The overall width of this building is ninety-eight metres. This building integrates a main entrance at the centre of the façade and a five metre grass strip.

Building B is portraying a typical Latin-Spanish church with two symmetric towers and a central main entrance. Typical ornaments of these types of buildings have not been incorporated in this example. The overall width of this building is twenty-six metres and the towers reach a height of fourteen metres.

Building C shows a colonnade façade with five sections in different planes. The building is divided into a central section and two pairs of identical modules on each side of the central section. The overall width of this façade is ninety-two metres with a height of 8.5 metres for the two side sections and 10.5 metres for the central section.

A water fountain has been located at the centre of the plaza. The central park of the plaza has an area of 3420 square metres.

5.1.2 The Brief and Lighting Requirements

As was mentioned in the introductory section, a common practice exists which is often used to enhance the aesthetic and technical requirements of the end users. This part of the design process usually takes place at the very beginning of the lighting project. Although this approach is invariably adhered to, it is only possible if one can define the primary aim of the lighting design. In a real situation, this information is often provided by the local authorities such as city councils through their architects or engineers or building owners in the case of private installations in accordance with the norms, standards and recommendations.

For the propose of this example and in concordance with the previous paragraph, the lighting parameters and the brief for this example were deduced from the useful relationships between the most important performance criteria and the various lighting parameters established in the previous chapters.

The lighting requirements follow the following brief:

1. Building A
 - Façade reflectance factor: 0.7
 - Floodlighting method: Uplights situated at four metres from the facade
2. Building B
 - Façade reflectance factor: 0.5
 - Floodlighting method: Frontlights situated at seven metres from the facade and five metres mounting height
3. Building C
 - Façade reflectance factor: 0.5
 - Floodlighting method: Frontlights situated at three metres from the facade and three metres mounting height
4. Feature object D
 - Floodlighting method: uplights
5. Light reflected onto street from lit façades measured at five metres from the luminaire position indicated in red in figure 5.2 assumed to be close to 4.5 Lux.
6. Provision of an essentially “zero” illuminance level from façade reflections close to the central feature of the plaza measured at eight metres from the position of the luminaires used to illuminate façades A, B and C.
7. Creation of more than one potential lighting scenario.

5.2 Estimating Lighting Conditions for Building “A”

As shown in the previous section, the illuminance levels at the required distance from the luminaire position are estimated using the following formula:

$$E_x = K \cdot (N \cdot SRR \cdot LM) \quad \text{Equation D}$$

Where:

E_x	= illuminance level in lux at “x” distance from the luminaire position
K	= LLO/3000
LLO	= Lumen output of the lamp (lumen)
N	= Normalised illuminance values
SRR	= Surface Reflectance Ratio
LM	= Light Multiplier (Lux)

The estimation of the illuminance levels using this method starts by determining the normalised illuminance values at street level at five and eight metres from the luminaire position from figure 4.11. In addition and according to the brief, as the building will be illuminated using the uplighting technique with a set of luminaires installed at four metres off from the façade at ground level, the required normalised curve to gather these values will correspond to the “4m-0m” curve in figure 4.8 from the previous chapter.

To facilitate the explanation of how to use these normalised curves, the curves will be individually plotted according to the position and mounting height of the luminaire established for the buildings. It is also important to highlight that the values shown along the Y-axis of the curve are dimensionless values that will provide a constant that does not depend on the surface reflectance ratio (SRR) and lumen output of the lamps (LLO).

Therefore, the **normalised illuminance values** (N) are taken from the intersection of the perpendicular line traced from the required

measured point at the X-axis to the “4m – 0” curve (figure 5.3). Using this approach, the normalised illuminance values at five metres from the luminaire position can be read as $N=0.45$ and at eight metres from the luminaire position as $N=0.27$ as shown in figure 5.3.

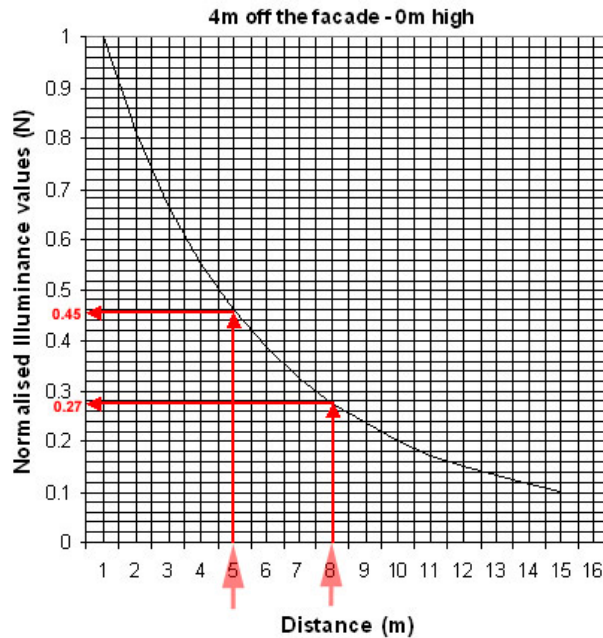


Figure 5.3 Normalised curve for 4m off the façade – luminaire at ground level.

The second value to gather is the **Surface Reflectance Ratio** (SRR). This can be obtained from figure 4.9 considering the surface reflectance factor for this building that was assumed as 70 percent. Therefore, the surface reflectance ratio (SRR) is taken from the intersection of the horizontal line traced from the reflectance factor at the Y-axis to the reflectance curve. Using this approach, the surface reflectance ratio can be read as $SRR=1.4$.

The third value to obtain is the **light multiplier** (LM) that can be obtained from figure 4.10 considering that the luminaire will be mounted at ground level and four metres from the façade. Therefore,

the light multiplier (LM) is taken from the intersection of the perpendicular line traced from the luminaire mounting height at the X-axis to the “4m off the façade” curve. Using this approach, the light multiplier (LM) for the required luminaire position can be read as LM=0.63 Lux.

Finally, the illuminance level (Lux) at street is estimated from the **Equation D** multiplying all these factors to K. Replacing the values that define K, the equation can be written as follows:

$$E_x \text{ (lux)} = \text{Illuminance level at “X” metres at street level} = \\ = \text{LLO} \cdot (\text{N} \cdot \text{SRR} \cdot \text{LM}) / 3000$$

However, the lumen output of the lamp becomes a variable value to try until the desired illuminance value at five metres is achieved. In this case, replacing LLO with 36000 lumens, the required illuminance level is achieved. The calculation is as follows:

Illuminance level at **five metres** from the luminaire position at street level:

$$E_{5m} = 36000 \text{ lumens} \cdot (0.45 \cdot 1.4 \cdot 0.63 \text{ lux}) / 3000 \text{ lumens} = 4.76\text{Lux}$$

The illuminance level at eight metres is thus a direct consequence of the selected lumen output needed to achieve the light levels at five metres, therefore:

Illuminance level at **eight metres** from the luminaire position at street level:

$$E_{8m} = 36000 \text{ lumens} \cdot (0.27 \cdot 1.4 \cdot 0.63 \text{ lux}) / 3000 \text{ lumens} = 2.85\text{Lux}$$

The values above were compared with the values calculated from the Lightscape® lighting software. The illumination of the building A was simulated and the light levels resulting from this process at five metres indicated above the five metres yellow line in figure 5.4.

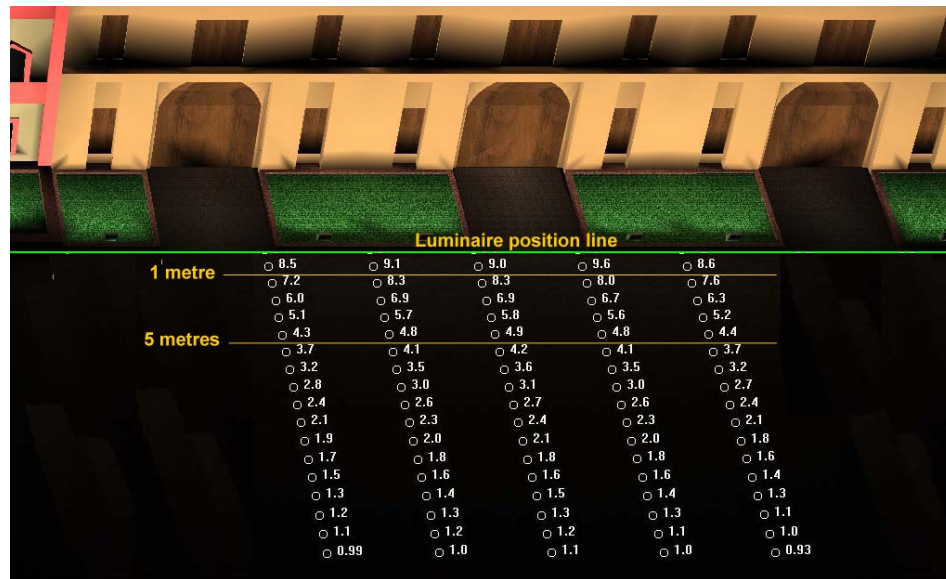


Figure 5.4 Illuminance levels at street level due to Building A lit façade

Although the numbers shown above the yellow line in figure 5.4 indicate differences in comparison with the estimated value from equation D, the divergences of these values in fact show what is often experienced in practice. Façade details often provide sources of divergences that estimations do not consider. However, in the urban complexity, these divergences are practically not relevant as minor differences of less than one lux are not presenting practical difficulties on an urban scale. It is possible to say that the estimated illuminance values at five metres from the luminaire position can be considered very close to the results from the lighting simulation, and therefore confirm the usefulness of the proposed method.

5.3 Estimating Lighting Conditions for Building “B”

This building will be illuminated using the floodlighting technique in front of the façade with a set of symmetrically arrayed luminaires installed at seven metres off the façade and at five metres mounting height. The surface reflectance factor for this building was established as 50 percent according to the provided brief.

Following the same procedure as explained previously, the normalised illuminance value (N) at five metres is estimated as $N=0.54$ and at eight metres as $N=0.36$ as shown in figure 5.5.

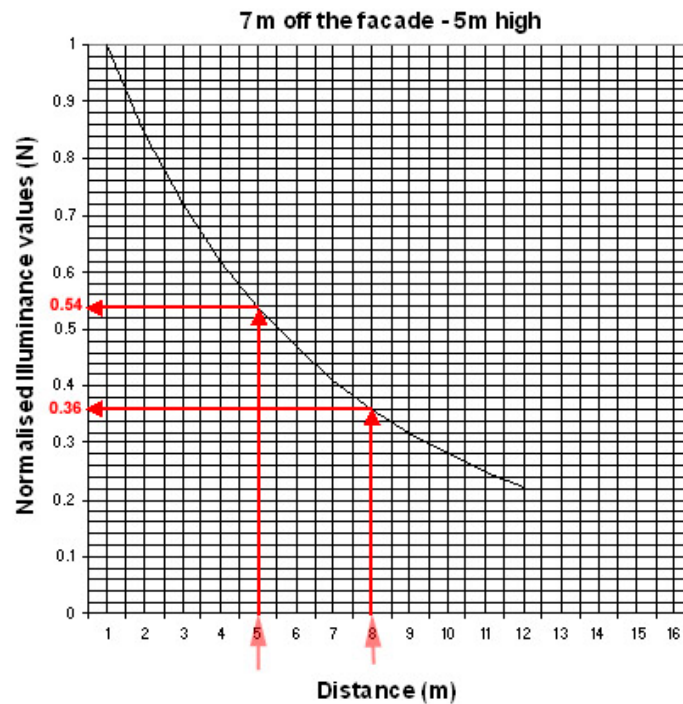


Figure 5.5 Normalised curve for 7m off the façade – luminaire at 5m high.

The surface reflectance ratio (SRR) is gathered from figure 4.9 considering the surface reflectance factor for this building as 0.5 and can be read as $SRR=1.0$

The light multiplier (LM) is obtained from figure 4.10 considering that the luminaire will be mounted at a height of five metres and seven metres from the façade. Thus, the light multiplier (LM) can be read as LM=0.8 Lux.

Finally, the illuminance levels at five and eight metres at street were estimated from **Equation D** with an LLO value of 22000 lumens as follows:

Illuminance level at **five metres** from the luminaire position at street level:

$$E_{5m} = 22000 \text{ lumens} \cdot (0.54 \cdot 1.0 \cdot 0.80 \text{ Lux}) / 3000 \text{ lumens} = 4.4 \text{ Lux}$$

The illuminance level at eight metres is then calculated with the same selected lumen output needed to achieve the light levels at five metres, therefore:

Illuminance level at **eight metres** from the luminaire position at street level:

$$E_{8m} = 22000 \text{ lumens} \cdot (0.36 \cdot 1.0 \cdot 0.80 \text{ Lux}) / 3000 \text{ lumens} = 3 \text{ Lux}$$

The lighting levels achieved at street level due to the illumination of this building were also contrasted with calculations from simulations. Figure 5.6 shows the illuminance levels resulting from the model as calculated by the software. As indicated by the values above the yellow line, the estimated illuminance values using the nomographs at five metres from the luminaire position can be considered very close to the results from the lighting simulation.



Figure 5.6 Illuminance levels at street level due to Building B lit façade

5.4 Estimating Lighting Conditions for Building “C”

To estimate the illuminance at street level due to the illumination of building C with floodlighting a set of symmetrically placed luminaires was installed at three metres off the façade and three metres mounting height. The surface reflectance factor for this building was assumed to be 0.5

Following the same procedure of the two previous buildings, the normalised illuminance value at five metres is estimated as $N=0.42$ and at eight metres as $N=0.26$ as shown in figure 5.7.

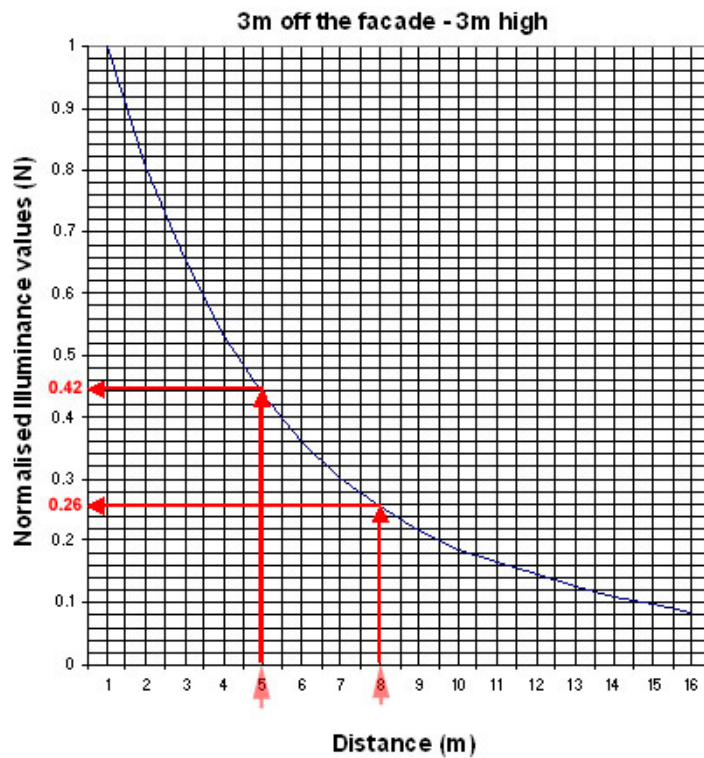


Figure 5.7 Normalised curve for 3m off the façade – luminaire at 3m high

The surface reflectance ratio (SRR) is gathered from figure 4.9 considering the surface reflectance factor for this building as 0.5 and can be read as $SRR=1.0$

The light multiplier (LM) is obtained from figure 4.10 for a luminaire mounted at a height of three metres and three metres from the façade. Thus, the light multiplier (LM) can be read as $LM=2.85$ Lux.

Finally, the illuminance at five and eight metre distance at street level was estimated from **Equation D** with LLO value of 12000 Lumens as follows:

Illuminance level at **five metres** from the luminaire position at street level:

$$E_{5m} = 12000 \text{ lumens} \cdot (0.42 \cdot 1.0 \cdot 2.85 \text{ Lux}) / 3000 \text{ lumens} = 4.78 \text{ Lux}$$

The illuminance level at eight metres is estimated with the same lumen output needed to achieve the light levels at five metres:

Illuminance level at **eight metres** from the luminaire position at street level:

$$E_{8m} = 12000 \text{ lumens} \cdot (0.26 \cdot 1.0 \cdot 2.85 \text{ Lux}) / 3000 \text{ lumens} = 2.96 \text{ Lux}$$

The lighting levels achieved at street level due to the illumination of this building were also compared with calculations from simulations. Figure 5.8 shows the illuminance levels resulting from the model as calculated by the software. As indicated by the numbers above the yellow line, the estimated illuminance values using the nomographs at five metres from the luminaire position can be considered very close to the results from the lighting simulation.



Figure 5.8 Illuminance levels at street level due to lit Building C façade

5.5 Central Object Incorporation: The “Dark Valley”

The integration of these three illuminated buildings results in a single nighttime scene for which the reflected light from each façade contributes to the general illumination of the area (figure 5.9). The low lighting conditions at the centre of the area, the “dark valley”, provide an opportunity required to incorporate another lighting application without overlapping reflected light from other lit elements in the area.



Figure 5.9 Lights used to illuminate the façades are providing a general or ambient illuminance levels affecting the surrounding area providing a certain illuminance level at ground level

In the example and according to the illuminance values estimated from equation D at eight metre distance from the façade, the lighting levels provided to illuminate the façade give reflected illuminance values of 2.85, 3 and 2.96 lux for buildings A, B and C respectively. These values give a clear indication that the central area will be barely visible in comparison with the illuminated buildings. This helps to draw the attention to the buildings without destroying other lighting scenarios such as the fountain of this example (figure 5.10). This could also be considered advantageous to designers as the illumination of this central object could be designed almost independently from the illuminated buildings, thus creating another lighting scene.



Figure 5.10 The lighting levels provided by the light coming from the façades allow the incorporation of lighting for central objects without light obstructions.

Finally, the possibility to estimate the light spread from light reflected from lit facades provides direct data to analyse the lighting balance between illuminated façades. For instance, if the light levels on one façade were increased, the illuminance levels at any given distance from the façade would increase as well. In the example, if the light levels washing building A were increased, the light levels measured at five metres from its façade would be higher than the light levels measured at five metres from building B and C. These differences between illuminance levels measured at the same distance at street level could indicate unbalanced light levels on facades, thus, a non-proportionally lit environment.

6.0 Conclusions

1. With the increasing demand for lighting solutions that provide a visually coherent and integrated environment, such as for safety and city beautification, the need to be able to predict the overall effect of the design prior to actually implementing it is growing in importance. It is in this context that the development of a consistent methodology to predict lighting results for desired solutions becomes a valuable tool for designers to be aware of undesired effects at the very first stage of the design process.

At present, while there are two main design techniques recommended for lighting a façade and no 'rules' for lighting design to follow, there is 'the secret' of good lighting design. This 'secret' is based on experimental approaches where the knowledge, understanding, experience and proficiency of the designer enable him/her to explore potential solutions. Although this seems very convenient when an individual façade is designed, these solutions consider just the lighting effect on the façade and provide limited information on how the lighting will affect surroundings.

The method presented in this thesis provides a foundation and tools to approach this type of lighting design systematically. The proposed method inserts the nomographs as a new tool between the designer's knowledge or experience and the number of calculations often required when the experimental approach is used. Hence, the major benefit given by this

proposed method is that the lighting parameters, such as the lumen output of lamps, luminaire mounting position - determined by the floodlighting technique desired - and the luminaire distance from the façade, are established at the very first stage of the design process. This tool is introducing a new 'secret' of good lighting design that designers can utilise to illuminate façades.

2. The nomograph method described in this thesis provides a tool for integrating different lighting scenarios while considering the exterior lighting requirements. It analyses the situation to find the lighting levels for the façade based on the lighting that will be reflected onto the surrounding street.

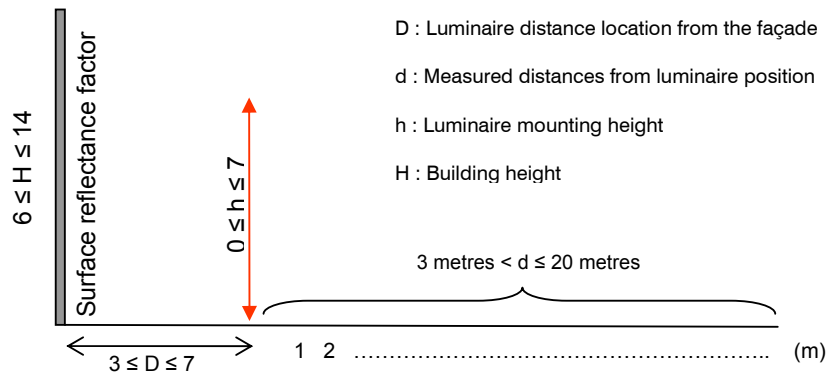
However, the proposed method considers luminaire arrangements in front of the building façade only, as was indicated in chapters three and four. For this reason, the proposed method is framed within the following restrictions:

- The illuminance levels achieved on the façade should be uniformly distributed from floodlighting arrangements.
- The building height must not be more than 14 metres.
- The distance of the luminaires from the façade should be considered from three metres to seven metres maximum.
- The luminaires should be mounted between the ground level and a maximum of seven metres in height.

In addition, the utilisation of the nomographs requires the establishment of the following parameters:

- a. The luminaire mounting position: determined by the floodlighting technique desired and the luminaire distance from the façade.
- b. The surface reflectance factor of the façade

The following figure schematises the main considerations mentioned above.



3. An assessment of computer simulations for lighting design is often based on the quality of the pictures that can be rendered from the lighting software. However, these results depend on the number of details put into the models and the careful selection of luminaires to perform the simulation. The selection of luminaires is not always easy and often a time consuming process when complex and detailed lighting simulations are required.

The proposed method facilitates the implementation of various lighting solutions by organising the required luminaire data for input into lighting software. This is possible as the lamp lumen output and luminaire arrangement parameters can be estimated with equation D. This method is in fact providing a procedure to find the adequate balance between lit façades prior to major lighting calculations and simulations.

4. The estimated illuminance values gathered from equation D provide information about how much light is received at street level. These values in conjunction with the street lighting standards can provide a substantial reduction of the numbers of street luminaires if the street lighting system is also included in the final lighting scene.

Using the example presented in chapter five, the street lighting is incorporated into the final solution. Figure 6.1 shows a view of how the lighting is distributed in the horizontal surface.

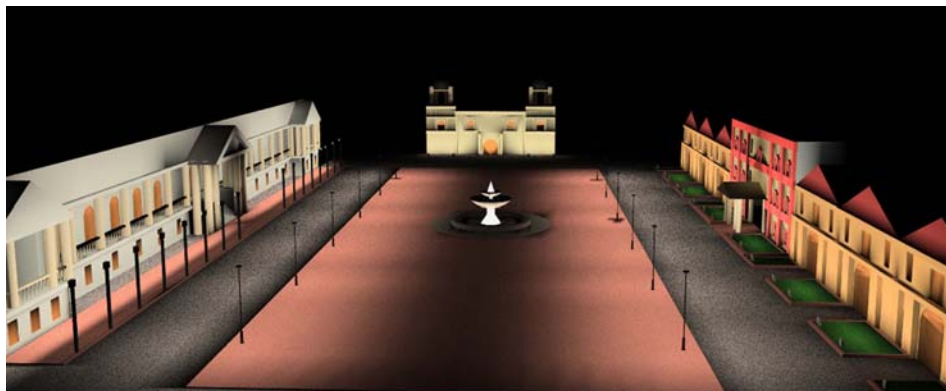


Figure 6.1 Final lighting solution that incorporates street luminaires to fulfil the lighting requirements

The street lighting levels in the area considered the contribution of the reflected light from the façades in its initial assessment. In this example, the initial condition was set to 4.5 lux measured at five metres from the luminaire position. Thus, the light level required for the street could be the difference between the light level necessary to the norms and standards and the light already contributed from other façades. This presents potentials for energy savings that would require further studies to develop effective procedures.

5. The procedure developed in the previous chapter shows three easy steps to achieve estimated lighting solutions. These can be summarised as follows:

Step 1

- The proposed method starts by establishing the illuminance value desired at street level at distance “d” from the façade as indicated in figure 6.1.

Point “A” in figure 6.2 indicates where the desired light level will be approximated by the equation D introduced in the analysis section.

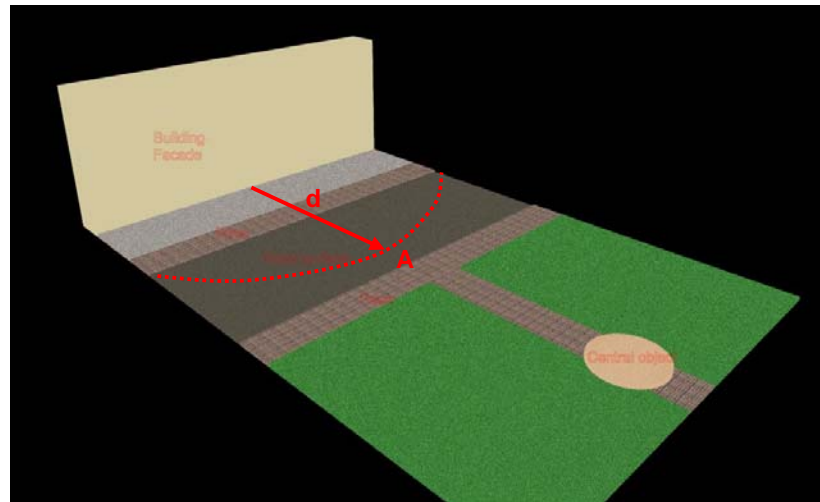


Figure 6.2 Light spread distance desired at street level. The letter **d** indicates the distance (metres) from the façade to point **A** at street level.

From the experience gained during the elaboration of this Thesis, the author recommends to initiate the calculation defining the illuminance value at distance “A” (figure 6.2) for each building as follows:

- Harmonious lit environment.

To reach a harmonious lit environment, light levels at distance “A” from all façades must be similar. The achievement of similar illuminance values at distance “A” often indicates that illuminance levels on each facade will not be excessive to make any façade prominently lit.

In the case of an environment where some of the buildings are already illuminated, values at distance “A” can be set up from the light levels already provided at street level from the other lit façades.

- Highlighting for distinction.

This requires that the illuminance value at “A” from the most prominent building be higher than the light levels reflected from the other façades.

Finally, using the reflectance values from the façade, the surface reflectance ratio can be estimated by the SRR curve shown below:

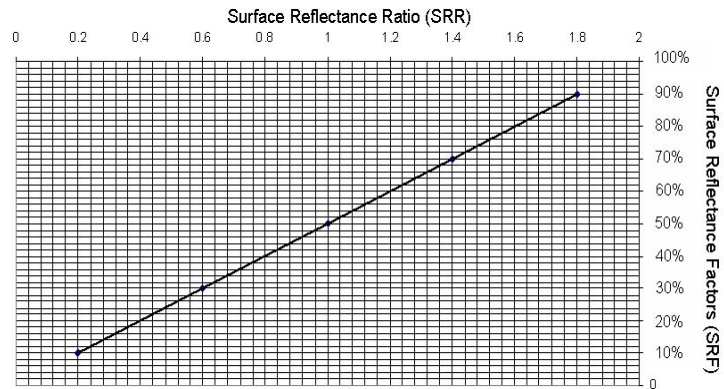


Figure 6.3 Surface Reflectance Ratios (SRR) curve

Step 2

The second step requires the selection of one of the floodlighting techniques indicated in chapter three.

- The luminaire position can be defined by considering the limitations of the installation, such as obstructions on or in the building structure.

From the previous information (refer to the floodlighting technique and luminaire location) the normalised value “N” can be gathered from the normalised curves (Figure 4.8, Analysis section) corresponding to the selected luminaire arrangement as well as the mounting distance from the façade. The normalised value “N” will be selected for the distance “x” from the luminaire position to point “A” as indicated in figure 6.4.

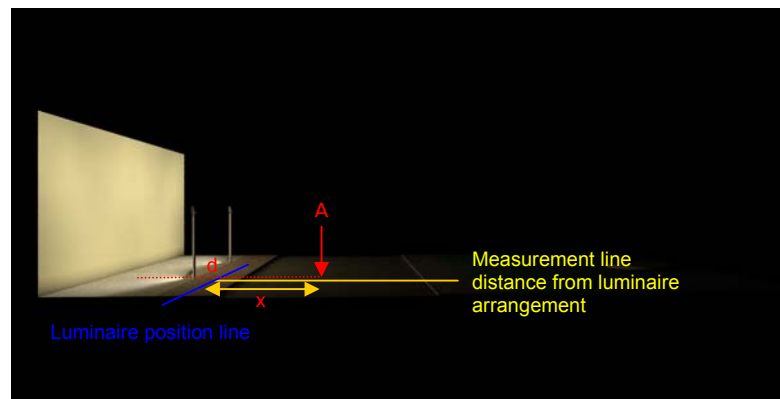


Figure 6.4 Distance from the luminaire position to measurement point “A”.

- Additionally, the light multiplier ratio can be determined from the curve indicated below:

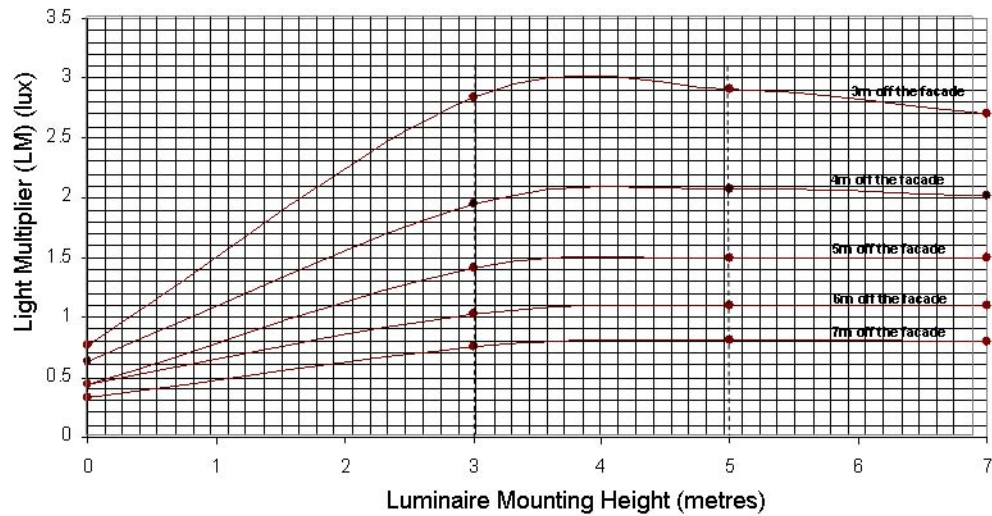


Figure 6.5 Light multiplier (LM) curve

Step 3

The normalised value (N), surface reflectance ratio (SRR) and light multiplier ratio (LM) are found from the previous steps and are used in Equation D.

This equation approximates the desired illuminance level at street level using the lumen output of the lamps as a variable. Considering that the desired illuminance at street level was established in the first step, the lumen output of the lamp is varied in the formula until that illuminance value is approximated.

$$E_x (\text{Lux}) = K \cdot (N \cdot \text{SRR} \cdot \text{LM}) \quad \text{Equation D}$$

Where:

- E_x = illuminance level in lux at "x" distance from the luminaire position
- K = LLO/3000
- LLO = Lumen output of the lamp
- N = Normalised illuminance values
- SRR = Surface Reflectance ratio
- LM = Light multiplier (lux)

The proposed Equation D allows designers arrive at lighting solutions through the selection of the most suitable lumen output, and luminaire arrangement to suit the pre-established illuminance at street level. Although the results obtained from the equation do not provide accurate calculations compared to lighting software, they do provide an acceptable value that can ensure a successful lighting solution.

7.0 Future Research Recommendations

The nomograph method presented has the potential for reducing overall energy consumption when street luminaires are included in the final solution of the lighting design. Thus, monetary savings can be achieved by the integration of the street lighting with exterior façade lighting design. Considering that there is reflected light already received at street level from lit façades the distance between street lighting poles could be increased or their illumination reduced, therefore reducing the need for lighting in public areas.

The characteristic curves found in this thesis are expressed in polynomial equations. With the help of a computer, these equations could be utilised for every lighting situation. This could entail the design of an inter-active web-site that can help guide designers through the tool quickly and efficiently. The web site would include a flow chart that asks the designer important questions regarding his or her required lighting solution. The graphs and charts shown here could be integrated into the web site allowing the designer to achieve a quick solution with all the illuminance data for his/her design.

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GE Lighting – www.gelighting.com

Ruud Lighting – www.ruudlighting.com

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Simple Nomographs for Assessing Lighting in Urban Environments

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Prepared by Tomas Sandoval Calderon

A thesis submitted in fulfillment of the requirements for the degree of

MBSc Master of Building Science

Victoria University of Wellington **School of Architecture**

May 2007

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1.75	0.80	1.10	1.63	2.11	1.4	4.82	8.24	11.0	15	1	3.4	5.84	8.06	10.0	0.8	2.5	4.16	5.88	7.82	0.81	1.8	3.13	4.41	5.71	0.81	1.8	3.13	4.41	5.71	7.01	8.30	9.59	10.88	12.17	13.46	14.75	16.04	17.33	18.62	19.91	21.20	22.49	23.78	25.07	26.36	27.65	28.94	30.23	31.52	32.81	34.10	35.39	36.68	37.97	39.26	40.55	41.84	43.13	44.42	45.71	47.00	48.29	49.58	50.87	52.16	53.45	54.74	56.03	57.32	58.61	59.90	61.19	62.48	63.77	65.06	66.35	67.64	68.93	70.22	71.51	72.80	74.09	75.38	76.67	77.96	79.25	80.54	81.83	83.12	84.41	85.70	86.99	88.28	89.57	90.86	92.15	93.44	94.73	96.02	97.31	98.60	99.89	101.18	102.47	103.76	105.05	106.34	107.63	108.92	110.21	111.50	112.79	114.08	115.37	116.66	117.95	119.24	120.53	121.82	123.11	124.40	125.69	126.98	128.27	129.56	130.85	132.14	133.43	134.72	136.01	137.30	138.59	139.88	141.17	142.46	143.75	145.04	146.33	147.62	148.91	150.20	151.49	152.78	154.07	155.36	156.65	157.94	159.23	160.52	161.81	163.10	164.39	165.68	166.97	168.26	169.55	170.84	172.13	173.42	174.71	176.00	177.29	178.58	179.87	181.16	182.45	183.74	185.03	186.32	187.61	188.90	190.19	191.48	192.77	194.06	195.35	196.64	197.93	199.22	200.51	201.80	203.09	204.38	205.67	206.96	208.25	209.54	210.83	212.12	213.41	214.70	216.00	217.29	218.58	219.87	221.16	222.45	223.74	225.03	226.32	227.61	228.90	230.19	231.48	232.77	234.06	235.35	236.64	237.93	239.22	240.51	241.80	243.09	244.38	245.67	246.96	248.25	249.54	250.83	252.12	253.41	254.70	256.00	257.29	258.58	259.87	261.16	262.45	263.74	265.03	266.32	267.61	268.90	270.19	271.48	272.77	274.06	275.35	276.64	277.93	279.22	280.51	281.80	283.09	284.38	285.67	286.96	288.25	289.54	290.83	292.12	293.41	294.70	296.00	297.29	298.58	299.87	301.16	302.45	303.74	305.03	306.32	307.61	308.90	310.19	311.48	312.77	314.06	315.35	316.64	317.93	319.22	320.51	321.80	323.09	324.38	325.67	326.96	328.25	329.54	330.83	332.12	333.41	334.70	336.00	337.29	338.58	339.87	341.16	342.45	343.74	345.03	346.32	347.61	348.90	350.19	351.48	352.77	354.06	355.35	356.64	357.93	359.22	360.51	361.80	363.09	364.38	365.67	366.96	368.25	369.54	370.83	372.12	373.41	374.70	376.00	377.29	378.58	379.87	381.16	382.45	383.74	385.03	386.32	387.61	388.90	390.19	391.48	392.77	394.06	395.35	396.64	397.93	399.22	400.51	401.80	403.09	404.38	405.67	406.96	408.25	409.54	410.83	412.12	413.41	414.70	416.00	417.29	418.58	419.87	421.16	422.45	423.74	425.03	426.32	427.61	428.90	430.19	431.48	432.77	434.06	435.35	436.64	437.93	439.22	440.51	441.80	443.09	444.38	445.67	446.96	448.25	449.54	450.83	452.12	453.41	454.70	456.00	457.29	458.58	459.87	461.16	462.45	463.74	465.03	466.32	467.61	468.90	470.19	471.48	472.77	474.06	475.35	476.64	477.93	479.22	480.51	481.80	483.09	484.38	485.67	486.96	488.25	489.54	490.83	492.12	493.41	494.70	496.00	497.29	498.58	499.87	501.16	502.45	503.74	505.03	506.32	507.61	508.90	510.19	511.48	512.77	514.06	515.35	516.64	517.93	519.22	520.51	521.80	523.09	524.38	525.67	526.96	528.25	529.54	530.83	532.12	533.41	534.70	536.00	537.29	538.58	539.87	541.16	542.45	543.74	545.03	546.32	547.61	548.90	550.19	551.48	552.77	554.06	555.35	556.64	557.93	559.22	560.51	561.80	563.09	564.38	565.67	566.96	568.25	569.54	570.83	572.12	573.41	574.70	576.00	577.29	578.58	579.87	581.16	582.45	583.74	585.03	586.32	587.61	588.90	590.19	591.48	592.77	594.06	595.35	596.64	597.93	599.22	600.51	601.80	603.09	604.38	605.67	606.96	608.25	609.54	610.83	612.12	613.41	614.70	616.00	617.29	618.58	619.87	621.16	622.45	623.74	625.03	626.32	627.61	628.90	630.19	631.48	632.77	634.06	635.35	636.64	637.93	639.22	640.51	641.80	643.09	644.38	645.67	646.96	648.25	649.54	650.83	652.12	653.41	654.70	656.00	657.29	658.58	659.87	661.16	662.45	663.74	665.03	666.32	667.61	668.90	670.19	671.48	672.77	674.06	675.35	676.64	677.93	679.22	680.51	681.80	683.09	684.38	685.67	686.96	688.25	689.54	690.83	692.12	693.41	694.70	696.00	697.29	698.58	699.87	701.16	702.45	703.74	705.03	706.32	707.61	708.90	710.19	711.48	712.77	714.06	715.35	716.64	717.93	719.22	720.51	721.80	723.09	724.38	725.67	726.96	728.25	729.54	730.83	732.12	733.41	734.70	736.00	737.29	738.58	739.87	741.16	742.45	743.74	745.03	746.32	747.61	748.90	750.19	751.48	752.77	754.06	755.35	756.64	757.93	759.22	760.51	761.80	763.09	764.38	765.67	766.96	768.25	769.54	770.83	772.12	773.41	774.70	776.00	777.29	778.58	779.87	781.16	782.45	783.74	785.03	786.32	787.61	788.90	790.19	791.48	792.77	794.06	795.35	796.64	797.93	799.22	800.51	801.80	803.09	804.38	805.67	806.96	808.25	809.54	810.83	812.12	813.41	814.70	816.00	817.29	818.58	819.87	821.16	822.45	823.74	825.03	826.32	827.61	828.90	830.19	831.48	832.77	834.06	835.35	836.64	837.93	839.22	840.51	841.80	843.09	844.38	845.67	846.96	848.25	849.54	850.83	852.12	853.41	854.70	856.00	857.29	858.58	859.87	861.16	862.45	863.74	865.03	866.32	867.61	868.90	870.19	871.48	872.77	874.06	875.35	876.64	877.93	879.22	880.51	881.80	883.09	884.38	885.67	886.96	888.25	889.54	890.83	892.12	893.41	894.70	896.00	897.29	898.58	899.87	901.16	902.45	903.74	905.03	906.32	907.61	908.90	910.19	911.48	912.77	914.06	915.35	916.64	917.93	919.22	920.51	921.80	923.09	924.38	925.67	926.96	928.25	929.54	930.83	932.12	933.41	934.70	936.00	937.29	938.58	939.87	941.16	942.45	943.74	945.03	946.32	947.61	948.90	950.19	951.48	952.77	954.06	955.35	956.64	957.93	959.22	960.51	961.80	963.09	964.38	965.67	966.96	968.25	969.54	970.83	972.12	973.41	974.70	976.00	977.29	978.58	979.87	981.16	982.45	983.74	985.03	986.32	987.61	988.90	990.19	991.48	992.77	994.06	995.35	996.64	997.93	999.22	1000.51	1001.80	1003.09	1004.38	1005.67	1006.96	1008.25	1009.54	1010.83	1012.12	1013.41	1014.70	1016.00	1017.29	1018.58	1019.87	1021.16	1022.45	1023.74	1025.03	1026.32	1027.61	1028.90	1030.19	1031.48	1032.77	1034.06	1035.35	1036.64	1037.93	1039.22	1040.51	1041.80	1043.09	1044.38	1045.67	1046.96	1048.25	1049.54	1050.83	1052.12	1053.41	1054.70	1056.00	1057.29	1058.58	1059.87	1061.16	1062.45	1063.74	1065.03	1066.32	1067.61	1068.90	1070.19	1071.48	1072.77	1074.06	1075.35	1076.64	1077.93	1079.22	1080.51	1081.80	1083.09	1084.38	1085.67	1086.96	1088.25	1089.54	1090.83	1092.12	1093.41	1094.70	1096.00	1097.29	1098.58	1099.87	1101.16	1102.45	1103.74	1105.03	1106.32	1107.61	1108.90	1110.19	1111.48	1112.77	1114.06	1115.35	1116.64	1117.93	1119.22	1120.51	1121.80	1123.09	1124.38	1125.67	1126.96	1128.25	1129.54	1130.83	1132.12	1133.41	1134.70	1136.00	1137.29	1138.58	1139.87	1141.16	1142.45	1143.74	1145.03	1146.32	1147.61	1148.90	1150.19	1151.48	1152.77	1154.06	1155.35	1156.64	1157.93	1159.22	1160.51	1161.80	1163.09	1164.38	1165.67	1166.96	1168.25	1169.54	1170.83	1172.12	1173.41	1174.70	1176.00	1177.29	1178.58	1179.87	1181.16	1182.45	1183.74	1185.03	1186.32	1187.61	1188.90	1190.19	1191.48	1192.77	1194.06	1195.35	1196.64	1197.93	1199.22	1200.51	1201.80	1203.09	1204.38	1205.67	1206.96	1208.25	1209.54	1210.83	1212.12	1213.41	1214.70	1216.00	1217.29	1218.58	1219.87	1221.16	1222.45	1223.74	1225.03	1226.32	1227.61	1228.90	1230.19	1231.48	1232.77	1234.06	1235.35	1236.64	1237.93	1239.22	1240.51	1241.80	1243.09	1244.38	1245.67	1246.96	1248.25	1249.54	1250.83	1252.12	1253.41	1254.70	1256.00	1257.29	1258.58	1259.87	1261.16	1262.45	1263.74	1265.03	1266.32	1267.61	1268.90	1270.19	1271.48	1272.77	1274.06	1275.35	1276.64	1277.93	1279.22	1280.51	1281.80	1283.09	1284.38	1285.67	1286.96	1288.25	1289.54	1290.83	1292.12	1293.41	1294.70	1296.00	1297.29	1298.58	1299.87	1301.16	1302.45	1303.74	1305.03	1306.32	1307.61	1308.90	1310.19	1311.48	1312.77	1314.06	1315.35	1316.64	1317.93	1319.22	1320.51	1321.80	1323.09	1324.38	1325.67	1326.96	1328.25	1329.54	1330.83	1332.12	1333.41	1334.70	1336.00	1337.29	1338.58	1339.87	1341.16	1342.45	1343.74	1345.03	1346.32	1347.61	1348.90	1350.19	1351.4

APPENDIX B

UPLIGHT LUMINAIRE ARRANGEMENT B – 1

FRONTLIGHT LUMINAIRE ARRANGEMENT – 3m mounting height B – 2

FRONTLIGHT LUMINAIRE ARRANGEMENT – 5m mounting height B – 3

FRONTLIGHT LUMINAIRE ARRANGEMENT – 7m mounting height B – 4

APPENDIX B

3m-3m		3m-4m		3m-5m		3m-6m		3m-7m		3m-8m		3m-9m		3m-10m						
10	30	50	70	90	10	30	50	70	90	10	30	50	70	90	10	30	50	70	90	
0.683439	0.802071	0.807006	0.811321	0.809703	0.849154	0.857620	0.858951	0.859250	0.859378	0.859454	0.859500	0.859529	0.859545	0.859558	0.859568	0.859575	0.859580	0.859583	0.859585	0.859586
0.766871	0.854503	0.855992	0.856806	0.857174	0.876514	0.887639	0.891063	0.892822	0.894018	0.894722	0.895050	0.895400	0.895764	0.896132	0.896504	0.896880	0.897260	0.897644	0.898032	0.898424
0.848972	0.940050	0.943928	0.945322	0.945401	0.963846	0.974837	0.978163	0.980091	0.981574	0.982616	0.983320	0.983784	0.984060	0.984256	0.984372	0.984410	0.984458	0.984496	0.984524	0.984542
0.894693	0.948071	0.949558	0.949951	0.949814	0.967261	0.978252	0.981578	0.983506	0.985089	0.986331	0.987245	0.987929	0.988393	0.988748	0.989004	0.989172	0.989264	0.989290	0.989310	0.989324
0.930235	0.973883	0.975370	0.975963	0.975826	0.992273	0.993264	0.993657	0.993950	0.994143	0.994246	0.994350	0.994454	0.994558	0.994662	0.994766	0.994870	0.994974	0.995078	0.995182	0.995286
0.958025	0.991673	0.993160	0.993753	0.993616	1.010063	1.011054	1.011447	1.011740	1.011933	1.012126	1.012319	1.012512	1.012705	1.012898	1.013091	1.013284	1.013477	1.013670	1.013863	1.014056
0.985816	1.019464	1.020951	1.021544	1.021407	1.037854	1.038845	1.039238	1.039531	1.039724	1.039917	1.040110	1.040303	1.040496	1.040689	1.040882	1.041075	1.041268	1.041461	1.041654	1.041847
1.013607	1.047255	1.048742	1.049335	1.049198	1.065645	1.066636	1.067029	1.067322	1.067515	1.067708	1.067901	1.068094	1.068287	1.068480	1.068673	1.068866	1.069059	1.069252	1.069445	1.069638
1.041398	1.075046	1.076533	1.077126	1.076989	1.093436	1.094427	1.094820	1.095113	1.095306	1.095499	1.095692	1.095885	1.096078	1.096271	1.096464	1.096657	1.096850	1.097043	1.097236	1.097429
1.069189	1.102837	1.104324	1.104917	1.104780	1.121227	1.122218	1.122611	1.122904	1.123097	1.123290	1.123483	1.123676	1.123869	1.124062	1.124255	1.124448	1.124641	1.124834	1.125027	1.125220
1.096980	1.130628	1.132115	1.132708	1.132571	1.149018	1.150009	1.150402	1.150695	1.150888	1.151081	1.151274	1.151467	1.151660	1.151853	1.152046	1.152239	1.152432	1.152625	1.152818	1.153011
1.124771	1.158419	1.159906	1.160499	1.160362	1.176809	1.177800	1.178193	1.178386	1.178579	1.178772	1.178965	1.179158	1.179351	1.179544	1.179737	1.179930	1.180123	1.180316	1.180509	1.180702
1.152562	1.186210	1.187697	1.188290	1.188153	1.204600	1.205591	1.205984	1.206177	1.206370	1.206563	1.206756	1.206949	1.207142	1.207335	1.207528	1.207721	1.207914	1.208107	1.208300	1.208493
1.180353	1.213999	1.215486	1.216079	1.215942	1.232389	1.233380	1.233773	1.234066	1.234259	1.234452	1.234645	1.234838	1.235031	1.235224	1.235417	1.235610	1.235803	1.236096	1.236289	1.236482
1.208144	1.241792	1.243279	1.243872	1.243735	1.260182	1.261173	1.261566	1.261759	1.261952	1.262145	1.262338	1.262531	1.262724	1.262917	1.263110	1.263303	1.263496	1.263689	1.263882	1.264075
1.235935	1.269583	1.271070	1.271663	1.271526	1.287973	1.288964	1.289357	1.289550	1.289743	1.289936	1.290129	1.290322	1.290515	1.290708	1.290901	1.291094	1.291287	1.291480	1.291673	1.291866
1.263726	1.297374	1.298861	1.299454	1.299317	1.315764	1.316755	1.317148	1.317341	1.317534	1.317727	1.317920	1.318113	1.318306	1.318499	1.318692	1.318885	1.319078	1.319271	1.319464	1.319657
1.291517	1.325165	1.326652	1.327245	1.327108	1.343555	1.344546	1.344939	1.345132	1.345325	1.345518	1.345711	1.345904	1.346097	1.346290	1.346483	1.346676	1.346869	1.347062	1.347255	1.347448
1.319308	1.352956	1.354443	1.355036	1.354899	1.371346	1.372337	1.372730	1.372923	1.373116	1.373309	1.373502	1.373695	1.373888	1.374081	1.374274	1.374467	1.374660	1.374853	1.375046	1.375239
1.347099	1.380747	1.382234	1.382827	1.382690	1.399137	1.399128	1.399119	1.399110	1.399101	1.399092	1.399083	1.399074	1.399065	1.399056	1.399047	1.399038	1.399029	1.399020	1.399011	1.399002
1.374890	1.408538	1.410025	1.410618	1.410481	1.426928	1.426919	1.426910	1.426901	1.426892	1.426883	1.426874	1.426865	1.426856	1.426847	1.426838	1.426829	1.426820	1.426811	1.426802	1.426793
1.402681	1.436329	1.437816	1.438409	1.438272	1.454719	1.454710	1.454701	1.454692	1.454683	1.454674	1.454665	1.454656	1.454647	1.454638	1.454629	1.454620	1.454611	1.454602	1.454593	1.454584
1.430472	1.464120	1.465607	1.466200	1.466063	1.482510	1.482501	1.482492	1.482483	1.482474	1.482465	1.482456	1.482447	1.482438	1.482429	1.482420	1.482411	1.482402	1.482393	1.482384	1.482375
1.458263	1.491911	1.493398	1.494001	1.493864	1.510311	1.510302	1.510293	1.510284	1.510275	1.510266	1.510257	1.510248	1.510239	1.510230	1.510221	1.510212	1.510203	1.510194	1.510185	1.510176
1.486054	1.519552	1.521039	1.521642	1.521505	1.537952	1.537943	1.537934	1.537925	1.537916	1.537907	1.537898	1.537889	1.537880	1.537871	1.537862	1.537853	1.537844	1.537835	1.537826	1.537817
1.513845	1.547493	1.548980	1.549583	1.549446	1.565893	1.565884	1.565875	1.565866	1.565857	1.565848	1.565839	1.565830	1.565821	1.565812	1.565803	1.565794	1.565785	1.565776	1.565767	1.565758
1.541636	1.575284	1.576771	1.577374	1.577237	1.593684	1.593675	1.593666	1.593657	1.593648	1.593639	1.593630	1.593621	1.593612	1.593603	1.593594	1.593585	1.593576	1.593567	1.593558	1.593549
1.569427	1.603075	1.604562	1.605165	1.605028	1.621475	1.621466	1.621457	1.621448	1.621439	1.621430	1.621421	1.621412	1.621403	1.621394	1.621385	1.621376	1.621367	1.621358	1.621349	1.621340
1.597218	1.630723	1.632210	1.632813	1.632676	1.649123	1.649114	1.649105	1.649096	1.649087	1.649078	1.649069	1.649060	1.649051	1.649042	1.649033	1.649024	1.649015	1.649006	1.648997	1.648988
1.625009	1.658657	1.660144	1.660747	1.660610	1.677057	1.677048	1.677039	1.677030	1.677021	1.677012	1.677003	1.676994	1.676985	1.676976	1.676967	1.676958	1.676949	1.676940	1.676931	1.676922
1.652800	1.686448	1.687935	1.688538	1.688401	1.704848	1.704839	1.704830	1.704821	1.704812	1.704803	1.704794	1.704785	1.704776	1.704767	1.704758	1.704749	1.704740	1.704731	1.704722	1.704713
1.680591	1.714099	1.715586	1.716189	1.716052	1.732500	1.732491	1.732482	1.732473	1.732464	1.732455	1.732446	1.732437	1.732428	1.732419	1.732410	1.732401	1.732392	1.732383	1.732374	1.732365
1.708382	1.741990	1.743477	1.744080	1.743943	1.760390	1.760381	1.760372	1.760363	1.760354	1.760345	1.760336	1.760327	1.760318	1.760309	1.760300	1.760291	1.760282	1.760273	1.760264	1.760255
1.736173	1.769781	1.771268	1.771871	1.771734	1.788181	1.788172	1.788163	1.788154	1.788145	1.788136	1.788127	1.788118	1.788109	1.788100	1.788091	1.788082	1.788073	1.788064	1.788055	1.788046
1.763964	1.797572	1.799059	1.799662	1.799525	1.815972	1.815963	1.815954	1.815945	1.815936	1.815927	1.815918	1.815909	1.815900	1.815891	1.815882	1.815873	1.815864	1.815855	1.815846	1.815837
1.791755	1.825223	1.826710	1.827313	1.827176	1.843623	1.843614	1.843605	1.843596	1.843587	1.843578	1.843569	1.843560	1.843551	1.843542	1.843533	1.843524	1.843515	1.843506	1.843497	1.843488
1.819546	1.852834	1.854321	1.854924	1.854787	1.871234	1.871225	1.871216	1.871207	1.871198	1.871189	1.871180	1.871171	1.871162	1.871153	1.871144	1.871135	1.871126	1.871117	1.871108	1.871099
1.847337	1.880985	1.882472	1.883075	1.882938	1.899385	1.899376	1.899367	1.899358	1.899349	1.899340	1.899331	1.899322	1.899313	1.899304	1.899295	1.899286	1.899277	1.899268	1.899259	1.899250
1.875128	1.908633	1.910120	1.910723	1.910586	1.927033	1.927024	1.927015	1.927006	1.926997	1.926988	1.926979	1.926970	1.926961	1.926952	1.926943	1.926934	1.926925	1.926916	1.926907	1.926898
1.902919	1.940567	1.942054	1.942657	1.942520	1.958967	1.958958	1.958949	1.958940	1.958931	1.958922	1.958913	1.958904	1.958895	1.958886	1.958877	1.958868	1.958859	1.958850		

5m-5m		12K		30		50		70		90	
0.875	0.811321	0.841921	0.839165	0.815094	0.818183	0.814654	0.815	0.815882	0.81781	0.819178	0.821646
0.791984	0.662475	0.706934	0.711517	0.715333	0.718353	0.720627	0.722146	0.723911	0.725914	0.728156	0.730634
0.694776	0.500073	0.593896	0.589175	0.593066	0.596967	0.600867	0.604767	0.608667	0.612567	0.616467	0.620367
0.597546	0.402009	0.495832	0.491111	0.494992	0.498873	0.502754	0.506635	0.510516	0.514397	0.518278	0.522159
0.442095	0.303653	0.331857	0.327136	0.331017	0.334898	0.338779	0.342660	0.346541	0.350422	0.354303	0.358184
0.3875	0.303653	0.331857	0.327136	0.331017	0.334898	0.338779	0.342660	0.346541	0.350422	0.354303	0.358184
0.300599	0.234151	0.243103	0.247782	0.251663	0.255544	0.259425	0.263306	0.267187	0.271068	0.274949	0.278830
0.240099	0.203872	0.210946	0.215625	0.220304	0.224983	0.229662	0.234341	0.239020	0.243699	0.248378	0.253057
0.205341	0.200995	0.205716	0.210437	0.215158	0.219879	0.224600	0.229321	0.234042	0.238763	0.243484	0.248205
0.205341	0.200995	0.205716	0.210437	0.215158	0.219879	0.224600	0.229321	0.234042	0.238763	0.243484	0.248205
0.205341	0.200995	0.205716	0.210437	0.215158	0.219879	0.224600	0.229321	0.234042	0.238763	0.243484	0.248205
0.188384	0.144537	0.14665	0.148767	0.150879	0.152991	0.155103	0.157215	0.159327	0.161439	0.163551	0.165663
0.168477	0.120318	0.1201	0.1201	0.1201	0.1201	0.1201	0.1201	0.1201	0.1201	0.1201	0.1201
0.149432	0.11562	0.115517	0.115412	0.115307	0.115202	0.115097	0.114992	0.114887	0.114782	0.114677	0.114572
0.123	0.110236	0.109823	0.109410	0.108997	0.108584	0.108171	0.107758	0.107345	0.106932	0.106519	0.106106
0.103354	0.0842105	0.0845714	0.0849323	0.0852932	0.0856541	0.0860150	0.0863759	0.0867368	0.0870977	0.0874586	0.0878195
0.080405	0.0708194	0.071428	0.072037	0.072646	0.073255	0.073864	0.074473	0.075082	0.075691	0.076300	0.076909
0.53023	0.569896	0.57143	0.57297	0.57451	0.57605	0.57759	0.57913	0.58067	0.58221	0.58375	0.58529
0.48373	0.50292	0.50297	0.50302	0.50307	0.50312	0.50317	0.50322	0.50327	0.50332	0.50337	0.50342
0.3404	0.30122	0.30357	0.30592	0.30827	0.31062	0.31297	0.31532	0.31767	0.32002	0.32237	0.32472
0.202023	0.20411	0.20549	0.20687	0.20825	0.20963	0.21101	0.21239	0.21377	0.21515	0.21653	0.21791
0.204451	0.24448	0.24586	0.24724	0.24862	0.25000	0.25138	0.25276	0.25414	0.25552	0.25690	0.25828
0.2475	0.21811	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215
0.2475	0.21811	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215
0.1625	0.174076	0.169813	0.165550	0.161287	0.157024	0.152761	0.148498	0.144235	0.139972	0.135709	0.131446
0.1625	0.174076	0.169813	0.165550	0.161287	0.157024	0.152761	0.148498	0.144235	0.139972	0.135709	0.131446
0.1625	0.174076	0.169813	0.165550	0.161287	0.157024	0.152761	0.148498	0.144235	0.139972	0.135709	0.131446
0.123	0.110236	0.109823	0.109410	0.108997	0.108584	0.108171	0.107758	0.107345	0.106932	0.106519	0.106106
0.103354	0.0842105	0.0845714	0.0849323	0.0852932	0.0856541	0.0860150	0.0863759	0.0867368	0.0870977	0.0874586	0.0878195
0.080405	0.0708194	0.071428	0.072037	0.072646	0.073255	0.073864	0.074473	0.075082	0.075691	0.076300	0.076909
0.53023	0.569896	0.57143	0.57297	0.57451	0.57605	0.57759	0.57913	0.58067	0.58221	0.58375	0.58529
0.48373	0.50292	0.50297	0.50302	0.50307	0.50312	0.50317	0.50322	0.50327	0.50332	0.50337	0.50342
0.3404	0.30122	0.30357	0.30592	0.30827	0.31062	0.31297	0.31532	0.31767	0.32002	0.32237	0.32472
0.202023	0.20411	0.20549	0.20687	0.20825	0.20963	0.21101	0.21239	0.21377	0.21515	0.21653	0.21791
0.204451	0.24448	0.24586	0.24724	0.24862	0.25000	0.25138	0.25276	0.25414	0.25552	0.25690	0.25828
0.2475	0.21811	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215
0.2475	0.21811	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215
0.1625	0.174076	0.169813	0.165550	0.161287	0.157024	0.152761	0.148498	0.144235	0.139972	0.135709	0.131446
0.1625	0.174076	0.169813	0.165550	0.161287	0.157024	0.152761	0.148498	0.144235	0.139972	0.135709	0.131446
0.1625	0.174076	0.169813	0.165550	0.161287	0.157024	0.152761	0.148498	0.144235	0.139972	0.135709	0.131446
0.123	0.110236	0.109823	0.109410	0.108997	0.108584	0.108171	0.107758	0.107345	0.106932	0.106519	0.106106
0.103354	0.0842105	0.0845714	0.0849323	0.0852932	0.0856541	0.0860150	0.0863759	0.0867368	0.0870977	0.0874586	0.0878195
0.080405	0.0708194	0.071428	0.072037	0.072646	0.073255	0.073864	0.074473	0.075082	0.075691	0.076300	0.076909
0.53023	0.569896	0.57143	0.57297	0.57451	0.57605	0.57759	0.57913	0.58067	0.58221	0.58375	0.58529
0.48373	0.50292	0.50297	0.50302	0.50307	0.50312	0.50317	0.50322	0.50327	0.50332	0.50337	0.50342
0.3404	0.30122	0.30357	0.30592	0.30827	0.31062	0.31297	0.31532	0.31767	0.32002	0.32237	0.32472
0.202023	0.20411	0.20549	0.20687	0.20825	0.20963	0.21101	0.21239	0.21377	0.21515	0.21653	0.21791
0.204451	0.24448	0.24586	0.24724	0.24862	0.25000	0.25138	0.25276	0.25414	0.25552	0.25690	0.25828
0.2475	0.21811	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215
0.2475	0.21811	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215
0.1625	0.174076	0.169813	0.165550	0.161287	0.157024	0.152761	0.148498	0.144235	0.139972	0.135709	0.131446
0.1625	0.174076	0.169813	0.165550	0.161287	0.157024	0.152761	0.148498	0.144235	0.139972	0.135709	0.131446
0.1625	0.174076	0.169813	0.165550	0.161287	0.157024	0.152761	0.148498	0.144235	0.139972	0.135709	0.131446
0.123	0.110236	0.109823	0.109410	0.108997	0.108584	0.108171	0.107758	0.107345	0.106932	0.106519	0.106106
0.103354	0.0842105	0.0845714	0.0849323	0.0852932	0.0856541	0.0860150	0.0863759	0.0867368	0.0870977	0.0874586	0.0878195
0.080405	0.0708194	0.071428	0.072037	0.072646	0.073255	0.073864	0.074473	0.075082	0.075691	0.076300	0.076909
0.53023	0.569896	0.57143	0.57297	0.57451	0.57605	0.57759	0.57913	0.58067	0.58221	0.58375	0.58529
0.48373	0.50292	0.50297	0.50302	0.50307	0.50312	0.50317	0.50322	0.50327	0.50332	0.50337	0.50342
0.3404	0.30122	0.30357	0.30592	0.30827	0.31062	0.31297	0.31532	0.31767	0.32002	0.32237	0.32472
0.202023	0.20411	0.20549	0.20687	0.20825	0.20963	0.21101	0.21239	0.21377	0.21515	0.21653	0.21791
0.204451	0.24448	0.24586	0.24724	0.24862	0.25000	0.25138	0.25276	0.25414	0.25552	0.25690	0.25828
0.2475	0.21811	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215
0.2475	0.21811	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215	0.211215
0.1625	0.174076	0.169813	0.165550	0.161287	0.157024	0.152761	0.148498	0.144235	0.139972	0.135709	0.131446
0.1625	0.174076	0.169813	0.165550	0.161287	0.157024	0.152761	0.148498	0.144235	0.139972	0.135709	0.131446
0.1625	0.174076	0.169813	0.165550	0.161287	0.157024	0.152761	0.148498	0.144235	0.139972	0.135709	0.131446
0.123	0.110236	0.109823	0.109410	0.108997	0.108584	0.108171	0.107758	0.107345	0.106932	0.106519	0.106106
0.103354	0.0842105	0.0845714	0.0849323	0.0852932	0.0856541	0.0860150	0.0863759	0.0867368	0.0870977	0.0874586	0.0878195
0.080405	0.0708194	0.071428	0.072037	0.072646	0.073255	0.073864	0.074473	0.075082	0.075691	0.076300	0.076909
0.53023	0.569896	0.57143	0.57297	0.57451	0.57605	0.57759	0.57913	0.58067	0.58221	0.58375	0.58529
0.48373	0.50292	0.50297	0.50302	0.50307	0.50312	0.50317	0.50322	0.50327	0.50332	0.50337	0.50342
0.3404	0.30122	0.30357	0.30592	0.30827	0.31062						

APPENDIX B

7m-3m		7m-4m		7m-5m		7m-6m		7m-7m		7m-7m	
10	30	50	70	90	10	30	50	70	90	10	30
0.85880	0.84132	0.82352	0.81194	0.80172	0.85743	0.84109	0.82452	0.81062	0.80224	0.85743	0.84109
0.77778	0.74301	0.75683	0.77083	0.78517	0.78714	0.74771	0.71278	0.71927	0.73695	0.78714	0.74771
0.68151	0.65135	0.63585	0.62781	0.62087	0.65743	0.64732	0.61791	0.60739	0.59780	0.65743	0.64732
0.51111	0.47830	0.45322	0.43487	0.42465	0.51111	0.48222	0.45922	0.44288	0.43487	0.51111	0.48222
0.34444	0.31411	0.29508	0.28159	0.27281	0.42574	0.43155	0.40842	0.40317	0.40174	0.42574	0.43155
0.24444	0.22409	0.20908	0.19944	0.19401	0.34257	0.33407	0.31626	0.30674	0.30222	0.34257	0.33407
0.16667	0.15682	0.14768	0.14053	0.13524	0.26428	0.26211	0.25023	0.24267	0.23724	0.26428	0.26211
0.11111	0.10237	0.09423	0.08755	0.08226	0.18428	0.18205	0.17028	0.16263	0.15720	0.18428	0.18205
0.06667	0.06346	0.06045	0.05744	0.05443	0.11428	0.11205	0.10626	0.10193	0.09860	0.11428	0.11205
0.02222	0.02148	0.02074	0.01999	0.01924	0.06428	0.06305	0.06026	0.05803	0.05680	0.06428	0.06305
0.01428	0.01374	0.01320	0.01266	0.01212	0.03428	0.03374	0.03220	0.03166	0.03112	0.03428	0.03374
0.00889	0.00860	0.00831	0.00802	0.00773	0.01928	0.01905	0.01826	0.01762	0.01708	0.01928	0.01905
0.00556	0.00537	0.00518	0.00500	0.00481	0.01128	0.01115	0.01076	0.01037	0.01000	0.01128	0.01115
0.00333	0.00324	0.00315	0.00306	0.00297	0.00628	0.00615	0.00596	0.00577	0.00558	0.00628	0.00615
0.00222	0.00213	0.00204	0.00195	0.00186	0.00328	0.00315	0.00306	0.00297	0.00288	0.00328	0.00315
0.00143	0.00134	0.00125	0.00116	0.00107	0.00174	0.00165	0.00156	0.00147	0.00138	0.00174	0.00165
0.00089	0.00080	0.00071	0.00062	0.00053	0.00094	0.00085	0.00076	0.00067	0.00058	0.00094	0.00085
0.00056	0.00047	0.00038	0.00029	0.00020	0.00044	0.00035	0.00026	0.00017	0.00008	0.00044	0.00035
0.00033	0.00024	0.00015	0.00006	0.00000	0.00014	0.00005	0.00000	0.00000	0.00000	0.00014	0.00005
0.00022	0.00013	0.00004	0.00000	0.00000	0.00004	0.00000	0.00000	0.00000	0.00000	0.00004	0.00000
0.00014	0.00005	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00008	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00005	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00003	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00002	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

B - 4 FRONTLIGHT LUMINAIRE ARRANGEMENT - 7m mounting height Normalized Illuminance Values

APPENDIX C

UPLIGHT LUMINAIRE ARRANGEMENT **C – 1**

Characteristic curve

FRONTLIGHT LUMINAIRE ARRANGEMENT **C – 2**

3m mounting height Characteristic curve

FRONTLIGHT LUMINAIRE ARRANGEMENT **C – 3**

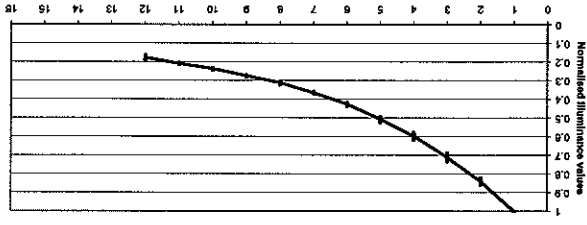
5m mounting height Characteristic curve

FRONTLIGHT LUMINAIRE ARRANGEMENT **C – 4**

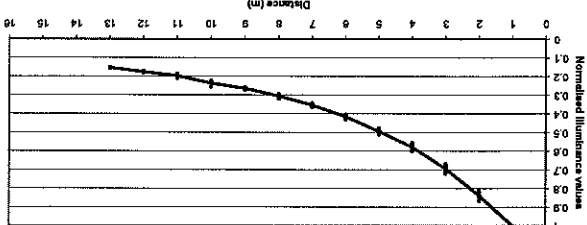
7m mounting height Characteristic curve

C-1 UPLIGHT LUMINAIRE ARRANGEMENT - Characteristic curve

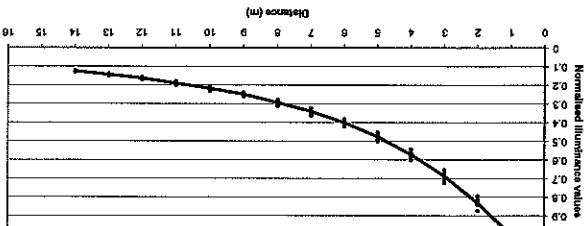
Distance	Max	Min	Average	% Deviation
1	0.85714286	0.85714286	0.85714286	0.00
2	0.73078923	0.6894058	0.709597514	2.50
3	0.617202126	0.57822308	0.59672177	3.25
4	0.521732913	0.49243508	0.507020908	2.81
5	0.43714286	0.41666667	0.426190476	2.19
6	0.3742857	0.35888887	0.365159636	1.89
7	0.32142857	0.3032033	0.312223437	2.88
8	0.27857143	0.26811594	0.273343665	1.89
9	0.24285714	0.23078923	0.236813187	2.49
10	0.21428571	0.20410007	0.209229218	2.38
11	0.1895952	0.18440281	0.175078666	6.03



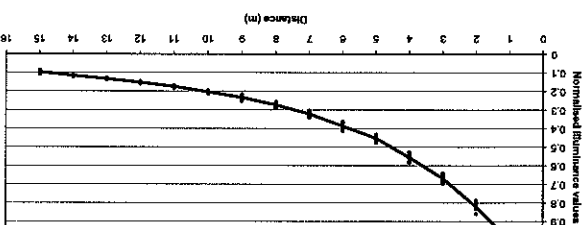
Distance	Max	Min	Average	% Deviation
1	0.85714286	0.85714286	0.85714286	0.00
2	0.73078923	0.6894058	0.709597514	2.50
3	0.617202126	0.57822308	0.59672177	3.25
4	0.521732913	0.49243508	0.507020908	2.81
5	0.43714286	0.41666667	0.426190476	2.19
6	0.3742857	0.35888887	0.365159636	1.89
7	0.32142857	0.3032033	0.312223437	2.88
8	0.27857143	0.26811594	0.273343665	1.89
9	0.24285714	0.23078923	0.236813187	2.49
10	0.21428571	0.20410007	0.209229218	2.38
11	0.1895952	0.18440281	0.175078666	6.03
12	0.16181818	0.15714286	0.15930244	3.55
13	0.1404908	0.13580244	0.13659621	5.59
14	0.12314148	0.11890244	0.12099621	8.19
15	0.1094476	0.10440281	0.1069231	3.91
16	0.09710203	0.09243508	0.0947913	2.99
17	0.0864854	0.08114883	0.0837913	2.81
18	0.07710203	0.07243508	0.0747913	3.23
19	0.0689558	0.06424242	0.0665987	3.70
20	0.06181818	0.05822308	0.0599091	3.59
21	0.0555556	0.0522308	0.0538833	4.13
22	0.04908091	0.04624242	0.0476617	3.70
23	0.42857143	0.409854	0.419114883	3.23
24	0.3835396	0.364854	0.3742013	3.70
25	0.3410203	0.322308	0.331658	3.59
26	0.3009091	0.2822308	0.291558	3.16
27	0.2622308	0.243508	0.252883	2.99
28	0.2242857	0.2055556	0.2149203	2.81
29	0.1872727	0.1685556	0.177913	2.81
30	0.15181818	0.1328833	0.142354	3.23
31	0.1172727	0.1015556	0.109413	3.70
32	0.0835396	0.0722308	0.0778833	3.59
33	0.0509091	0.04024242	0.0455556	4.13
34	0.01908091	0.00822308	0.013658	3.70
35	0.00822308	0.00722308	0.007713	3.59
36	0.00722308	0.00622308	0.006713	3.16
37	0.00622308	0.00522308	0.005713	2.99
38	0.00522308	0.00422308	0.004713	2.81
39	0.00422308	0.00322308	0.003713	2.19
40	0.00322308	0.00222308	0.002713	1.89
41	0.00222308	0.00122308	0.001713	1.89
42	0.00122308	0.00022308	0.000713	1.89
43	0.00022308	0.00022308	0.00022308	0.00



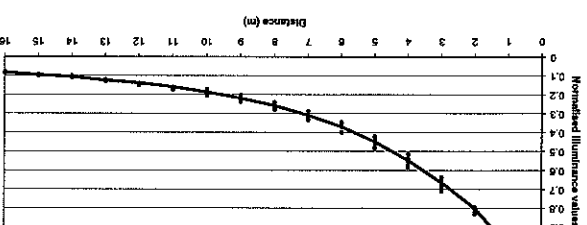
Distance	Max	Min	Average	% Deviation
1	0.85714286	0.85714286	0.85714286	0.00
2	0.73078923	0.6894058	0.709597514	2.50
3	0.617202126	0.57822308	0.59672177	3.25
4	0.521732913	0.49243508	0.507020908	2.81
5	0.43714286	0.41666667	0.426190476	2.19
6	0.3742857	0.35888887	0.365159636	1.89
7	0.32142857	0.3032033	0.312223437	2.88
8	0.27857143	0.26811594	0.273343665	1.89
9	0.24285714	0.23078923	0.236813187	2.49
10	0.21428571	0.20410007	0.209229218	2.38
11	0.1895952	0.18440281	0.175078666	6.03
12	0.16181818	0.15714286	0.15930244	3.55
13	0.1404908	0.13580244	0.13659621	5.59
14	0.12314148	0.11890244	0.12099621	8.19
15	0.1094476	0.10440281	0.1069231	3.91
16	0.09710203	0.09243508	0.0947913	2.99
17	0.0864854	0.08114883	0.0837913	2.81
18	0.07710203	0.07243508	0.0747913	3.23
19	0.0689558	0.06424242	0.0665987	3.70
20	0.06181818	0.05822308	0.0599091	3.59
21	0.0555556	0.0522308	0.0538833	4.13
22	0.04908091	0.04624242	0.0476617	3.70
23	0.0435396	0.04024242	0.042354	3.23
24	0.03809091	0.03522308	0.036617	3.70
25	0.0326413	0.029854	0.031248	3.59
26	0.0271926	0.02440281	0.025798	4.13
27	0.0217439	0.01924242	0.020494	3.70
28	0.0162952	0.01404242	0.015168	3.23
29	0.0108465	0.00864242	0.009744	3.70
30	0.0053968	0.0031926	0.004294	3.23
31	0.00022308	0.00022308	0.00022308	0.00



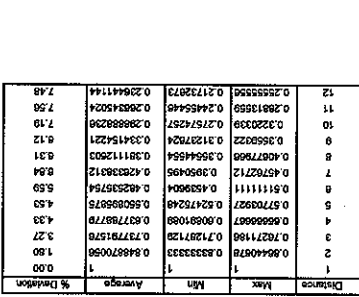
Distance	Max	Min	Average	% Deviation
1	0.85714286	0.85714286	0.85714286	0.00
2	0.73078923	0.6894058	0.709597514	2.50
3	0.617202126	0.57822308	0.59672177	3.25
4	0.521732913	0.49243508	0.507020908	2.81
5	0.43714286	0.41666667	0.426190476	2.19
6	0.3742857	0.35888887	0.365159636	1.89
7	0.32142857	0.3032033	0.312223437	2.88
8	0.27857143	0.26811594	0.273343665	1.89
9	0.24285714	0.23078923	0.236813187	2.49
10	0.21428571	0.20410007	0.209229218	2.38
11	0.1895952	0.18440281	0.175078666	6.03
12	0.16181818	0.15714286	0.15930244	3.55
13	0.1404908	0.13580244	0.13659621	5.59
14	0.12314148	0.11890244	0.12099621	8.19
15	0.1094476	0.10440281	0.1069231	3.91
16	0.09710203	0.09243508	0.0947913	2.99
17	0.0864854	0.08114883	0.0837913	2.81
18	0.07710203	0.07243508	0.0747913	3.23
19	0.0689558	0.06424242	0.0665987	3.70
20	0.06181818	0.05822308	0.0599091	3.59
21	0.0555556	0.0522308	0.0538833	4.13
22	0.04908091	0.04624242	0.0476617	3.70
23	0.0435396	0.04024242	0.042354	3.23
24	0.03809091	0.03522308	0.036617	3.70
25	0.0326413	0.029854	0.031248	3.59
26	0.0271926	0.02440281	0.025798	4.13
27	0.0217439	0.01924242	0.020494	3.70
28	0.0162952	0.01404242	0.015168	3.23
29	0.0108465	0.00864242	0.009744	3.70
30	0.0053968	0.0031926	0.004294	3.23
31	0.00022308	0.00022308	0.00022308	0.00



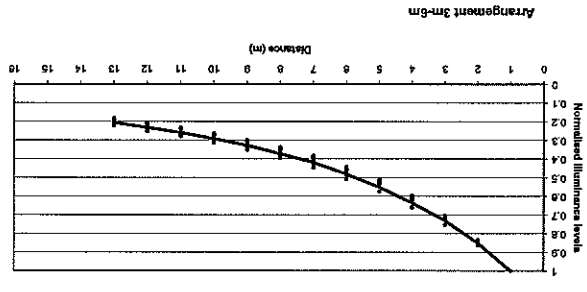
Distance	Max	Min	Average	% Deviation
1	0.85714286	0.85714286	0.85714286	0.00
2	0.73078923	0.6894058	0.709597514	2.50
3	0.617202126	0.57822308	0.59672177	3.25
4	0.521732913	0.49243508	0.507020908	2.81
5	0.43714286	0.41666667	0.426190476	2.19
6	0.3742857	0.35888887	0.365159636	1.89
7	0.32142857	0.3032033	0.312223437	2.88
8	0.27857143	0.26811594	0.273343665	1.89
9	0.24285714	0.23078923	0.236813187	2.49
10	0.21428571	0.20410007	0.209229218	2.38
11	0.1895952	0.18440281	0.175078666	6.03
12	0.16181818	0.15714286	0.15930244	3.55
13	0.1404908	0.13580244	0.13659621	5.59
14	0.12314148	0.11890244	0.12099621	8.19
15	0.1094476	0.10440281	0.1069231	3.91
16	0.09710203	0.09243508	0.0947913	2.99
17	0.0864854	0.08114883	0.0837913	2.81
18	0.07710203	0.07243508	0.0747913	3.23
19	0.0689558	0.06424242	0.0665987	3.70
20	0.06181818	0.05822308	0.0599091	3.59
21	0.0555556	0.0522308	0.0538833	4.13
22	0.04908091	0.04624242	0.0476617	3.70
23	0.0435396	0.04024242	0.042354	3.23
24	0.03809091	0.03522308	0.036617	3.70
25	0.0326413	0.029854	0.031248	3.59
26	0.0271926	0.02440281	0.025798	4.13
27	0.0217439	0.01924242	0.020494	3.70
28	0.0162952	0.01404242	0.015168	3.23
29	0.0108465	0.00864242	0.009744	3.70
30	0.0053968	0.0031926	0.004294	3.23
31	0.00022308	0.00022308	0.00022308	0.00



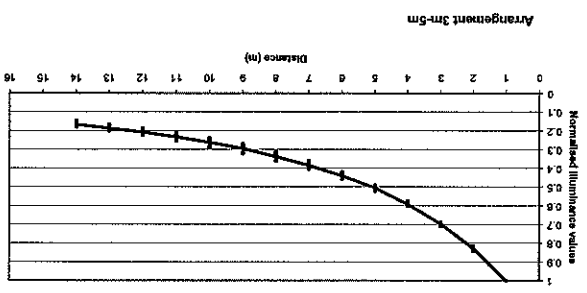
C-2 FRONTLIGHT: LUMINAIRE ARRANGEMENT - 3m mounting height Characteristic curve



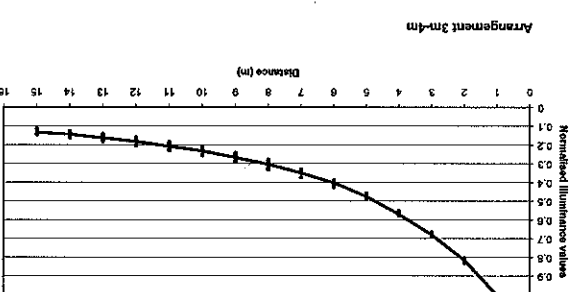
Distance	Max	Min	Average	% Deviation
1	0.89440878	0.83333333	0.86870058	1.80
2	0.70271198	0.73791578	0.73791578	3.27
3	0.66666667	0.60691088	0.63778978	4.33
4	0.57703927	0.52475248	0.55098875	4.53
5	0.51111111	0.4539804	0.48253754	6.59
6	0.45702712	0.3950495	0.42638312	8.84
7	0.40877868	0.35544554	0.381112803	9.31
8	0.3659322	0.31297824	0.334154221	9.12
9	0.3282039	0.27574257	0.29888228	7.58
10	0.29213559	0.24455446	0.268345024	7.48
11	0.25855556	0.21732973	0.236441144	7.48



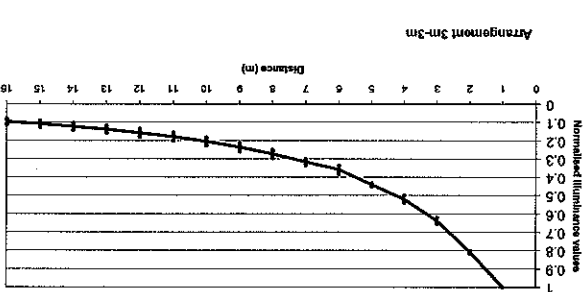
Distance	Max	Min	Average	% Deviation
1	0.87012887	0.850318172	0.85318172	0.00
2	0.78571428	0.70250986	0.744111823	8.29
3	0.67523468	0.5948208	0.635153377	8.59
4	0.5925714	0.5085657	0.55066888	7.08
5	0.5214257	0.4421875	0.48180838	7.00
6	0.45714286	0.38020833	0.418875595	7.90
7	0.40714286	0.33820072	0.371871787	8.71
8	0.35714286	0.2983871	0.327784877	8.23
9	0.3124257	0.2609877	0.291192878	8.23
10	0.27142857	0.23142857	0.25142857	8.23
11	0.23142857	0.20483871	0.21813345	8.50
12	0.19142857	0.17483871	0.18313345	10.17
13	0.15142857	0.14483871	0.14813345	10.31



Distance	Max	Min	Average	% Deviation
1	0.87878788	0.82105283	0.84992036	1.00
2	0.78787879	0.68911881	0.7385038	0.85
3	0.68911881	0.5770701	0.633094456	6.87
4	0.5985986	0.4888882	0.54374344	8.91
5	0.51818182	0.4142105	0.466196163	9.30
6	0.44444444	0.3605282	0.40248633	10.34
7	0.38095238	0.3102048	0.3455786	10.83
8	0.32380952	0.27105283	0.297431176	11.87
9	0.27272727	0.23877551	0.25575139	11.83
10	0.22727273	0.19446467	0.2108687	11.23
11	0.18787879	0.15111111	0.16949495	11.04
12	0.15238095	0.11888889	0.13563528	12.78
13	0.12105283	0.09483871	0.10794577	13.36
14	0.09483871	0.07483871	0.08483871	13.36

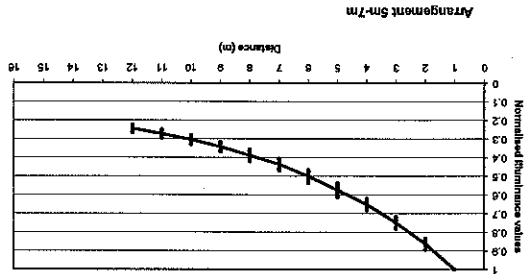


Distance	Max	Min	Average	% Deviation
1	0.82989432	0.798875	0.814384935	1.98
2	0.682135	0.6282135	0.65517425	2.33
3	0.55050505	0.5050505	0.52777778	6.02
4	0.4325	0.382884	0.407692	10.40
5	0.325	0.285778	0.305692	13.52
6	0.2325	0.20759133	0.22007083	14.34
7	0.1525	0.1385778	0.1455415	15.52
8	0.0825	0.075928	0.079214	15.82
9	0.0325	0.030300	0.031400	15.82
10	0.0025	0.002500	0.002500	17.06
11	0.0025	0.002500	0.002500	17.06
12	0.0025	0.002500	0.002500	17.06
13	0.0025	0.002500	0.002500	17.06
14	0.0025	0.002500	0.002500	17.06
15	0.0025	0.002500	0.002500	17.06

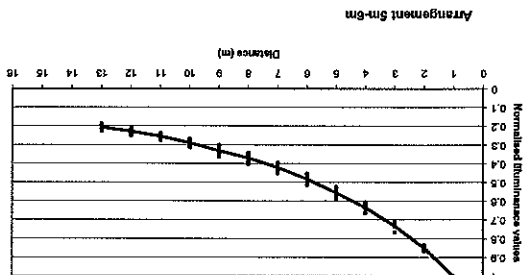


Distance	Max	Min	Average	% Deviation
1	0.81888889	0.7844581	0.8016735	1.25
2	0.65508889	0.62015504	0.637621964	2.67
3	0.54005235	0.48878931	0.514420838	3.82
4	0.4485752	0.4044519	0.426513559	5.78
5	0.3785281	0.3391731	0.3588506	6.78
6	0.328502	0.2907885	0.30964525	6.25
7	0.2852538	0.2498785	0.26756615	7.84
8	0.2452538	0.21259061	0.228922222	8.82
9	0.2085052	0.18187028	0.19518775	9.84
10	0.1741935	0.15187028	0.163031907	10.87
11	0.141935	0.1241383	0.133036914	11.91
12	0.111935	0.09817028	0.10505281	12.95
13	0.0841935	0.0741383	0.079165914	14.00
14	0.0581935	0.0521383	0.055165914	15.05
15	0.0341935	0.0301383	0.032165914	15.51

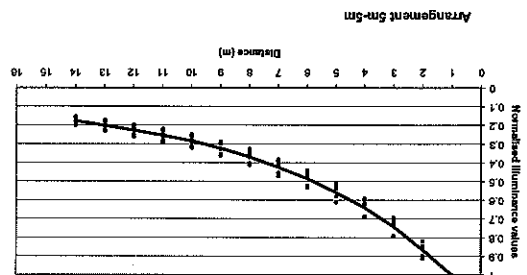
C - 3 FRONTLIGHT: LUMINAIRE ARRANGEMENT - 5m mounting height Characteristic curve



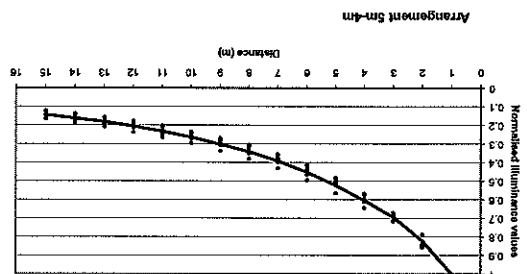
Distance	Max	Min	Average	% Deviation
1	1	1	1	0.00
2	0.85090909	0.83070593	0.84070006	3.38
3	0.78181818	0.7158633	0.74870258	4.24
4	0.68181818	0.6181731	0.65097745	4.56
5	0.61111111	0.5359148	0.573511357	5.15
6	0.53939394	0.46518337	0.500778303	6.49
7	0.46909091	0.40502263	0.43844749	6.60
8	0.41818182	0.35707763	0.387629722	7.31
9	0.36868687	0.3132511	0.34198669	6.97
10	0.32786869	0.27866526	0.30317056	7.36
11	0.29508187	0.24684421	0.271883088	7.66
12	0.26389393	0.22171059	0.24279445	7.95



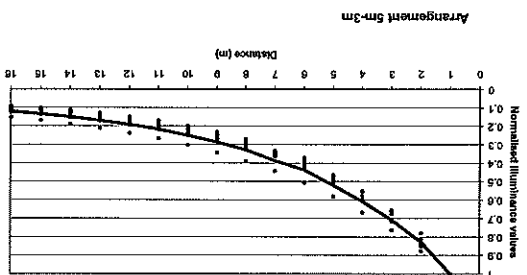
Distance	Max	Min	Average	% Deviation
1	1	1	1	0.00
2	0.65699997	0.6205128	0.64058974	2.00
3	0.7025	0.7025941	0.72523051	3.33
4	0.6625	0.60512821	0.63814109	4.33
5	0.5975	0.52079922	0.55928462	5.48
6	0.5125	0.4525941	0.48252051	5.55
7	0.45	0.38134415	0.42077077	6.62
8	0.4	0.3402439	0.370121951	7.47
9	0.3625	0.2999939	0.331046748	6.68
10	0.3125	0.2646415	0.28847073	7.66
11	0.2725	0.2345285	0.25477423	7.56
12	0.235	0.2025399	0.22026293	8.28
13	0.225	0.1861099	0.2055947	8.64



Distance	Max	Min	Average	% Deviation
1	1	1	1	0.00
2	0.81	0.81818182	0.86496969	5.04
3	0.79	0.69181818	0.740086694	6.32
4	0.69	0.5818596	0.636577962	7.45
5	0.61	0.50642292	0.558211008	6.49
6	0.53	0.43743017	0.48715084	6.73
7	0.47	0.3781651	0.42468257	6.99
8	0.41	0.32528189	0.367445814	10.33
9	0.36	0.2844368	0.322217886	10.50
10	0.32	0.24791887	0.28395333	11.28
11	0.28	0.2145236	0.25422818	12.34
12	0.26	0.1945236	0.22972210	12.80
13	0.23	0.1745236	0.20990148	12.82
14	0.2	0.1532597	0.17662852	11.69

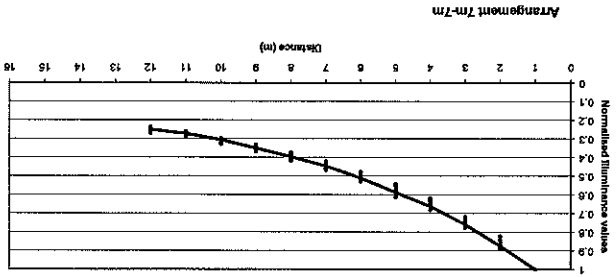


Distance	Max	Min	Average	% Deviation
1	1	1	1	0.00
2	0.85714286	0.78571429	0.821428571	4.17
3	0.773913	0.66840052	0.69296912	3.41
4	0.64285714	0.5556987	0.604293422	6.00
5	0.56428571	0.46114434	0.525716029	7.37
6	0.49285714	0.41952326	0.4518021	8.31
7	0.42857143	0.35370911	0.39119377	6.75
8	0.37857143	0.30429129	0.341431356	9.01
9	0.33857143	0.28777149	0.307182866	10.10
10	0.29857143	0.23939484	0.26896041	10.09
11	0.26428571	0.20039461	0.23230102	12.10
12	0.2371429	0.17542735	0.20570818	12.78
13	0.20714286	0.1491453	0.18128864	13.01
14	0.1871429	0.1295974	0.16186512	13.10
15	0.16428571	0.1056736	0.14248545	13.31

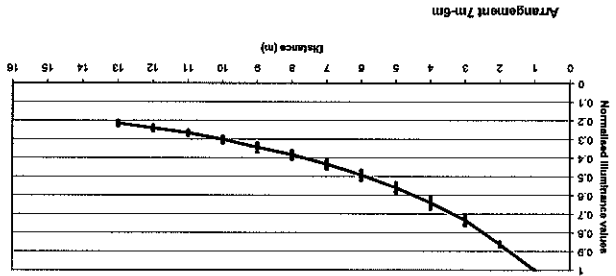


Distance	Max	Min	Average	% Deviation
1	1	1	1	0.00
2	0.875	0.77840909	0.82704545	5.62
3	0.78181818	0.65340909	0.70798364	7.09
4	0.69477273	0.55	0.60788304	8.63
5	0.57554545	0.4620704	0.50781246	10.14
6	0.50454545	0.3981818	0.439301818	12.46
7	0.44204545	0.3318955	0.386971003	15.29
8	0.3875	0.29802409	0.329297045	16.29
9	0.34090909	0.23965991	0.2859375	16.13
10	0.30058182	0.19772727	0.248147727	17.11
11	0.26540909	0.16875	0.21704545	18.20
12	0.23527273	0.14744318	0.191335227	18.66
13	0.20860909	0.12872727	0.16604081	19.16
14	0.18939394	0.11352227	0.146657065	19.58
15	0.16947727	0.1002509	0.13330862	19.88
16	0.1493182	0.0882045	0.11978136	20.25

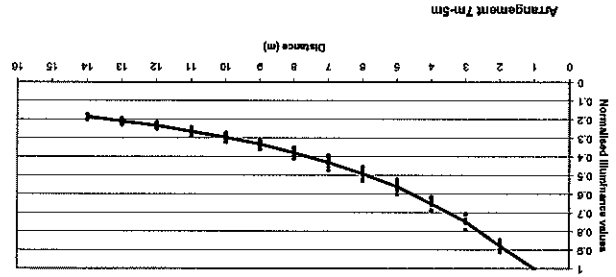
C - 4 FRONTLIGHT: LUMINAIRE ARRANGEMENT - 7m mounting height Characteristic curve



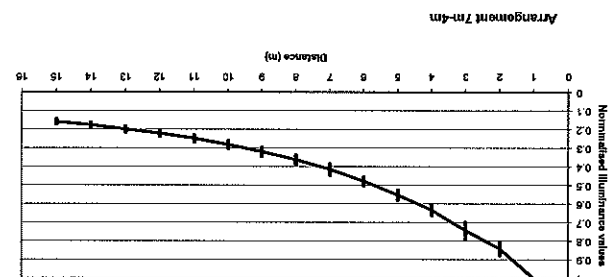
Distance	Max	Min	Average	% Deviation
1	1	1	1	0.00
2	0.83333333	0.8524825	0.8742876	1.02
3	0.76666667	0.7573065	0.768218658	0.87
4	0.69999999	0.6902637	0.691347616	0.80
5	0.6	0.57440589	0.597234043	2.13
6	0.51666667	0.5035461	0.510106933	1.27
7	0.43333333	0.42553191	0.4400926281	4.41
8	0.35	0.3788852	0.358278598	4.89
9	0.26666667	0.3181488	0.34825078	4.74
10	0.18333333	0.25971493	0.305319146	3.89
11	0.28333333	0.28209874	0.272895035	3.75
12	0.26666667	0.23478177	0.25070923	5.88



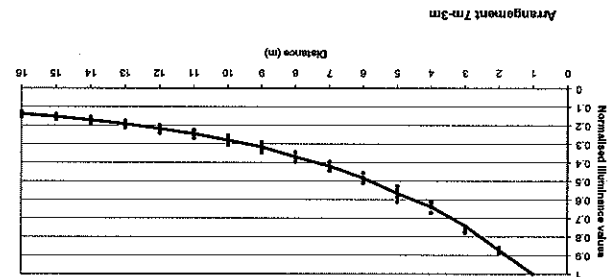
Distance	Max	Min	Average	% Deviation
1	1	1	1	0.00
2	0.875	0.854585	0.86274769	1.45
3	0.75449808	0.7022909	0.73081874	3.77
4	0.67088808	0.6084354	0.63984807	4.62
5	0.5882209	0.5382306	0.558420978	4.57
6	0.5188734	0.4652464	0.492113962	5.18
7	0.45333333	0.4058815	0.433444742	5.43
8	0.3908829	0.3488905	0.38247817	5.58
9	0.3308829	0.31871958	0.324262583	6.88
10	0.2708829	0.2828877	0.28177164	5.33
11	0.2108829	0.2181746	0.23578465	4.91
12	0.2518829	0.22519369	0.23919123	5.54
13	0.2328829	0.2278491	0.24492923	6.94



Distance	Max	Min	Average	% Deviation
1	1	1	1	0.00
2	0.841	0.8455985	0.87779923	3.54
3	0.719	0.7058254	0.747819281	5.33
4	0.618	0.6138229	0.651706117	6.54
5	0.518	0.5180394	0.53889887	6.72
6	0.433	0.4319879	0.460878887	7.36
7	0.35	0.3519598	0.402978888	8.30
8	0.27	0.2648489	0.317922348	7.50
9	0.19	0.20010391	0.233331855	7.40
10	0.11	0.1189388	0.257541919	7.58
11	0.03	0.0407812	0.28531081	8.40
12	0.25	0.2141439	0.232072652	7.17
13	0.27	0.19713914	0.21051568	8.44
14	0.2	0.1705945	0.18528226	7.87



Distance	Max	Min	Average	% Deviation
1	1	1	1	0.00
2	0.87360565	0.8092329	0.840820821	3.74
3	0.78577425	0.6988283	0.74288808	5.55
4	0.69522205	0.6058235	0.632587194	4.35
5	0.57892308	0.4559239	0.551402715	4.42
6	0.44285714	0.386889	0.413773059	6.57
7	0.38577429	0.33792057	0.36161743	6.27
8	0.34285714	0.29817225	0.319514698	6.81
9	0.3	0.26124402	0.28082201	6.46
10	0.26584682	0.23110048	0.248242547	6.46
11	0.23571429	0.2049812	0.220290771	6.54
12	0.21428571	0.1822965	0.198291883	7.46
13	0.19846154	0.14297843	0.175570482	6.84
14	0.17142857	0.14408222	0.157760385	7.87



Distance	Max	Min	Average	% Deviation
1	1	1	1	0.00
2	0.8823077	0.85714286	0.873188813	1.80
3	0.7777778	0.7022887	0.74033324	4.61
4	0.67078923	0.6054894	0.638208883	4.85
5	0.61111111	0.5240589	0.568	7.38
6	0.51111111	0.4328287	0.482018991	5.69
7	0.44444444	0.39354839	0.41886416	5.73
8	0.39444444	0.3416547	0.368804826	6.50
9	0.34444444	0.29708808	0.315785259	6.33
10	0.30555556	0.25165583	0.278605592	8.82
11	0.26666667	0.22152318	0.24404823	8.46
12	0.22888889	0.1865538	0.217292727	9.04
13	0.20228889	0.1737881	0.191	9.04
14	0.18888889	0.1587931	0.17431199	8.21
15	0.16666667	0.13741722	0.152041943	8.77
16	0.15	0.12275281	0.139378404	9.08

APPENDIX D

UPLIGHT: 0m – 3m arrangement	D – 1
UPLIGHT: 0m – 4m arrangement	D – 2
UPLIGHT: 0m – 5m arrangement	D – 3
UPLIGHT: 0m – 6m arrangement	D – 4
UPLIGHT: 0m – 7m arrangement	D – 5
FRONTLIGHT: 3m – 3m arrangement	D – 6
FRONTLIGHT: 3m – 4m arrangement	D – 7
FRONTLIGHT: 3m – 5m arrangement	D – 8
FRONTLIGHT: 3m – 6m arrangement	D – 9
FRONTLIGHT: 3m – 7m arrangement	D – 10
FRONTLIGHT: 5m – 3m arrangement	D – 11
FRONTLIGHT: 5m – 4m arrangement	D – 12
FRONTLIGHT: 5m – 5m arrangement	D – 13

FRONTLIGHT: 5m – 6m arrangement	D – 14
FRONTLIGHT: 5m – 7m arrangement	D – 15
FRONTLIGHT: 7m – 3m arrangement	D – 16
FRONTLIGHT: 7m – 4m arrangement	D – 17
FRONTLIGHT: 7m – 5m arrangement	D – 18
FRONTLIGHT: 7m – 6m arrangement	D – 19
FRONTLIGHT: 7m – 7m arrangement	D – 20

APPENDIX D

Legend

- A Illuminance values calculated by lighting software
- B Estimated Illuminance value from the reference indicated in bolds = (A x 35000/Lumen) x Surface reflectance factor
- C Difference in % between A and B values = (A - B / A) x 100
- D Difference in Lux of the calculated values and the estimated values = A - B

10	12K				30				70				90						
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D			
0.81	0.80	-6.17	-0.05	2.4	2.50	-7.50	-0.18	4	4.30	-7.60	-0.13	6.9	6.02	-0.23	-0.12	7.7	7.74	-0.04	
0.87	0.89	-2.49	-0.02	2	2.05	-3.00	-0.06	3.3	3.43	-4.04	-0.13	6.9	6.02	-0.23	-0.12	7.7	7.74	-0.04	
0.95	0.95	0.00	0.00	1.7	1.64	3.29	0.00	2.8	2.74	2.14	0.00	3.9	3.84	1.64	0.06	5	4.93	1.35	0.07
1.00	1.00	0.00	0.00	1.1	1.05	4.89	0.07	2.3	2.22	3.48	0.08	3.2	3.11	2.88	0.09	4.1	4.00	2.84	0.10
0.93	0.96	6.84	0.03	1.1	1.05	4.89	0.07	2.3	2.22	3.48	0.08	3.2	3.11	2.88	0.09	4.1	4.00	2.84	0.10
0.98	0.98	0.00	0.00	0.55	0.55	0.00	0.00	1.5	1.42	6.38	0.00	2.7	2.54	5.00	0.16	2.8	2.68	4.21	0.12
0.92	0.92	0.00	0.00	0.8	0.80	0.00	0.00	1.3	1.33	-0.05	-0.03	1.5	1.48	2.25	0.04	2	2.01	-0.50	-0.01
0.82	0.82	-1.82	0.00	0.07	0.67	0.00	0.00	1.1	1.12	-1.62	-0.02	1.6	1.56	2.29	0.04	2	2.01	-0.50	-0.01
0.19	0.19	0.35	0.00	0.37	0.37	0.35	0.00	0.85	0.85	0.35	0.00	1.1	1.13	-0.95	-0.03	1.7	1.70	-0.24	0.05
0.25	0.25	0.00	0.00	0.43	0.48	1.32	0.01	0.81	0.81	0.41	0.00	1.1	1.13	-0.67	-0.01	1.2	1.25	-0.50	-0.05
0.14	0.14	0.68	0.00	0.38	0.38	0.00	0.00	0.86	0.70	0.97	0.00	0.97	0.88	-0.65	-0.01	1.1	1.07	2.36	0.00
0.12	0.12	0.66	0.00	0.38	0.38	0.00	0.00	0.86	0.70	0.97	0.00	0.97	0.88	-0.65	-0.01	1.1	1.07	2.36	0.00
0.11	0.11	0.66	0.00	0.38	0.38	0.00	0.00	0.86	0.70	0.97	0.00	0.97	0.88	-0.65	-0.01	1.1	1.07	2.36	0.00
0.10	0.10	-3.33	0.00	0.31	0.31	0.00	0.00	0.62	0.52	0.64	0.00	0.73	0.72	0.00	0.00	0.81	0.81	0.00	0.00
0.09	0.09	0.00	0.00	0.27	0.27	0.00	0.00	0.46	0.40	0.40	0.00	0.63	0.63	-0.57	-0.01	0.61	0.61	-0.66	0.00
0.09	0.09	-0.42	0.00	0.24	0.24	0.83	0.00	0.4	0.40	0.83	0.00	0.63	0.63	-0.57	-0.01	0.61	0.61	-0.66	0.00
0.08	0.07	-0.49	0.00	0.21	0.21	0.95	0.00	0.25	0.25	0.95	0.00	0.49	0.49	0.95	0.00	0.63	0.62	0.85	0.01
21K																			
1.6	1.50	-6.11	-0.08	4.4	4.73	-7.50	-0.33	9.3	7.50	15.23	1.42	11.1	11.04	0.57	0.06	14.2	14.10	0.07	0.01
1.2	1.20	-0.00	0.00	3.7	3.76	-2.67	-0.08	7.4	6.25	14.84	1.11	6.74	8.81	-0.83	-0.07	11.3	11.33	-0.27	-0.03
0.84	0.84	-0.47	0.00	3	3.01	-0.47	-0.01	5.9	5.92	14.96	0.08	7.03	7.03	-0.04	0.00	9.05	9.04	0.09	0.01
0.85	0.87	3.48	0.02	2.1	2.00	4.42	0.05	4.5	4.07	15.21	0.73	5.7	5.70	0.04	0.00	7.34	7.30	0.19	0.01
0.89	0.95	6.60	0.03	1.7	1.64	3.99	0.05	3.4	2.23	10.65	0.07	4.05	3.82	0.57	0.09	6	5.00	0.85	0.00
0.49	0.49	0.73	0.00	1.5	1.48	2.71	0.04	2.9	2.43	10.13	0.47	3.41	3.41	0.14	0.00	4.28	4.38	-0.27	-0.12
0.41	0.41	0.14	0.00	1.2	1.23	-2.36	-0.03	2.4	2.05	14.70	0.35	2.87	2.87	0.14	0.00	3.69	3.69	0.14	0.00
0.35	0.35	0.83	0.00	1	1.04	-4.13	-0.04	2.1	1.74	15.01	0.22	2.09	2.07	0.54	0.02	2.87	2.88	0.30	0.01
0.23	0.23	2.41	0.00	0.88	0.89	0.30	0.00	1.7	1.49	15.01	0.22	1.78	1.78	-0.48	-0.01	2.29	2.30	-0.39	-0.01
0.22	0.22	2.41	0.00	0.88	0.89	0.30	0.00	1.5	1.35	16.85	0.22	1.78	1.78	-0.48	-0.01	2.29	2.30	-0.39	-0.01
0.22	0.22	0.86	0.00	0.88	0.89	0.30	0.00	1.5	1.35	16.85	0.22	1.78	1.78	-0.48	-0.01	2.29	2.30	-0.39	-0.01
0.19	0.19	0.25	0.00	0.67	0.67	0.29	0.00	1.1	0.95	15.89	0.15	1.33	1.33	0.28	0.00	1.71	1.71	0.05	0.00
0.17	0.17	2.84	0.00	0.65	0.66	1.00	0.01	0.88	0.83	15.82	0.16	1.16	1.16	0.43	0.00	1.49	1.49	0.34	0.00
0.14	0.14	-3.89	-0.01	0.43	0.44	-1.47	-0.01	0.85	0.79	14.44	0.12	1.01	1.02	-0.00	-0.01	1.3	1.31	-0.69	-0.01
0.13	0.13	2.22	0.00	0.38	0.38	-0.35	0.00	0.75	0.64	15.23	0.11	0.89	0.89	0.14	0.00	1.15	1.14	0.62	0.01
30K																			
2.4	2.58	-7.50	-0.15	7.6	7.74	-1.84	-0.14	12.9	12.9	11.15	0.23	16.1	18.03	0.22	0.04	25.5	23.22	1.81	0.35
2	2.08	-3.00	-0.06	6.1	6.18	-1.21	-0.08	10.3	10.3	11.15	0.23	16.1	18.03	0.22	0.04	25.5	23.22	1.81	0.35
1.7	1.84	3.28	0.08	4.8	4.83	-0.65	-0.03	8.22	8.22	12.79	0.88	11.6	11.51	0.79	0.08	15	14.80	1.36	0.29
1.1	1.10	0.00	0.00	3.4	3.41	0.00	0.00	5.84	5.84	12.79	0.88	8.22	8.22	0.08	0.01	12	11.99	0.10	0.01
1.1	1.09	0.81	0.01	3.4	3.27	3.81	0.15	5.84	5.84	12.79	0.88	8.22	8.22	0.08	0.01	12	11.99	0.10	0.01
0.85	0.89	5.89	0.06	2.8	2.59	4.21	0.12	4.47	4.47	8.22	0.00	5.21	6.57	-0.55	-0.01	8.08	8.05	0.17	0.01
0.87	0.87	-0.75	0.00	2.4	2.4	0.00	0.00	3.35	3.35	8.22	0.00	4.41	4.89	-0.38	-0.08	6.59	6.63	-0.48	-0.04
0.67	0.67	0.00	0.00	2	2.01	-0.50	-0.01	2.84	2.84	8.22	0.00	3.98	3.98	0.10	0.00	4.7	5.11	-0.77	-0.14
0.57	0.57	0.35	0.00	1.7	1.70	-0.24	0.00	2.84	2.84	8.22	0.00	3.74	3.38	0.35	0.01	4.37	4.38	0.02	0.01
0.41	0.41	-1.55	-0.01	1.5	1.45	3.20	0.05	2.48	2.48	8.22	0.00	2.51	2.51	0.15	0.00	3.22	3.22	0.00	0.00
0.41	0.41	-1.55	-0.01	1.5	1.45	3.20	0.05	2.48	2.48	8.22	0.00	2.51	2.51	0.15	0.00	3.22	3.22	0.00	0.00
0.30	0.30	0.66	0.00	1.1	1.07	2.36	0.03	1.79	1.79	8.22	0.00	2.17	2.17	0.00	0.00	2.5	2.70	-0.36	0.01
0.31	0.31	0.00	0.00	0.93	0.93	0.00	0.00	1.55	1.55	8.22	0.00	1.89	1.89	0.00	0.00	2.44	2.43	0.41	0.01
0.27	0.27	0.00	0.00	0.81	0.81	0.00	0.00	1.25	1.25	8.22	0.00	1.56	1.56	-0.36	-0.01	2.13	2.14	-0.58	-0.01
0.24	0.24	0.83	0.00	0.71	0.71	-0.56	0.00	1.19	1.19	8.22	0.00	1.46	1.46	0.27	0.00	1.5	1.87	-4.00	-0.07
0.21	0.21	0.95	0.00	0.62	0.62	-0.05	0.00	1.04	1.04	8.22	0.00	1.27	1.27	0.26	0.00	1.32	3.53	-3.32	-0.01
60K																			
3.8	4.01	-6.01	-0.21	12	12.94	-0.33	-0.04	20.3	20.07	11.15	0.23	28.5	28.08	1.43	0.41	37	36.12	2.35	0.88
3.1	3.20	-3.27	-0.10	9.0	9.01	-0.14	-0.01	16.1	16.02	0.48	0.08	22.9	22.43	2.05	0.47	24.9	24.84	-15.62	-0.04
2.6	2.65	1.94	0.04	7.7	7.67	0.38	0.03	12.5	12.79	0.88	0.11	15.3	17.90	2.16	0.40	25.5	23.02	2.65	0.48
1.8	1.70	5.90	0.16	5.1	5.05	0.35	0.01	8.57	8.48	-0.28	-0.03	11.9	11.87	0.33	0.20	18	18.65	1.85	0.35
1.2	1.24	7.29	0.11	4.4	4.17	6.15	0.23	6.90	6.85	0.10	0.01	9.75	9.73	0.15	0.02	12.5	12.82	-0.13	-0.02
1	1.04	-4.22	-0.04	3.7	3.71	-0.40	-0.01	6.79	6.19	-6.53	-0.40	8.1	8.67	-7.01	-0.57	10.4	11.14	-7.15	-0.74
0.88	0.88	-0.40	0.00	3.1	3.13	-0.85	-0.03	4.82	5.21	-1.11	-0.39	6.78	7.30	-7.52	-0.64	8.89	9.38	-7.84	-0.69
0.75	0.75	-0.35	0.00	2.7	2.65	1.80	0.05	4.35	4.42	-1.56	-0.07	6.69	6.18	-4.70	-0.49	7.22	7.85	-6.63	-0.63
0.66	0.66	-0.35	0.00	2.3	2.28	1.80	0.04	3.77	3.78	0.15	0.01	4.82	5.27	-4.38	-0.46	6.2	6.78	-6.29	-0.58
0.58	0.58	0.00	0.00	1.9	1.87	2.78	0.03	3.29	3.29	0.20	0.01	3.81	3.90	0.30	0.01				

APPENDIX D

Legend

- A Illuminance values calculated by lighting software
- B Estimated illuminance value from the reference indicated in bold = (A x 39000/Lumen) x Surface reflectance factor
- C Differences in % between A and B values = (A - B / A) x 100
- D Differences in Lux of the calculated values and the estimated values = A - B

12K		15K		18K		20K		25K		30K		35K		40K		45K		50K		55K		60K	
A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
0.52	0.63	-2.58	-0.01	1.5	1.60	0.00	0.00	2.5	2.67	-2.98	-0.07	3.0	3.17	-5.70	-0.13	4.7	4.90	-2.13	0.00	4.7	4.90	-2.13	0.00
0.43	0.43	0.00	0.00	1.3	1.30	0.15	0.00	2.1	2.15	-2.02	-0.06	3	3.03	-0.95	-0.03	3.9	3.93	0.01	0.00	3.9	3.93	0.01	0.00
0.35	0.35	0.00	0.00	1.1	1.08	3.82	0.04	1.8	1.78	2.04	0.04	2.5	2.47	1.25	0.03	3.2	3.17	0.81	0.03	3.2	3.17	0.81	0.03
0.24	0.25	-2.20	-0.01	0.9	0.92	-0.25	-0.01	1.5	1.47	2.00	0.03	2.1	2.08	2.00	0.04	2.7	2.65	2.90	0.05	2.7	2.65	2.90	0.05
0.21	0.21	0.00	0.00	0.7	0.70	0.32	0.00	1	1.03	-3.90	-0.03	1.7	1.72	-0.22	-0.02	2.2	2.21	-0.39	-0.01	2.2	2.21	-0.39	-0.01
0.17	0.17	0.00	0.00	0.62	0.62	0.00	0.00	0.87	0.87	0.58	0.00	1.2	1.21	-1.11	-0.01	1.3	1.29	0.44	0.03	1.3	1.29	0.44	0.03
0.15	0.15	1.78	0.00	0.44	0.44	-4.16	0.00	0.74	0.74	0.45	0.00	1	1.03	-0.13	-0.03	1.3	1.33	-2.00	-0.03	1.1	1.13	-3.09	-0.03
0.13	0.13	0.00	0.00	0.39	0.39	3.08	0.01	0.63	0.63	0.00	0.00	0.89	0.88	0.00	0.01	0.87	0.87	0.41	0.00	0.84	0.83	0.71	0.01
0.11	0.11	0.00	0.00	0.32	0.32	4.82	0.00	0.54	0.54	0.02	0.00	0.85	0.86	0.21	0.00	0.84	0.83	0.71	0.01	0.82	0.79	-0.83	-0.01
0.093	0.09	0.35	0.00	0.24	0.24	-0.83	0.00	0.4	0.40	-0.72	0.00	0.65	0.64	0.03	0.00	0.72	0.70	0.85	0.01	0.72	0.70	0.85	0.01
0.07	0.07	0.00	0.00	0.21	0.21	0.00	0.00	0.35	0.35	0.00	0.00	0.46	0.46	0.03	0.00	0.46	0.46	0.03	0.00	0.46	0.46	0.03	0.00
0.061	0.06	-5.44	0.00	0.19	0.18	3.26	0.01	0.31	0.31	1.19	0.00	0.43	0.43	0.26	0.00	0.43	0.43	0.26	0.00	0.43	0.43	0.26	0.00
0.054	0.05	0.23	0.00	0.16	0.16	-1.50	0.00	0.27	0.27	0.25	0.00	0.38	0.38	0.77	0.00	0.48	0.48	1.06	0.00	0.48	0.48	1.06	0.00
0.05	0.05	-0.03	0.00	2.8	2.83	-4.76	-0.13	4.8	4.89	-1.85	-0.06	6.85	6.84	0.08	0.01	8.81	8.80	0.11	0.01	8.81	8.80	0.11	0.01
0.76	0.79	-1.70	-0.01	2.4	2.28	0.85	0.02	3.8	3.97	-1.70	-0.07	5.65	5.68	-0.03	0.00	7.14	7.14	0.01	0.00	7.14	7.14	0.01	0.00
0.65	0.65	0.00	0.00	1.8	1.84	-2.09	-0.04	3.2	3.23	-1.02	-0.03	4.65	4.63	0.63	0.02	5.83	5.82	0.19	0.01	5.83	5.82	0.19	0.01
0.48	0.48	0.00	0.00	1.6	1.62	-1.06	-0.02	2.7	2.70	0.19	0.00	3.79	3.77	0.45	0.02	4.82	4.85	-0.64	-0.03	4.82	4.85	-0.64	-0.03
0.39	0.38	3.16	0.01	1.1	1.13	-3.00	-0.05	2.2	2.25	-2.52	-0.05	3.16	3.16	0.05	0.00	4.05	4.05	0.05	0.00	4.05	4.05	0.05	0.00
0.32	0.32	0.00	0.00	0.95	0.95	-0.35	0.00	1.6	1.59	0.00	0.01	2.23	2.23	0.08	0.00	3.4	3.40	0.03	0.00	3.4	3.40	0.03	0.00
0.27	0.27	-0.04	0.00	0.81	0.81	-0.04	0.00	1.3	1.35	-0.08	-0.05	1.89	1.89	-0.04	0.00	2.43	2.43	-0.04	0.00	2.43	2.43	-0.04	0.00
0.23	0.23	-0.43	0.00	0.69	0.69	-0.43	0.00	1.2	1.19	3.76	0.04	1.61	1.62	-0.43	-0.01	2.07	2.09	-0.43	-0.01	2.07	2.09	-0.43	-0.01
0.2	0.20	1.61	0.00	0.59	0.59	-0.06	0.00	0.85	0.85	-0.40	0.00	1.28	1.28	0.15	0.00	1.77	1.77	0.00	0.00	1.83	1.83	0.00	0.00
0.17	0.17	0.00	0.00	0.51	0.51	0.07	0.00	0.85	0.85	0.07	0.00	1.10	1.10	0.07	0.00	1.59	1.59	-0.09	0.00	1.59	1.59	-0.09	0.00
0.15	0.15	1.41	0.00	0.44	0.44	-0.04	0.00	0.74	0.74	-0.06	0.00	1.00	1.00	-0.04	-0.01	1.32	1.32	-0.09	0.00	1.32	1.32	-0.09	0.00
0.13	0.13	1.26	0.00	0.38	0.38	-1.32	-0.01	0.64	0.64	-0.06	0.00	0.87	0.87	0.09	0.00	1.01	1.01	-0.05	0.00	1.01	1.01	-0.05	0.00
0.11	0.11	-2.11	0.00	0.34	0.34	0.89	0.00	0.49	0.49	-0.26	0.00	0.787	0.787	0.09	0.00	0.89	0.89	-0.86	-0.03	0.89	0.89	-0.86	-0.03
0.099	0.10	0.26	0.00	0.3	0.30	1.24	0.00	0.46	0.46	-0.77	0.00	0.691	0.691	-0.04	0.00	0.609	0.609	-0.89	-0.03	0.609	0.609	-0.89	-0.03
1.8	1.89	0.00	0.00	4.7	4.80	-2.13	-0.10	8	8.46	2.01	0.20	11.3	11.20	0.26	0.00	14.9	14.40	3.38	0.00	14.9	14.40	3.38	0.00
1.3	1.30	3.82	0.04	3.8	3.89	-2.47	-0.03	6.46	6.46	0.00	0.00	9.96	9.96	0.04	0.00	11.7	11.68	0.15	0.02	11.7	11.68	0.15	0.02
0.89	0.88	0.90	0.01	2.9	2.85	-1.77	-0.06	4.41	4.41	-0.06	-0.01	6.92	6.92	-1.28	-0.03	8.84	8.84	-1.25	-0.10	8.84	8.84	-1.25	-0.10
0.78	0.78	0.00	0.00	2.2	2.21	-0.25	-0.01	3.88	3.88	-0.01	0.00	5.82	5.82	-0.01	0.00	7.84	7.84	0.00	0.00	7.84	7.84	0.00	0.00
0.62	0.62	0.00	0.00	1.6	1.56	2.86	0.04	2.8	2.8	0.00	0.00	4.18	4.18	0.00	0.00	6.49	6.49	-0.06	-0.17	6.49	6.49	-0.06	-0.17
0.44	0.44	0.44	0.00	1.3	1.33	-2.00	-0.03	2.21	2.21	0.00	0.00	3.96	3.96	-0.13	0.00	5.88	5.88	0.05	0.00	5.88	5.88	0.05	0.00
0.38	0.38	0.63	0.00	1.1	1.13	-3.09	-0.03	1.88	1.88	-0.03	0.00	2.84	2.85	-0.23	-0.01	3.39	3.40	-0.35	-0.01	3.39	3.40	-0.35	-0.01
0.32	0.32	-0.83	0.00	0.97	0.97	0.41	0.00	1.81	1.81	0.00	0.00	2.89	2.85	0.27	0.01	2.9	2.90	0.07	0.00	2.9	2.90	0.07	0.00
0.28	0.28	0.71	0.00	0.83	0.83	-0.48	0.00	1.38	1.38	-0.00	0.00	1.96	1.96	0.21	0.00	2.51	2.50	0.32	0.01	2.51	2.50	0.32	0.01
0.24	0.24	0.00	0.00	0.74	0.74	0.00	0.00	1.04	1.04	-0.00	0.00	1.69	1.69	-0.24	0.00	2.17	2.18	-0.37	-0.01	2.17	2.18	-0.37	-0.01
0.21	0.21	0.00	0.00	0.63	0.63	0.00	0.00	0.89	0.89	0.00	0.00	1.26	1.26	0.00	0.00	1.86	1.86	0.00	0.00	1.86	1.86	0.00	0.00
0.19	0.19	3.26	0.01	0.55	0.55	-2.26	0.00	0.819	0.819	0.00	0.00	1.26	1.26	0.26	0.00	1.46	1.45	0.38	0.01	1.46	1.45	0.38	0.01
0.18	0.18	-1.00	0.00	0.4	0.4	-2.10	-0.05	0.608	0.608	0.00	0.00	0.89	0.89	-0.11	0.00	1.13	1.13	0.00	0.00	1.13	1.13	0.00	0.00
2.4	2.49	-3.70	-0.09	7.4	7.47	-0.90	-0.07	12.7	12.44	2.01	0.20	18	17.42	3.21	0.58	25.2	25.2	0.00	0.00	25.2	25.2	0.00	0.00
2.02	2.02	-0.05	0.00	6	6.00	-0.96	-0.04	10.1	10.10	0.04	0.00	14.4	14.43	1.85	0.27	18.7	18.17	2.82	0.53	18.7	18.17	2.82	0.53
1.6	1.52	-2.89	-0.05	4.8	4.94	-0.76	-0.04	8.22	8.23	-0.11	-0.01	11.5	11.52	-0.16	-0.02	15.2	14.81	2.65	0.39	15.2	14.81	2.65	0.39
1.4	1.37	2.00	0.03	4.1	4.12	-0.39	-0.02	6.76	6.80	-1.03	-0.15	8.46	8.46	-1.52	-0.14	12.2	12.25	-4.21	-0.30	12.2	12.25	-4.21	-0.30
0.96	0.96	-0.14	0.00	3.4	3.43	-1.02	-0.03	5.57	5.72	-2.77	-0.16	7.8	8.01	-2.75	-0.21	10	10.30	-3.04	-0.27	10	10.30	-3.04	-0.27
0.86	0.86	0.00	0.00	2.89	2.89	0.00	0.00	4.73	4.81	-1.82	-0.02	6.91	6.73	-3.37	-0.22	8.37	8.05	-3.97	-0.28	8.37	8.05	-3.97	-0.28
0.68	0.69	-1.11	-0.01	2.1	2.08	1.78	0.04	3.42	3.44	-0.12	-0.02	4.59	4.81	-4.85	-0.21	5.91	7.28	-3.86	-0.27	5.91	7.28	-3.86	-0.27
0.59	0.59	0.34	0.00	1.8	1.79	2.00	0.04	2.92	2.94	-0.68	-0.02	4.69	4.12	-6.84	-0.03	6.02	5.92	-5.42	-0.27	6.02	5.92	-5.42	-0.27
0.5																							

APPENDIX D

Legend

- A Illuminance values calculated by lighting software
- B Estimated Illuminance value from the reference indicated in bolds = (A x 38000/Lumen) X Surface reflectance factor
- C Differences in % between A and B values = (A - B) / A x 100
- D Differences in Lux of the calculated values and the estimated values = A - B

10		15K		20		25		30		35		40		45		50		55		60		65		70		75		80		85		90		95		100	
		A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
0.35	0.35	0.35	0.35	-0.05	0.00	1.1	1.1	-0.0	-0.1	1.7	1.7	-0.0	-0.0	2.3	2.3	-0.0	-0.0	2.9	2.9	-0.0	-0.0	3.5	3.5	-0.0	-0.0	4.1	4.1	-0.0	-0.0	4.7	4.7	-0.0	-0.0	5.3	5.3	-0.0	-0.0
0.39	0.39	0.39	0.39	0.00	0.00	0.7	0.7	0.0	0.0	1.4	1.4	0.0	0.0	2.1	2.1	0.0	0.0	2.8	2.8	0.0	0.0	3.5	3.5	0.0	0.0	4.2	4.2	0.0	0.0	4.9	4.9	0.0	0.0	5.6	5.6	0.0	0.0
0.43	0.43	0.43	0.43	0.00	0.00	0.7	0.7	0.0	0.0	1.2	1.2	0.0	0.0	1.9	1.9	0.0	0.0	2.6	2.6	0.0	0.0	3.3	3.3	0.0	0.0	4.0	4.0	0.0	0.0	4.7	4.7	0.0	0.0	5.4	5.4	0.0	0.0
0.47	0.47	0.47	0.47	0.00	0.00	0.6	0.6	0.0	0.0	0.9	0.9	0.0	0.0	1.6	1.6	0.0	0.0	2.3	2.3	0.0	0.0	3.0	3.0	0.0	0.0	3.7	3.7	0.0	0.0	4.4	4.4	0.0	0.0	5.1	5.1	0.0	0.0
0.51	0.51	0.51	0.51	0.00	0.00	0.4	0.4	0.0	0.0	0.8	0.8	0.0	0.0	1.5	1.5	0.0	0.0	2.2	2.2	0.0	0.0	2.9	2.9	0.0	0.0	3.6	3.6	0.0	0.0	4.3	4.3	0.0	0.0	5.0	5.0	0.0	0.0
0.55	0.55	0.55	0.55	0.00	0.00	0.3	0.3	0.0	0.0	0.6	0.6	0.0	0.0	1.3	1.3	0.0	0.0	2.0	2.0	0.0	0.0	2.7	2.7	0.0	0.0	3.4	3.4	0.0	0.0	4.1	4.1	0.0	0.0	4.8	4.8	0.0	0.0
0.59	0.59	0.59	0.59	0.00	0.00	0.3	0.3	0.0	0.0	0.5	0.5	0.0	0.0	1.2	1.2	0.0	0.0	1.9	1.9	0.0	0.0	2.6	2.6	0.0	0.0	3.3	3.3	0.0	0.0	4.0	4.0	0.0	0.0	4.7	4.7	0.0	0.0
0.63	0.63	0.63	0.63	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
0.67	0.67	0.67	0.67	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
0.71	0.71	0.71	0.71	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
0.75	0.75	0.75	0.75	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
0.79	0.79	0.79	0.79	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
0.83	0.83	0.83	0.83	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
0.87	0.87	0.87	0.87	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
0.91	0.91	0.91	0.91	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
0.95	0.95	0.95	0.95	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
0.99	0.99	0.99	0.99	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.03	1.03	1.03	1.03	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.07	1.07	1.07	1.07	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.11	1.11	1.11	1.11	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.15	1.15	1.15	1.15	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.19	1.19	1.19	1.19	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.23	1.23	1.23	1.23	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.27	1.27	1.27	1.27	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.31	1.31	1.31	1.31	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.35	1.35	1.35	1.35	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.39	1.39	1.39	1.39	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.43	1.43	1.43	1.43	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.47	1.47	1.47	1.47	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.51	1.51	1.51	1.51	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.55	1.55	1.55	1.55	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.59	1.59	1.59	1.59	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0	0.0	4.6	4.6	0.0	0.0
1.63	1.63	1.63	1.63	0.00	0.00	0.3	0.3	0.0	0.0	0.4	0.4	0.0	0.0	1.1	1.1	0.0	0.0	1.8	1.8	0.0	0.0	2.5	2.5	0.0	0.0	3.2	3.2	0.0	0.0	3.9	3.9	0.0					

APPENDIX D

Legend

A	Illuminance values calculated by lighting software
B	Estimated illuminance value from the reference indicated in table = (A x 30000/Lumen) x Surface reflectance factor
C	Difference in % between A and B values = (A - B) / A x 100
D	Differences in Lux of the calculated values and the estimate value = A - B

THK	10				30				50				70				90			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
10	0.38	0.52	-2.1	-0.04	1.1	1.10	-0.04	-0.04	1.0	1.04	-2.1	-0.04	2.7	2.72	-0.60	-0.02	2.43	2.48	-1.5	-0.06
20	0.28	0.52	0.21	0.00	0.90	0.90	-0.04	-0.04	1.0	1.00	0.21	0.00	2.2	2.24	-1.51	-0.04	2.38	2.37	0.42	0.01
30	0.22	0.52	-0.25	0.00	0.70	0.70	0.00	0.00	1.3	1.32	-0.28	-0.02	1.5	1.54	-2.41	-0.04	2.36	2.37	0.00	0.00
40	0.19	0.19	0.00	0.00	0.90	0.90	0.00	0.00	1.0	1.00	-0.04	-0.04	1.0	1.00	0.00	0.00	1.00	1.00	0.00	0.00
50	0.15	0.15	0.00	0.00	0.47	0.47	-0.04	-0.04	0.70	0.70	0.00	0.00	0.95	0.94	0.00	0.00	1.00	1.00	0.00	0.00
60	0.12	0.12	0.00	0.00	0.40	0.40	-0.04	-0.04	0.60	0.60	0.00	0.00	0.81	0.81	0.00	0.00	1.04	1.04	0.00	0.00
70	0.09	0.09	0.00	0.00	0.35	0.35	0.00	0.00	0.60	0.60	0.00	0.00	0.70	0.70	0.00	0.00	0.80	0.80	0.00	0.00
80	0.07	0.07	0.00	0.00	0.26	0.26	0.00	0.00	0.50	0.50	0.00	0.00	0.63	0.63	0.00	0.00	0.78	0.78	-0.28	-0.04
90	0.06	0.06	0.00	0.00	0.23	0.23	0.00	0.00	0.38	0.38	0.00	0.00	0.52	0.52	-0.33	-0.04	0.64	0.64	0.00	0.00
100	0.05	0.05	0.00	0.00	0.17	0.17	-0.24	-0.04	0.28	0.28	0.00	0.00	0.41	0.41	1.36	0.00	0.52	0.52	0.00	0.00
110	0.17	0.17	-1.62	-0.01	2.1	2.13	-1.62	-0.01	3.5	3.56	-1.62	-0.01	4.8	4.86	0.01	0.00	6.4	6.40	-0.03	0.00
120	0.09	0.09	0.00	0.00	1.7	1.70	-0.31	-0.01	2.9	2.93	-0.04	-0.01	4.0	4.00	-0.04	-0.01	5.2	5.27	0.49	0.02
130	0.08	0.08	0.00	0.00	1.2	1.20	-0.04	-0.01	2.0	2.00	-0.04	-0.01	2.8	2.80	0.00	0.00	3.8	3.80	0.00	0.00
140	0.04	0.04	1.05	0.00	1.2	1.20	-1.44	-0.01	2.1	2.05	-1.44	-0.01	3.0	2.98	0.02	0.00	4.0	4.00	0.00	0.00
150	0.34	0.34	-0.68	0.00	1.1	1.03	-0.27	-0.02	1.7	1.71	-0.95	-0.01	2.4	2.40	0.10	0.00	3.0	3.00	0.00	0.00
160	0.29	0.29	0.11	0.00	0.87	0.87	0.11	0.00	1.5	1.45	0.06	0.00	2.0	2.00	0.11	0.00	2.8	2.81	0.11	0.00
170	0.25	0.25	1.24	0.00	0.74	0.74	-0.06	0.00	1.2	1.20	-0.07	-0.01	1.7	1.70	0.10	0.00	2.2	2.22	0.06	0.01
180	0.23	0.23	0.00	0.00	0.60	0.60	0.00	0.00	1.0	1.00	0.00	0.00	1.4	1.40	-0.01	0.00	1.9	1.90	0.00	0.00
190	0.19	0.19	0.00	0.00	0.55	0.55	0.00	0.00	0.94	0.94	-0.01	0.00	1.3	1.30	-0.01	0.00	1.8	1.80	0.00	0.00
200	0.16	0.16	0.00	0.00	0.49	0.49	0.00	0.00	0.79	0.79	-0.05	0.00	1.1	1.11	0.00	0.00	1.4	1.40	0.00	0.00
210	0.14	0.14	0.00	0.00	0.41	0.41	-0.08	0.00	0.69	0.69	-0.08	0.00	0.97	0.97	0.02	0.00	1.24	1.24	-0.04	0.00
220	0.12	0.12	0.00	0.00	0.38	0.38	-0.07	0.00	0.66	0.66	-0.07	0.00	0.89	0.89	-0.02	0.00	1.09	1.09	0.00	0.00
230	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
240	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
250	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
260	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
270	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
280	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
290	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
300	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
310	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
320	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
330	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
340	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
350	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
360	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
370	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
380	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
390	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
400	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
410	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
420	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
430	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
440	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
450	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
460	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
470	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
480	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
490	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
500	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
510	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
520	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
530	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
540	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
550	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
560	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
570	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
580	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
590	0.11	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.60	0.60	-0.03	0.00	0.84	0.84	0.00	0.00	1.00	1.00	0.00	0.00
600	0.11	0.11	0.00	0.00	0.32	0.32	0.00													

APPENDIX D

Legend

A	Illuminance values calculated by lighting software
B	Estimated illuminance values from the reference indicated in table = (A x 39000/Lumen) x Surface reflectance factor
C	Difference (In %) between A and B values = (A - B) / A x 100
D	Difference in Lux of the calculated values and the estimated values = A - B

10	1PK				30				50				70				90			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
0.20	0.20	0.20	0.00	0.00	0.78	0.78	0.00	0.00	1.3	1.3	0.00	0.00	1.8	1.8	0.00	0.00	2.3	2.3	0.00	0.00
0.22	0.22	0.22	0.00	0.00	0.85	0.85	0.00	0.00	1.1	1.1	0.00	0.00	1.5	1.5	0.00	0.00	1.9	1.9	0.00	0.00
0.24	0.24	0.24	0.00	0.00	0.92	0.92	0.00	0.00	0.81	0.81	0.00	0.00	1.1	1.1	0.00	0.00	1.5	1.5	0.00	0.00
0.26	0.26	0.26	0.00	0.00	1.00	1.00	0.00	0.00	0.88	0.88	0.00	0.00	1.2	1.2	0.00	0.00	1.6	1.6	0.00	0.00
0.28	0.28	0.28	0.00	0.00	1.08	1.08	0.00	0.00	0.95	0.95	0.00	0.00	1.3	1.3	0.00	0.00	1.7	1.7	0.00	0.00
0.30	0.30	0.30	0.00	0.00	1.16	1.16	0.00	0.00	1.02	1.02	0.00	0.00	1.4	1.4	0.00	0.00	1.8	1.8	0.00	0.00
0.32	0.32	0.32	0.00	0.00	1.24	1.24	0.00	0.00	1.10	1.10	0.00	0.00	1.5	1.5	0.00	0.00	1.9	1.9	0.00	0.00
0.34	0.34	0.34	0.00	0.00	1.32	1.32	0.00	0.00	1.18	1.18	0.00	0.00	1.6	1.6	0.00	0.00	2.0	2.0	0.00	0.00
0.36	0.36	0.36	0.00	0.00	1.40	1.40	0.00	0.00	1.26	1.26	0.00	0.00	1.7	1.7	0.00	0.00	2.1	2.1	0.00	0.00
0.38	0.38	0.38	0.00	0.00	1.48	1.48	0.00	0.00	1.34	1.34	0.00	0.00	1.8	1.8	0.00	0.00	2.2	2.2	0.00	0.00
0.40	0.40	0.40	0.00	0.00	1.56	1.56	0.00	0.00	1.42	1.42	0.00	0.00	1.9	1.9	0.00	0.00	2.3	2.3	0.00	0.00
0.42	0.42	0.42	0.00	0.00	1.64	1.64	0.00	0.00	1.50	1.50	0.00	0.00	2.0	2.0	0.00	0.00	2.4	2.4	0.00	0.00
0.44	0.44	0.44	0.00	0.00	1.72	1.72	0.00	0.00	1.58	1.58	0.00	0.00	2.1	2.1	0.00	0.00	2.5	2.5	0.00	0.00
0.46	0.46	0.46	0.00	0.00	1.80	1.80	0.00	0.00	1.66	1.66	0.00	0.00	2.2	2.2	0.00	0.00	2.6	2.6	0.00	0.00
0.48	0.48	0.48	0.00	0.00	1.88	1.88	0.00	0.00	1.74	1.74	0.00	0.00	2.3	2.3	0.00	0.00	2.7	2.7	0.00	0.00
0.50	0.50	0.50	0.00	0.00	1.96	1.96	0.00	0.00	1.82	1.82	0.00	0.00	2.4	2.4	0.00	0.00	2.8	2.8	0.00	0.00
0.52	0.52	0.52	0.00	0.00	2.04	2.04	0.00	0.00	1.90	1.90	0.00	0.00	2.5	2.5	0.00	0.00	2.9	2.9	0.00	0.00
0.54	0.54	0.54	0.00	0.00	2.12	2.12	0.00	0.00	1.98	1.98	0.00	0.00	2.6	2.6	0.00	0.00	3.0	3.0	0.00	0.00
0.56	0.56	0.56	0.00	0.00	2.20	2.20	0.00	0.00	2.06	2.06	0.00	0.00	2.7	2.7	0.00	0.00	3.1	3.1	0.00	0.00
0.58	0.58	0.58	0.00	0.00	2.28	2.28	0.00	0.00	2.14	2.14	0.00	0.00	2.8	2.8	0.00	0.00	3.2	3.2	0.00	0.00
0.60	0.60	0.60	0.00	0.00	2.36	2.36	0.00	0.00	2.22	2.22	0.00	0.00	2.9	2.9	0.00	0.00	3.3	3.3	0.00	0.00
0.62	0.62	0.62	0.00	0.00	2.44	2.44	0.00	0.00	2.30	2.30	0.00	0.00	3.0	3.0	0.00	0.00	3.4	3.4	0.00	0.00
0.64	0.64	0.64	0.00	0.00	2.52	2.52	0.00	0.00	2.38	2.38	0.00	0.00	3.1	3.1	0.00	0.00	3.5	3.5	0.00	0.00
0.66	0.66	0.66	0.00	0.00	2.60	2.60	0.00	0.00	2.46	2.46	0.00	0.00	3.2	3.2	0.00	0.00	3.6	3.6	0.00	0.00
0.68	0.68	0.68	0.00	0.00	2.68	2.68	0.00	0.00	2.54	2.54	0.00	0.00	3.3	3.3	0.00	0.00	3.7	3.7	0.00	0.00
0.70	0.70	0.70	0.00	0.00	2.76	2.76	0.00	0.00	2.62	2.62	0.00	0.00	3.4	3.4	0.00	0.00	3.8	3.8	0.00	0.00
0.72	0.72	0.72	0.00	0.00	2.84	2.84	0.00	0.00	2.70	2.70	0.00	0.00	3.5	3.5	0.00	0.00	3.9	3.9	0.00	0.00
0.74	0.74	0.74	0.00	0.00	2.92	2.92	0.00	0.00	2.78	2.78	0.00	0.00	3.6	3.6	0.00	0.00	4.0	4.0	0.00	0.00
0.76	0.76	0.76	0.00	0.00	3.00	3.00	0.00	0.00	2.86	2.86	0.00	0.00	3.7	3.7	0.00	0.00	4.1	4.1	0.00	0.00
0.78	0.78	0.78	0.00	0.00	3.08	3.08	0.00	0.00	2.94	2.94	0.00	0.00	3.8	3.8	0.00	0.00	4.2	4.2	0.00	0.00
0.80	0.80	0.80	0.00	0.00	3.16	3.16	0.00	0.00	3.02	3.02	0.00	0.00	3.9	3.9	0.00	0.00	4.3	4.3	0.00	0.00
0.82	0.82	0.82	0.00	0.00	3.24	3.24	0.00	0.00	3.10	3.10	0.00	0.00	4.0	4.0	0.00	0.00	4.4	4.4	0.00	0.00
0.84	0.84	0.84	0.00	0.00	3.32	3.32	0.00	0.00	3.18	3.18	0.00	0.00	4.1	4.1	0.00	0.00	4.5	4.5	0.00	0.00
0.86	0.86	0.86	0.00	0.00	3.40	3.40	0.00	0.00	3.26	3.26	0.00	0.00	4.2	4.2	0.00	0.00	4.6	4.6	0.00	0.00
0.88	0.88	0.88	0.00	0.00	3.48	3.48	0.00	0.00	3.34	3.34	0.00	0.00	4.3	4.3	0.00	0.00	4.7	4.7	0.00	0.00
0.90	0.90	0.90	0.00	0.00	3.56	3.56	0.00	0.00	3.42	3.42	0.00	0.00	4.4	4.4	0.00	0.00	4.8	4.8	0.00	0.00
0.92	0.92	0.92	0.00	0.00	3.64	3.64	0.00	0.00	3.50	3.50	0.00	0.00	4.5	4.5	0.00	0.00	4.9	4.9	0.00	0.00
0.94	0.94	0.94	0.00	0.00	3.72	3.72	0.00	0.00	3.58	3.58	0.00	0.00	4.6	4.6	0.00	0.00	5.0	5.0	0.00	0.00
0.96	0.96	0.96	0.00	0.00	3.80	3.80	0.00	0.00	3.66	3.66	0.00	0.00	4.7	4.7	0.00	0.00	5.1	5.1	0.00	0.00
0.98	0.98	0.98	0.00	0.00	3.88	3.88	0.00	0.00	3.74	3.74	0.00	0.00	4.8	4.8	0.00	0.00	5.2	5.2	0.00	0.00
1.00	1.00	1.00	0.00	0.00	3.96	3.96	0.00	0.00	3.82	3.82	0.00	0.00	4.9	4.9	0.00	0.00	5.3	5.3	0.00	0.00
1.02	1.02	1.02	0.00	0.00	4.04	4.04	0.00	0.00	3.90	3.90	0.00	0.00	5.0	5.0	0.00	0.00	5.4	5.4	0.00	0.00
1.04	1.04	1.04	0.00	0.00	4.12	4.12	0.00	0.00	3.98	3.98	0.00	0.00	5.1	5.1	0.00	0.00	5.5	5.5	0.00	0.00
1.06	1.06	1.06	0.00	0.00	4.20	4.20	0.00	0.00	4.06	4.06	0.00	0.00	5.2	5.2	0.00	0.00	5.6	5.6	0.00	0.00
1.08	1.08	1.08	0.00	0.00	4.28	4.28	0.00	0.00	4.14	4.14	0.00	0.00	5.3	5.3	0.00	0.00	5.7	5.7	0.00	0.00
1.10	1.10	1.10	0.00	0.00	4.36	4.36	0.00	0.00	4.22	4.22	0.00	0.00	5.4	5.4	0.00	0.00	5.8	5.8	0.00	0.00
1.12	1.12	1.12	0.00	0.00	4.44	4.44	0.00	0.00	4.30	4.30	0.00	0.00	5.5	5.5	0.00	0.00	5.9	5.9	0.00	0.00
1.14	1.14	1.14	0.00	0.00	4.52	4.52	0.00	0.00	4.38	4.38	0.00	0.00	5.6	5.6	0.00	0.00	6.0	6.0	0.00	0.00
1.16	1.16	1.16	0.00	0.00	4.60	4.60	0.00	0.00	4.46	4.46	0.00	0.00	5.7	5.7	0.00	0.00	6.1	6.1	0.00	0.00
1.18	1.18	1.18	0.00	0.00	4.68	4.68	0.00	0.00	4.54	4.54	0.00	0.00	5.8	5.8	0.00	0.00	6.2	6.2	0.00	0.00
1.20	1.20	1.20	0.00	0.00	4.76	4.76	0.00	0.00	4.62	4.62	0.00	0.00	5.9	5.9	0.00	0.00	6.3	6.3	0.00	0.00
1.22	1.22	1.22	0.00	0.00	4.84	4.84	0.00	0.00	4.70	4.70	0.00	0.00	6.0	6.0	0.00	0.00	6.4	6.4	0.00	0.00
1.24	1.24	1.24	0.00	0.00	4.92	4.92	0.00	0.00	4.78	4.78	0.00	0.00	6.1	6.1	0.00	0.00	6.5	6.5	0.00	0.00
1.26	1.26	1.26	0.00	0.00	5.00	5.00	0.00	0.00	4.86	4.86	0.00	0.00	6.2	6.2	0.00	0.00	6.6	6.6	0.00	0.00
1.28	1.28	1.28	0.00	0.00	5.08	5.08	0.00	0.00	4.94	4.94	0.00	0.00	6.3	6.3	0.00	0.00	6.7	6.7	0.00	0.00
1.30	1.30	1.30	0.00	0.00	5.16	5.16	0.00	0.00	5.02	5.02	0.00	0.00	6.4	6.4	0.0					

APPENDIX D

Legend

- A Illuminance values calculated by lighting software
- B Estimated illuminance value from the reference indicated in table = (A X 36000/Lumen) X Surface reflectance factor
- C Differences in % between A and B values = (A - B) / A X 100
- D Differences in Lux of the calculated values and the estimated values = A - B

15K		30		70		90		90		90	
A	B	C	D	A	B	C	D	A	B	C	D
0.09	1.13	-93.80	-0.14	3.34	3.38	-1.20	-0.04	7.49	7.48	0.01	0.00
0.16	0.93	-72.8	-0.09	2.79	2.60	-6.80	-0.71	6.53	6.40	-1.90	-0.20
0.26	0.76	-65.4	-0.07	2.32	2.14	-7.76	-0.82	5.50	5.30	-3.80	-0.73
0.36	0.65	-53.1	-0.01	1.90	1.64	-13.7	0.00	4.72	4.68	-0.10	0.10
0.50	0.55	-9.09	0.04	1.74	1.65	-4.37	0.33	4.72	4.68	-0.10	0.10
0.65	0.47	-26.9	-0.34	1.53	1.42	-7.19	-0.11	3.47	3.47	0.00	0.00
0.82	0.42	-48.8	-0.48	1.34	1.26	-6.72	-0.08	2.99	2.92	-2.45	-0.87
1.00	0.35	-65.0	-0.65	1.19	1.08	-9.31	-0.11	2.49	2.49	0.00	0.00
1.20	0.30	-75.0	-0.75	1.06	0.95	-11.32	-0.11	2.01	1.91	-1.62	-0.50
1.40	0.27	-81.5	-0.64	0.92	0.82	-11.64	-0.11	1.51	1.41	-1.62	-0.50
1.60	0.25	-84.4	-0.64	0.82	0.72	-12.73	-0.11	1.01	0.91	-1.62	-0.50
1.80	0.24	-87.2	-0.64	0.73	0.63	-13.74	-0.10	0.51	0.41	-1.62	-0.50
2.00	0.24	-88.0	-0.63	0.67	0.56	-14.78	-0.10	0.01	0.01	-1.62	-0.50
2.20	0.23	-89.1	-0.63	0.58	0.50	-15.78	-0.09	0.01	0.01	-1.62	-0.50
2.40	0.22	-90.0	-0.62	0.50	0.43	-16.78	-0.08	0.01	0.01	-1.62	-0.50
2.60	0.21	-90.8	-0.62	0.43	0.38	-17.78	-0.08	0.01	0.01	-1.62	-0.50
2.80	0.20	-91.4	-0.61	0.38	0.33	-18.78	-0.07	0.01	0.01	-1.62	-0.50
3.00	0.19	-92.0	-0.61	0.33	0.29	-19.78	-0.07	0.01	0.01	-1.62	-0.50
3.20	0.18	-92.6	-0.60	0.29	0.25	-20.78	-0.06	0.01	0.01	-1.62	-0.50
3.40	0.17	-93.1	-0.60	0.25	0.22	-21.78	-0.06	0.01	0.01	-1.62	-0.50
3.60	0.16	-93.6	-0.59	0.22	0.19	-22.78	-0.05	0.01	0.01	-1.62	-0.50
3.80	0.15	-94.0	-0.59	0.19	0.17	-23.78	-0.05	0.01	0.01	-1.62	-0.50
4.00	0.14	-94.5	-0.58	0.17	0.15	-24.78	-0.05	0.01	0.01	-1.62	-0.50
4.20	0.13	-94.9	-0.58	0.15	0.13	-25.78	-0.04	0.01	0.01	-1.62	-0.50
4.40	0.12	-95.3	-0.57	0.13	0.11	-26.78	-0.04	0.01	0.01	-1.62	-0.50
4.60	0.11	-95.7	-0.57	0.11	0.09	-27.78	-0.04	0.01	0.01	-1.62	-0.50
4.80	0.10	-96.0	-0.56	0.09	0.08	-28.78	-0.04	0.01	0.01	-1.62	-0.50
5.00	0.09	-96.4	-0.56	0.08	0.07	-29.78	-0.04	0.01	0.01	-1.62	-0.50
5.20	0.08	-96.7	-0.55	0.07	0.06	-30.78	-0.04	0.01	0.01	-1.62	-0.50
5.40	0.07	-97.0	-0.55	0.06	0.05	-31.78	-0.04	0.01	0.01	-1.62	-0.50
5.60	0.06	-97.3	-0.54	0.05	0.04	-32.78	-0.04	0.01	0.01	-1.62	-0.50
5.80	0.05	-97.6	-0.54	0.04	0.03	-33.78	-0.04	0.01	0.01	-1.62	-0.50
6.00	0.04	-97.9	-0.53	0.03	0.02	-34.78	-0.04	0.01	0.01	-1.62	-0.50
6.20	0.03	-98.2	-0.53	0.02	0.01	-35.78	-0.04	0.01	0.01	-1.62	-0.50
6.40	0.02	-98.5	-0.52	0.01	0.00	-36.78	-0.04	0.01	0.01	-1.62	-0.50
6.60	0.01	-98.8	-0.52	0.00	0.00	-37.78	-0.04	0.01	0.01	-1.62	-0.50
6.80	0.00	-99.1	-0.51	0.00	0.00	-38.78	-0.04	0.01	0.01	-1.62	-0.50
7.00	0.00	-99.4	-0.51	0.00	0.00	-39.78	-0.04	0.01	0.01	-1.62	-0.50
7.20	0.00	-99.7	-0.50	0.00	0.00	-40.78	-0.04	0.01	0.01	-1.62	-0.50
7.40	0.00	-100.0	-0.50	0.00	0.00	-41.78	-0.04	0.01	0.01	-1.62	-0.50
7.60	0.00	-100.3	-0.49	0.00	0.00	-42.78	-0.04	0.01	0.01	-1.62	-0.50
7.80	0.00	-100.6	-0.49	0.00	0.00	-43.78	-0.04	0.01	0.01	-1.62	-0.50
8.00	0.00	-100.9	-0.48	0.00	0.00	-44.78	-0.04	0.01	0.01	-1.62	-0.50
8.20	0.00	-101.2	-0.48	0.00	0.00	-45.78	-0.04	0.01	0.01	-1.62	-0.50
8.40	0.00	-101.5	-0.47	0.00	0.00	-46.78	-0.04	0.01	0.01	-1.62	-0.50
8.60	0.00	-101.8	-0.47	0.00	0.00	-47.78	-0.04	0.01	0.01	-1.62	-0.50
8.80	0.00	-102.1	-0.46	0.00	0.00	-48.78	-0.04	0.01	0.01	-1.62	-0.50
9.00	0.00	-102.4	-0.46	0.00	0.00	-49.78	-0.04	0.01	0.01	-1.62	-0.50
9.20	0.00	-102.7	-0.45	0.00	0.00	-50.78	-0.04	0.01	0.01	-1.62	-0.50
9.40	0.00	-103.0	-0.45	0.00	0.00	-51.78	-0.04	0.01	0.01	-1.62	-0.50
9.60	0.00	-103.3	-0.44	0.00	0.00	-52.78	-0.04	0.01	0.01	-1.62	-0.50
9.80	0.00	-103.6	-0.44	0.00	0.00	-53.78	-0.04	0.01	0.01	-1.62	-0.50
10.00	0.00	-103.9	-0.43	0.00	0.00	-54.78	-0.04	0.01	0.01	-1.62	-0.50
10.20	0.00	-104.2	-0.43	0.00	0.00	-55.78	-0.04	0.01	0.01	-1.62	-0.50
10.40	0.00	-104.5	-0.42	0.00	0.00	-56.78	-0.04	0.01	0.01	-1.62	-0.50
10.60	0.00	-104.8	-0.42	0.00	0.00	-57.78	-0.04	0.01	0.01	-1.62	-0.50
10.80	0.00	-105.1	-0.41	0.00	0.00	-58.78	-0.04	0.01	0.01	-1.62	-0.50
11.00	0.00	-105.4	-0.41	0.00	0.00	-59.78	-0.04	0.01	0.01	-1.62	-0.50
11.20	0.00	-105.7	-0.40	0.00	0.00	-60.78	-0.04	0.01	0.01	-1.62	-0.50
11.40	0.00	-106.0	-0.40	0.00	0.00	-61.78	-0.04	0.01	0.01	-1.62	-0.50
11.60	0.00	-106.3	-0.39	0.00	0.00	-62.78	-0.04	0.01	0.01	-1.62	-0.50
11.80	0.00	-106.6	-0.39	0.00	0.00	-63.78	-0.04	0.01	0.01	-1.62	-0.50
12.00	0.00	-106.9	-0.38	0.00	0.00	-64.78	-0.04	0.01	0.01	-1.62	-0.50
12.20	0.00	-107.2	-0.38	0.00	0.00	-65.78	-0.04	0.01	0.01	-1.62	-0.50
12.40	0.00	-107.5	-0.37	0.00	0.00	-66.78	-0.04	0.01	0.01	-1.62	-0.50
12.60	0.00	-107.8	-0.37	0.00	0.00	-67.78	-0.04	0.01	0.01	-1.62	-0.50
12.80	0.00	-108.1	-0.36	0.00	0.00	-68.78	-0.04	0.01	0.01	-1.62	-0.50
13.00	0.00	-108.4	-0.36	0.00	0.00	-69.78	-0.04	0.01	0.01	-1.62	-0.50
13.20	0.00	-108.7	-0.35	0.00	0.00	-70.78	-0.04	0.01	0.01	-1.62	-0.50
13.40	0.00	-109.0	-0.35	0.00	0.00	-71.78	-0.04	0.01	0.01	-1.62	-0.50
13.60	0.00	-109.3	-0.34	0.00	0.00	-72.78	-0.04	0.01	0.01	-1.62	-0.50
13.80	0.00	-109.6	-0.34	0.00	0.00	-73.78	-0.04	0.01	0.01	-1.62	-0.50
14.00	0.00	-109.9	-0.33	0.00	0.00	-74.78	-0.04	0.01	0.01	-1.62	-0.50
14.20	0.00	-110.2	-0.33	0.00	0.00	-75.78	-0.04	0.01	0.01	-1.62	-0.50
14.40	0.00	-110.5	-0.32	0.00	0.00	-76.78	-0.04	0.01	0.01	-1.62	-0.50
14.60	0.00	-110.8	-0.32	0.00	0.00	-77.78	-0.04	0.01	0.01	-1.62	-0.50
14.80	0.00	-111.1	-0.31	0.00	0.00	-78.78	-0.04	0.01	0.01	-1.62	-0.50
15.00	0.00	-111.4	-0.31	0.00	0.00	-79.78	-0.04	0.01	0.01	-1.62	-0.50
15.20	0.00	-111.7	-0.30	0.00	0.00	-80.78	-0.04	0.01	0.01	-1.62	-0.50
15.40	0.00	-112.0	-0.30	0.00	0.00	-81.78	-0.04	0.01	0.01	-1.62	-0.50
15.60	0.00	-112.3	-0.29	0.00	0.00	-82.78	-0.04	0.01	0.01	-1.62	-0.50
15.80	0.00	-112.6	-0.29	0.00	0.00	-83.78	-0.04	0.01	0.01	-1.62	-0.50
16.00	0.00	-112.9	-0.28	0.00	0.00	-84.78	-0.04	0.01	0.01	-1.62	-0.50
16.20	0.00	-113.2	-0.28	0.00	0.00	-85.78	-0.04	0.01	0.01	-1.62	-0.50
16.40	0.00	-113.5	-0.27	0.00	0.00	-86.78	-0.04	0.01	0.01	-1.62	-0.50
16.60	0.00	-113.8	-0.27	0.00	0.00	-87.78	-0.04	0.01	0.01	-1.62	-0.50
16.80	0.00	-114.1	-0.26	0.00	0.00	-88.78	-0.04	0.01	0.01	-1.62	-0.50
17.00	0.00	-114.4	-0.26	0.00	0.00	-89.78	-0.04	0.01	0.01	-1.62	-0.50
17.20	0.00	-114.7	-0.25	0.00	0.00	-90.78	-0.04	0.01	0.01	-1.62	-0.50
17.40	0.00	-115.0	-0.25	0.00	0.00	-91.78	-0.04	0.01	0.01	-1.62	-0.50
17.60	0.00	-115.3	-0.24	0.00	0.00	-92.78	-0.04	0.01	0.01	-1.62	-0.50
17.80	0.00	-115.6	-0.24	0.00	0.00	-93.78	-0.04	0.01	0.01	-1.62	-0.50
18.00	0.00	-115.9	-0.23	0.00	0.00	-94.78	-0.04	0.01	0		

APPENDIX D

Legend

- A Illuminance values calculated by lighting software
- B Estimated illuminance value from the reference indicated in bolds = (A x 30000/Lumen) x Surface reflectance factor
- C Differences in % between A and B values = (A - B / A) x 100
- D Differences in Lux of the calculated values and the estimated values = A - B

ID	18K				30K				50K				70K				90K			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
10	0.77	0.83	-7.50	-0.06	2.37	2.48	-4.64	-0.11	4.14	4.13	0.16	0.01	6.8	6.79	0.23	0.01	7.53	7.44	1.20	0.09
11	0.59	0.65	-3.49	-0.05	1.75	1.81	-0.03	0.03	3.0	3.0	0.00	0.00	4.94	4.95	1.76	0.09	5.39	5.24	2.35	0.15
12	0.59	0.60	-4.74	0.02	1.59	1.61	-0.05	0.06	2.97	2.91	2.07	0.06	4.21	4.07	3.23	0.14	4.69	4.46	3.89	0.21
13	0.45	0.44	3.25	0.01	1.35	1.31	4.76	0.05	2.28	2.18	4.41	0.05	3.81	3.47	3.95	0.14	4.03	3.92	2.78	0.11
14	0.4	0.37	6.33	0.03	1.2	1.12	6.53	0.08	2.01	1.87	8.50	0.14	2.98	2.82	2.50	0.07	3.04	2.95	3.48	0.12
15	0.35	0.35	7.24	0.00	1.09	1.09	8.11	0.09	1.77	1.62	8.29	0.15	2.51	2.27	6.48	0.24	3.04	2.95	3.48	0.12
16	0.31	0.29	8.03	0.03	0.954	0.85	8.42	0.09	1.66	1.41	9.62	0.15	2.22	1.97	11.08	0.25	2.85	2.54	4.29	0.11
17	0.27	0.25	8.84	0.02	0.828	0.74	10.03	0.09	1.38	1.23	11.27	0.15	1.97	1.73	13.33	0.24	2.85	2.22	13.84	0.33
18	0.22	0.18	13.05	0.02	0.796	0.65	11.98	0.09	1.23	1.09	11.92	0.15	1.76	1.62	13.33	0.23	2.27	1.95	14.10	0.32
19	0.19	0.17	10.88	0.02	0.596	0.51	14.77	0.05	0.932	0.86	10.03	0.14	1.68	1.54	14.15	0.22	2.02	1.72	14.76	0.30
20	0.17	0.16	11.76	0.02	0.525	0.46	14.29	0.05	0.88	0.75	14.77	0.13	1.25	1.05	16.09	0.20	1.82	1.58	16.57	0.27
21	1.4	1.52	-8.35	-0.10	4.59	4.65	-0.17	-0.02	7.85	7.68	-0.37	-0.03	16.7	16.81	0.85	0.09	13.5	13.64	1.16	0.10
22	1.2	1.27	-5.59	-0.07	3.25	3.26	-0.04	0.04	5.4	5.24	0.22	0.01	9.02	8.90	1.38	0.12	11.7	11.44	2.22	0.28
23	1.1	1.07	3.09	0.03	3.24	3.20	1.20	0.04	5.4	5.24	0.22	0.01	9.02	8.90	1.38	0.12	11.7	11.44	2.22	0.28
24	0.94	0.91	3.39	0.03	2.77	2.72	1.65	0.05	4.69	4.54	3.35	0.11	6.81	6.56	3.91	0.25	7.38	7.18	2.97	0.36
25	0.83	0.80	3.84	0.03	2.4	2.39	0.24	0.01	3.69	3.69	-0.01	0.00	4.03	4.03	0.00	0.00	4.39	4.39	0.00	0.00
26	0.73	0.69	5.91	0.04	2.19	2.08	5.81	0.13	3.44	3.43	0.01	0.01	4.03	4.03	0.00	0.00	4.39	4.39	0.00	0.00
27	0.64	0.60	7.00	0.04	1.93	1.79	7.49	0.14	2.96	2.96	0.00	0.00	3.74	3.62	3.24	0.12	4.85	4.65	4.08	0.20
28	0.57	0.52	9.30	0.05	1.71	1.56	9.30	0.16	2.69	2.59	0.19	0.00	3.74	3.62	3.24	0.12	4.85	4.65	4.08	0.20
29	0.48	0.45	11.75	0.05	1.42	1.31	11.75	0.15	2.38	2.26	1.19	0.19	3.26	3.17	3.49	0.11	4.28	4.07	4.46	0.19
30	0.45	0.42	11.75	0.05	1.36	1.29	11.75	0.15	2.29	2.19	1.10	0.27	3.26	3.17	3.49	0.11	4.28	4.07	4.46	0.19
31	0.4	0.35	13.77	0.05	1.2	1.05	13.31	0.15	2.09	1.75	3.17	0.37	2.8	2.76	3.79	0.11	3.75	3.58	4.97	0.19
32	0.36	0.31	13.77	0.05	1.07	0.93	12.88	0.14	1.8	1.65	3.17	0.37	2.8	2.76	3.79	0.11	3.75	3.58	4.97	0.19
33	0.32	0.28	14.09	0.05	0.961	0.83	14.15	0.14	1.62	1.38	15.12	0.23	2.79	2.79	15.67	0.30	2.52	2.49	6.53	0.15
34	2.02	2.08	-5.53	-0.10	7.35	7.44	-1.22	-0.08	12.4	12.4	-0.00	0.00	17.7	17.78	1.93	0.34	22.0	20.92	5.53	0.56
35	1.76	1.76	0.00	0.01	5.3	5.24	1.17	0.09	8.73	8.73	0.00	0.00	14.7	14.66	0.95	0.14	18.2	18.72	2.58	0.49
36	1.54	1.49	3.51	0.05	4.53	4.46	1.59	0.07	7.43	7.43	0.00	0.00	12.5	12.22	2.22	0.28	16.2	16.72	3.00	0.49
37	1.35	1.31	3.28	0.04	3.84	3.82	-0.08	-0.04	6.83	6.83	0.00	0.00	9.22	9.14	0.85	0.09	11.8	11.76	1.28	0.10
38	1.19	1.12	5.35	0.07	3.24	3.17	4.98	0.03	5.42	5.42	0.00	0.00	8.94	7.87	2.14	0.17	10.3	10.12	1.79	0.18
39	1.0	0.95	5.14	0.08	2.8	2.74	4.11	0.03	4.23	4.23	0.00	0.00	7	6.82	2.60	0.18	9.01	8.77	2.71	0.24
40	0.925	0.85	6.64	0.08	2.5	2.4	4.11	0.03	4.23	4.23	0.00	0.00	7	6.82	2.60	0.18	9.01	8.77	2.71	0.24
41	0.831	0.74	9.07	0.09	2.3	2.22	3.45	0.08	3.7	3.7	0.00	0.00	5.36	5.18	3.38	0.19	6.92	6.61	3.69	0.31
42	0.720	0.65	10.44	0.09	2.2	2.15	11.36	0.25	3.25	3.25	0.00	0.00	4.72	4.65	3.90	0.17	6.12	5.85	4.44	0.27
43	0.65	0.57	11.69	0.09	1.66	1.72	12.14	0.24	2.87	2.87	0.00	0.00	4.17	4.02	3.65	0.15	6.41	6.17	4.61	0.24
44	0.61	0.51	12.66	0.07	1.78	1.82	13.41	0.24	2.54	2.54	0.00	0.00	3.7	3.66	3.69	0.14	4.8	4.67	4.75	0.22
45	0.62	0.45	13.46	0.07	1.57	1.56	14.01	0.22	2.24	2.24	0.00	0.00	3.3	3.15	4.55	0.16	4.27	4.05	6.15	0.22
46	3.82	3.88	-0.59	-0.04	11.4	11.57	-1.52	-0.17	19.29	19.29	-0.48	-0.09	27.9	27.00	3.21	0.50	35.7	34.72	2.75	0.98
47	3.22	3.24	-0.48	-0.02	9.59	9.71	-1.22	-0.17	16.1	16.16	-0.46	-0.08	23.4	22.85	3.21	0.75	30.4	29.12	4.21	1.28
48	2.79	2.72	0.51	0.01	8.08	8.15	-0.84	-0.07	13.6	13.58	0.16	0.02	19.8	18.81	3.00	0.89	26.6	24.44	4.62	1.16
49	2.38	2.31	2.98	0.07	6.92	6.92	-0.21	-0.01	11.6	11.56	0.38	0.04	16.5	16.18	2.62	0.42	21.8	20.89	4.57	1.50
50	2.1	2.06	2.28	0.04	6.04	6.09	-0.81	-0.05	10.19	10.19	-0.02	-0.02	14.2	14.22	-0.15	-0.02	16.6	16.28	1.70	0.19
51	1.8	1.75	2.85	0.03	5.25	5.25	-0.65	-0.05	8.73	8.73	0.00	0.00	12.4	12.24	1.80	0.18	15.9	15.76	1.03	0.15
52	1.63	1.58	3.19	0.03	4.45	4.45	-0.01	-0.01	7.3	7.29	-0.17	-0.02	10.4	10.4	1.30	0.13	12.2	11.84	2.82	0.32
53	1.44	1.32	6.61	0.12	3.91	3.85	-0.97	-0.04	6.59	6.59	0.16	0.01	8.28	8.21	1.70	0.17	12.2	11.84	2.82	0.32
54	1.26	1.16	10.07	0.13	3.42	3.45	-0.57	-0.03	5.79	5.76	0.08	0.00	8.24	8.05	3.39	0.28	10.7	10.38	3.19	0.34
55	1.13	1.01	16.92	0.12	3	3.03	-1.11	-0.03	5.09	5.09	0.09	0.00	7.34	7.00	3.67	0.20	9.48	9.10	4.01	0.38
56	0.903	0.79	12.49	0.11	2.64	2.68	-1.09	-0.03	4.48	4.48	-0.10	0.00	6.76	6.63	3.69	0.24	8.43	8.04	4.67	0.39
57	0.828	0.73	15.47	0.11	2.39	2.37	-1.31	-0.02	3.95	3.95	-0.09	0.00	6.12	6.03	3.87	0.23	7.48	7.11	4.92	0.37
58	0.828	0.73	15.47	0.11	2.39	2.37	-1.31	-0.02	3.51	3.50	0.28	0.01	5.12	4.90	4.50	0.22	6.83	6.39	5.41	0.58

Reference

D-9 FRONTLIGHT: 3m - 6m arrangement. The table shows the comparison between the illuminance levels calculated from the model using the computer software and the illuminance values manually estimated from the reference

APPENDIX D

Legend

- A Illuminance values calculated by lighting software
- B Estimated illuminance value from the reference indicated in bolds = (A x 380000 lumens) x Surface reflectance factor
- C Difference in % between A and B values = (A - B) / A x 100
- D Difference in Lux of the calculated values and the estimated values = A - B

10	20	30	40	50	60	70	80	90	100
0.08	0.16	0.24	0.32	0.40	0.48	0.56	0.64	0.72	0.80
0.09	0.18	0.27	0.36	0.45	0.54	0.63	0.72	0.81	0.90
0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
0.11	0.22	0.33	0.44	0.55	0.66	0.77	0.88	0.99	1.10
0.12	0.24	0.36	0.48	0.60	0.72	0.84	0.96	1.08	1.20
0.13	0.26	0.39	0.52	0.65	0.78	0.91	1.04	1.17	1.30
0.14	0.28	0.42	0.56	0.70	0.84	0.98	1.12	1.26	1.40
0.15	0.30	0.45	0.60	0.75	0.90	1.05	1.20	1.35	1.50
0.16	0.32	0.48	0.64	0.80	0.96	1.12	1.28	1.44	1.60
0.17	0.34	0.51	0.68	0.85	1.02	1.19	1.36	1.53	1.70
0.18	0.36	0.54	0.72	0.90	1.08	1.26	1.44	1.62	1.80
0.19	0.38	0.57	0.76	0.95	1.14	1.33	1.52	1.71	1.90
0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
0.21	0.42	0.63	0.84	1.05	1.26	1.47	1.68	1.89	2.10
0.22	0.44	0.66	0.88	1.10	1.32	1.54	1.76	1.98	2.20
0.23	0.46	0.69	0.92	1.15	1.38	1.60	1.82	2.04	2.30
0.24	0.48	0.72	0.96	1.20	1.44	1.66	1.88	2.10	2.40
0.25	0.50	0.75	1.00	1.25	1.50	1.72	1.94	2.16	2.50
0.26	0.52	0.78	1.04	1.30	1.56	1.78	2.00	2.22	2.60
0.27	0.54	0.81	1.08	1.35	1.62	1.84	2.06	2.28	2.70
0.28	0.56	0.84	1.12	1.40	1.68	1.90	2.12	2.34	2.80
0.29	0.58	0.87	1.16	1.45	1.74	1.96	2.18	2.40	2.90
0.30	0.60	0.90	1.20	1.50	1.80	2.02	2.24	2.46	3.00
0.31	0.62	0.93	1.24	1.55	1.86	2.08	2.30	2.52	3.10
0.32	0.64	0.96	1.28	1.60	1.92	2.14	2.36	2.58	3.20
0.33	0.66	0.99	1.32	1.65	1.98	2.20	2.42	2.64	3.30
0.34	0.68	1.02	1.36	1.70	2.04	2.26	2.48	2.70	3.40
0.35	0.70	1.05	1.40	1.75	2.10	2.32	2.54	2.76	3.50
0.36	0.72	1.08	1.44	1.80	2.16	2.38	2.60	2.82	3.60
0.37	0.74	1.11	1.48	1.85	2.22	2.44	2.66	2.88	3.70
0.38	0.76	1.14	1.52	1.90	2.28	2.50	2.72	2.94	3.80
0.39	0.78	1.17	1.56	1.95	2.34	2.56	2.78	3.00	3.90
0.40	0.80	1.20	1.60	2.00	2.40	2.62	2.84	3.06	4.00
0.41	0.82	1.23	1.64	2.05	2.46	2.68	2.90	3.12	4.10
0.42	0.84	1.26	1.68	2.10	2.52	2.74	2.96	3.18	4.20
0.43	0.86	1.29	1.72	2.15	2.58	2.80	3.02	3.24	4.30
0.44	0.88	1.32	1.76	2.20	2.64	2.86	3.08	3.30	4.40
0.45	0.90	1.35	1.80	2.25	2.70	2.92	3.14	3.36	4.50
0.46	0.92	1.38	1.84	2.30	2.76	2.98	3.20	3.42	4.60
0.47	0.94	1.41	1.88	2.35	2.82	3.04	3.26	3.48	4.70
0.48	0.96	1.44	1.92	2.40	2.88	3.10	3.32	3.54	4.80
0.49	0.98	1.47	1.96	2.45	2.94	3.16	3.38	3.60	4.90
0.50	1.00	1.50	2.00	2.50	3.00	3.22	3.44	3.66	5.00
0.51	1.02	1.53	2.04	2.55	3.06	3.28	3.50	3.72	5.10
0.52	1.04	1.56	2.08	2.60	3.12	3.34	3.56	3.78	5.20
0.53	1.06	1.59	2.12	2.65	3.18	3.40	3.62	3.84	5.30
0.54	1.08	1.62	2.16	2.70	3.24	3.46	3.68	3.90	5.40
0.55	1.10	1.65	2.20	2.75	3.30	3.52	3.74	3.96	5.50
0.56	1.12	1.68	2.24	2.80	3.36	3.58	3.80	4.02	5.60
0.57	1.14	1.71	2.28	2.85	3.42	3.64	3.86	4.08	5.70
0.58	1.16	1.74	2.32	2.90	3.48	3.70	3.92	4.14	5.80
0.59	1.18	1.77	2.36	2.95	3.54	3.76	3.98	4.20	5.90
0.60	1.20	1.80	2.40	3.00	3.60	3.82	4.04	4.26	6.00
0.61	1.22	1.83	2.44	3.05	3.66	3.88	4.10	4.32	6.10
0.62	1.24	1.86	2.48	3.10	3.72	3.94	4.16	4.38	6.20
0.63	1.26	1.89	2.52	3.15	3.78	4.00	4.22	4.44	6.30
0.64	1.28	1.92	2.56	3.20	3.84	4.06	4.28	4.50	6.40
0.65	1.30	1.95	2.60	3.25	3.90	4.12	4.34	4.56	6.50
0.66	1.32	1.98	2.64	3.30	3.96	4.18	4.40	4.62	6.60
0.67	1.34	2.01	2.68	3.35	4.02	4.24	4.46	4.68	6.70
0.68	1.36	2.04	2.72	3.40	4.08	4.30	4.52	4.74	6.80
0.69	1.38	2.07	2.76	3.45	4.14	4.36	4.58	4.80	6.90
0.70	1.40	2.10	2.80	3.50	4.20	4.42	4.64	4.86	7.00
0.71	1.42	2.13	2.84	3.55	4.26	4.48	4.70	4.92	7.10
0.72	1.44	2.16	2.88	3.60	4.32	4.54	4.76	4.98	7.20
0.73	1.46	2.19	2.92	3.65	4.38	4.60	4.82	5.04	7.30
0.74	1.48	2.22	2.96	3.70	4.44	4.66	4.88	5.10	7.40
0.75	1.50	2.25	3.00	3.75	4.50	4.72	4.94	5.16	7.50
0.76	1.52	2.28	3.04	3.80	4.56	4.78	5.00	5.22	7.60
0.77	1.54	2.31	3.08	3.85	4.62	4.84	5.06	5.28	7.70
0.78	1.56	2.34	3.12	3.90	4.68	4.90	5.12	5.34	7.80
0.79	1.58	2.37	3.16	3.95	4.74	4.96	5.18	5.40	7.90
0.80	1.60	2.40	3.20	4.00	4.80	5.02	5.24	5.46	8.00
0.81	1.62	2.43	3.24	4.05	4.86	5.08	5.30	5.52	8.10
0.82	1.64	2.46	3.28	4.10	4.92	5.14	5.36	5.58	8.20
0.83	1.66	2.49	3.32	4.15	4.98	5.20	5.42	5.64	8.30
0.84	1.68	2.52	3.36	4.20	5.04	5.26	5.48	5.70	8.40
0.85	1.70	2.55	3.40	4.25	5.10	5.32	5.54	5.76	8.50
0.86	1.72	2.58	3.44	4.30	5.16	5.38	5.60	5.82	8.60
0.87	1.74	2.61	3.48	4.35	5.22	5.44	5.66	5.88	8.70
0.88	1.76	2.64	3.52	4.40	5.28	5.50	5.72	5.94	8.80
0.89	1.78	2.67	3.56	4.45	5.34	5.56	5.78	6.00	8.90
0.90	1.80	2.70	3.60	4.50	5.40	5.62	5.84	6.06	9.00
0.91	1.82	2.73	3.64	4.55	5.46	5.68	5.90	6.12	9.10
0.92	1.84	2.76	3.68	4.60	5.52	5.74	5.96	6.18	9.20
0.93	1.86	2.79	3.72	4.65	5.58	5.80	6.02	6.24	9.30
0.94	1.88	2.82	3.76	4.70	5.64	5.86	6.08	6.30	9.40
0.95	1.90	2.85	3.80	4.75	5.70	5.92	6.14	6.36	9.50
0.96	1.92	2.88	3.84	4.80	5.76	5.98	6.20	6.42	9.60
0.97	1.94	2.91	3.88	4.85	5.82	6.04	6.26	6.48	9.70
0.98	1.96	2.94	3.92	4.90	5.88	6.10	6.32	6.54	9.80
0.99	1.98	2.97	3.96	4.95	5.94	6.16	6.38	6.60	9.90
1.00	2.00	3.00	4.00	5.00	6.00	6.22	6.44	6.66	10.00

Reference

D-10 FRONTLIGHT: 3m - 7m arrangement. The table shows the comparison between the illuminance levels calculated from the model using the computer software and the illuminance values manually estimated from the reference

APPENDIX D

Legend

- A Illuminance values calculated by lighting software
- B Estimated illuminance values from the reference indicated in bold = (A - 30000/Lumen) * Standard illuminance factor
- C Differences in % between A and B values = (A - B) / A * 100
- D Differences in Log of the calculated values and the estimated values = A - B

	10K				30K				50K				70K				90K			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
1.4	1.60	-18.07	-0.28	-0.38	4.62	4.68	-0.79	-0.36	8.24	8.36	-0.73	-0.08	11.6	11.62	-0.17	-0.02	15	14.94	0.00	0.06
1.2	1.39	-18.11	-0.19	-0.28	3.80	4.18	-0.46	-0.28	8.00	8.87	-0.87	-0.08	8.81	9.75	-0.94	0.00	12.7	12.84	1.25	0.16
1.0	1.00	-11.11	-0.19	-0.21	3.00	3.00	-0.00	-0.37	6.00	6.00	0.00	0.00	8.3	8.26	0.04	0.04	10.7	10.62	0.70	0.06
0.8	0.79	-6.65	-0.02	-0.06	2.30	2.30	-0.00	-0.21	4.60	4.60	0.00	-0.27	6.84	6.84	0.00	-0.11	9.15	9.00	1.42	0.13
0.6	0.69	-4.78	-0.04	-0.08	1.83	1.83	-0.00	-0.20	3.66	3.66	0.00	-0.27	5.49	5.49	0.00	-0.20	7.32	7.00	4.50	0.32
0.4	0.41	-3.39	0.03	0.03	1.41	1.41	0.00	-0.19	2.82	2.82	0.00	-0.19	4.16	4.16	0.00	-0.26	5.59	5.00	1.17	0.23
0.2	0.21	-2.44	0.02	0.02	1.05	1.05	0.00	-0.19	2.10	2.10	0.00	0.17	3.13	3.11	0.02	0.02	4.00	4.00	1.43	0.05
0.1	0.11	-1.83	0.01	0.01	0.77	0.77	0.00	-0.19	1.54	1.54	0.00	0.17	2.19	2.18	0.01	0.01	2.84	2.84	1.30	0.05
0.05	0.05	-1.39	0.01	0.01	0.56	0.56	0.00	-0.19	1.12	1.12	0.00	0.17	1.59	1.58	0.01	0.01	2.11	2.09	1.52	0.04
0.02	0.02	-1.04	0.01	0.01	0.41	0.41	0.00	-0.19	0.81	0.81	0.00	0.17	1.07	1.06	0.01	0.01	1.41	1.41	1.41	0.00
0.01	0.01	-0.79	0.01	0.01	0.30	0.30	0.00	-0.19	0.59	0.59	0.00	0.17	0.78	0.77	0.01	0.01	1.00	1.00	1.00	0.00
0.005	0.005	-0.60	0.01	0.01	0.22	0.22	0.00	-0.19	0.44	0.44	0.00	0.17	0.58	0.57	0.01	0.01	0.75	0.74	1.33	0.18
0.002	0.002	-0.46	0.01	0.01	0.16	0.16	0.00	-0.19	0.32	0.32	0.00	0.17	0.42	0.41	0.01	0.01	0.55	0.54	1.46	0.09
0.001	0.001	-0.35	0.01	0.01	0.11	0.11	0.00	-0.19	0.23	0.23	0.00	0.17	0.30	0.29	0.01	0.01	0.40	0.39	1.50	0.09
0.0005	0.0005	-0.26	0.01	0.01	0.08	0.08	0.00	-0.19	0.17	0.17	0.00	0.17	0.22	0.21	0.01	0.01	0.30	0.29	1.50	0.09
0.0002	0.0002	-0.19	0.01	0.01	0.06	0.06	0.00	-0.19	0.12	0.12	0.00	0.17	0.16	0.01	0.01	0.22	0.21	1.70	0.18	
0.0001	0.0001	-0.14	0.01	0.01	0.04	0.04	0.00	-0.19	0.08	0.08	0.00	0.17	0.11	0.06	0.05	0.21	0.21	1.88	0.29	
0.00005	0.00005	-0.10	0.01	0.01	0.03	0.03	0.00	-0.19	0.06	0.06	0.00	0.17	0.08	0.05	0.21	0.21	0.21	0.21	1.88	0.29
0.00002	0.00002	-0.07	0.01	0.01	0.02	0.02	0.00	-0.19	0.04	0.04	0.00	0.17	0.06	0.05	0.21	0.21	0.21	0.21	1.88	0.29
0.00001	0.00001	-0.05	0.01	0.01	0.01	0.01	0.00	-0.19	0.03	0.03	0.00	0.17	0.05	0.05	0.21	0.21	0.21	0.21	1.88	0.29
0.000005	0.000005	-0.04	0.01	0.01	0.01	0.01	0.00	-0.19	0.02	0.02	0.00	0.17	0.04	0.04	0.21	0.21	0.21	0.21	1.88	0.29
0.000002	0.000002	-0.03	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.03	0.03	0.21	0.21	0.21	0.21	1.88	0.29
0.000001	0.000001	-0.02	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.02	0.02	0.21	0.21	0.21	0.21	1.88	0.29
0.0000005	0.0000005	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.0000002	0.0000002	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.0000001	0.0000001	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.00000005	0.00000005	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.00000002	0.00000002	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.00000001	0.00000001	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.000000005	0.000000005	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.000000002	0.000000002	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.000000001	0.000000001	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.0000000005	0.0000000005	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.0000000002	0.0000000002	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.0000000001	0.0000000001	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.00000000005	0.00000000005	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.00000000002	0.00000000002	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.00000000001	0.00000000001	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.000000000005	0.000000000005	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.000000000002	0.000000000002	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.000000000001	0.000000000001	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.0000000000005	0.0000000000005	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.0000000000002	0.0000000000002	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.0000000000001	0.0000000000001	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.00000000000005	0.00000000000005	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.00000000000002	0.00000000000002	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.00000000000001	0.00000000000001	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.000000000000005	0.000000000000005	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.000000000000002	0.000000000000002	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.000000000000001	0.000000000000001	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.0000000000000005	0.0000000000000005	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.0000000000000002	0.0000000000000002	-0.01	0.01	0.01	0.01	0.01	0.00	-0.19	0.01	0.01	0.00	0.17	0.01	0.01	0.21	0.21	0.21	0.21	1.88	0.29
0.0000000000000001	0.0000000000000001																			

APPENDIX D

Legend

- A Illuminance values calculated by lighting software
- B Estimated Illuminance value from the reference footcandle in foot-candles = (A x 300000/Lumen) x Surface reflectance factor
- C Differences in % between A and B values = (A - B) / A x 100
- D Differences in Lux of the calculated values and the estimated values = A - B

10	15K	20	30	40	50	70	90	100	120	150	200
A	B	C	D	A	B	C	D	A	B	C	D
1	1.19	-10.03	-0.19	3.4	3.6	-0.20	-0.16	6.14	6.07	-0.07	-0.07
0.79	0.86	-0.06	-0.14	4.8	4.8	0.00	-0.00	8.54	8.54	0.00	0.00
0.61	0.61	0.00	0.00	2.4	2.89	-0.49	-0.16	4.1	4.30	-0.20	-0.20
0.81	0.81	0.00	0.00	2.22	2.71	-0.49	-0.16	3.70	3.70	0.00	0.00
0.53	0.52	0.01	0.01	1.5	1.5	0.00	0.00	3.17	3.17	0.00	0.00
0.47	0.45	0.02	0.02	1.4	1.36	0.04	0.04	2.97	2.97	0.00	0.00
0.39	0.35	0.04	0.04	1.2	1.19	0.01	0.01	2.70	2.77	-0.07	-0.07
0.32	0.35	-0.03	-0.03	1.1	1.04	0.06	0.06	2.44	2.42	0.02	0.02
0.27	0.27	0.00	0.00	0.89	0.91	-0.02	-0.02	2.21	2.13	0.08	0.08
0.23	0.24	-0.01	-0.01	0.77	0.80	-0.03	-0.03	1.98	1.88	0.10	0.10
0.23	0.21	0.02	0.02	0.71	0.72	-0.01	-0.01	1.83	1.69	0.14	0.14
0.2	0.18	0.02	0.02	0.69	0.63	0.06	0.06	1.65	1.55	0.10	0.10
0.2	0.18	0.02	0.02	0.62	0.56	0.06	0.06	1.54	1.43	0.11	0.11
20	2.19	-15.15	-0.20	6.17	6.66	-0.49	-0.20	10.9	10.64	0.26	0.26
1.7	1.68	-0.02	-0.02	6.25	6.67	-0.42	-0.20	9.28	9.20	-0.08	-0.08
1.6	1.58	-0.02	-0.02	4.48	4.73	-0.25	-0.25	7.76	7.59	0.17	0.17
1.3	1.36	-0.06	-0.06	3.64	4.07	-0.43	-0.23	6.43	6.78	-0.35	-0.35
1.1	1.16	-0.07	-0.07	3.3	3.49	-0.19	-0.19	5.54	5.81	-0.27	-0.27
0.99	0.96	0.03	0.03	2.85	2.87	-0.02	-0.02	4.78	4.79	0.00	0.00
0.92	0.92	0.00	0.00	2.65	2.65	0.00	0.00	4.15	4.15	0.00	0.00
0.76	0.72	0.04	0.04	2.06	2.17	-0.11	-0.11	3.13	3.17	-0.04	-0.04
0.69	0.62	0.07	0.07	1.90	1.90	0.00	0.00	2.79	2.79	0.00	0.00
0.59	0.56	0.03	0.03	1.76	1.67	0.09	0.09	2.39	2.39	0.00	0.00
0.53	0.49	0.04	0.04	1.69	1.47	0.22	0.22	2.18	1.73	0.45	0.45
0.47	0.44	0.03	0.03	1.42	1.31	0.11	0.11	2.3	2.18	0.12	0.12
0.42	0.38	0.04	0.04	1.27	1.16	0.11	0.11	2.19	1.93	0.26	0.26
0.3	0.34	-0.04	-0.04	1.14	1.00	0.14	0.14	1.91	1.72	0.19	0.19
30	3.4	-5.29	-0.18	10.0	10.74	-0.74	-0.14	17.8	17.8	0.00	0.00
2.4	2.58	-0.18	-0.18	7.57	7.72	-0.15	-0.17	13.8	13.8	0.00	0.00
2.1	2.22	-0.12	-0.12	6.37	6.66	-0.29	-0.31	11.5	11.5	0.00	0.00
1.8	1.90	-0.12	-0.12	5.4	5.71	-0.31	-0.31	9.61	9.61	0.00	0.00
1.4	1.46	-0.06	-0.06	4.05	4.08	-0.03	-0.03	7.83	7.83	0.00	0.00
1.1	1.16	-0.06	-0.06	3.65	3.66	-0.01	-0.01	6.8	6.8	0.00	0.00
1.1	1.16	-0.06	-0.06	3.65	3.66	-0.01	-0.01	6.8	6.8	0.00	0.00
0.97	0.91	0.06	0.06	2.72	2.74	-0.02	-0.02	4.68	4.68	0.00	0.00
0.85	0.80	0.05	0.05	2.43	2.41	0.02	0.02	4.02	4.02	0.00	0.00
0.69	0.71	-0.02	-0.02	2.32	2.14	0.18	0.18	3.68	3.68	0.00	0.00
0.61	0.56	0.05	0.05	2.07	1.90	0.17	0.17	3.18	3.18	0.00	0.00
0.51	0.53	-0.02	-0.02	1.80	1.89	-0.09	-0.17	2.82	2.82	0.00	0.00
10	1.0	-5.29	-0.18	10.0	10.74	-0.74	-0.14	17.8	17.8	0.00	0.00
0.74	0.74	0.00	0.00	7.57	7.72	-0.15	-0.17	13.8	13.8	0.00	0.00
0.63	0.63	0.00	0.00	6.37	6.66	-0.29	-0.31	11.5	11.5	0.00	0.00
0.54	0.54	0.00	0.00	5.4	5.71	-0.31	-0.31	9.61	9.61	0.00	0.00
0.44	0.44	0.00	0.00	4.05	4.08	-0.03	-0.03	7.83	7.83	0.00	0.00
0.34	0.34	0.00	0.00	3.65	3.66	-0.01	-0.01	6.8	6.8	0.00	0.00
0.24	0.24	0.00	0.00	2.72	2.74	-0.02	-0.02	4.68	4.68	0.00	0.00
0.14	0.14	0.00	0.00	2.43	2.41	0.02	0.02	4.02	4.02	0.00	0.00
0.04	0.04	0.00	0.00	2.32	2.14	0.18	0.18	3.68	3.68	0.00	0.00
0.04	0.04	0.00	0.00	2.07	1.90	0.17	0.17	3.18	3.18	0.00	0.00
0.04	0.04	0.00	0.00	1.80	1.89	-0.09	-0.17	2.82	2.82	0.00	0.00
50K	5.24	-5.29	-0.05	16.5	16.71	-0.21	-0.21	28.3	27.64	0.66	0.66
4.44	4.78	-0.34	-0.34	14	14.19	-0.19	-0.19	24.1	23.64	0.45	0.45
3.79	3.91	-0.12	-0.12	12	12.04	-0.25	-0.25	20.8	20.07	0.73	0.73
3.19	3.18	0.01	0.01	10	10	0.00	0.00	18	18	0.00	0.00
2.77	2.98	-0.21	-0.21	8.66	8.68	-0.02	-0.02	15	14.79	0.21	0.21
2.41	2.44	-0.03	-0.03	7.25	7.31	-0.06	-0.06	12.8	12.16	0.62	0.62
2.18	2.12	0.06	0.06	6.3	6.35	-0.05	-0.05	11.1	10.58	0.42	0.42
1.92	1.84	0.08	0.08	5.49	5.53	-0.04	-0.04	9.8	9.22	0.58	0.58
1.7	1.61	0.09	0.09	4.8	4.83	-0.03	-0.03	8.66	8.06	0.60	0.60
1.51	1.52	-0.01	-0.01	4.22	4.26	-0.04	-0.04	7.59	7.06	0.53	0.53
1.31	1.32	-0.01	-0.01	3.65	3.68	-0.03	-0.03	6.8	6.38	0.42	0.42
1.19	1.11	0.08	0.08	3.28	3.32	-0.04	-0.04	5.83	5.54	0.29	0.29
1.07	1.08	-0.01	-0.01	2.93	2.95	-0.02	-0.02	4.91	4.92	-0.01	-0.01
0.956	0.88	0.076	0.076	2.61	2.63	-0.02	-0.02	4.38	4.39	-0.01	-0.01
30K	3.4	-5.29	-0.18	10.0	10.74	-0.74	-0.14	17.8	17.8	0.00	0.00
2.4	2.58	-0.18	-0.18	7.57	7.72	-0.15	-0.17	13.8	13.8	0.00	0.00
2.1	2.22	-0.12	-0.12	6.37	6.66	-0.29	-0.31	11.5	11.5	0.00	0.00
1.8	1.90	-0.12	-0.12	5.4	5.71	-0.31	-0.31	9.61	9.61	0.00	0.00
1.4	1.46	-0.06	-0.06	4.05	4.08	-0.03	-0.03	7.83	7.83	0.00	0.00
1.1	1.16	-0.06	-0.06	3.65	3.66	-0.01	-0.01	6.8	6.8	0.00	0.00
0.97	0.91	0.06	0.06	2.72	2.74	-0.02	-0.02	4.68	4.68	0.00	0.00
0.85	0.80	0.05	0.05	2.43	2.41	0.02	0.02	4.02	4.02	0.00	0.00
0.69	0.71	-0.02	-0.02	2.32	2.14	0.18	0.18	3.68	3.68	0.00	0.00
0.61	0.56	0.05	0.05	2.07	1.90	0.17	0.17	3.18	3.18	0.00	0.00
0.51	0.53	-0.02	-0.02	1.80	1.89	-0.09	-0.17	2.82	2.82	0.00	0.00
10K	1.0	-5.29	-0.18	10.0	10.74	-0.74	-0.14	17.8	17.8	0.00	0.00
0.74	0.74	0.00	0.00	7.57	7.72	-0.15	-0.17	13.8	13.8	0.00	0.00
0.63	0.63	0.00	0.00	6.37	6.66	-0.29	-0.31	11.5	11.5	0.00	0.00
0.54	0.54	0.00	0.00	5.4	5.71	-0.31	-0.31	9.61	9.61	0.00	0.00
0.44	0.44	0.00	0.00	4.05	4.08	-0.03	-0.03	7.83	7.83	0.00	0.00
0.34	0.34	0.00	0.00	3.65	3.66	-0.01	-0.01	6.8	6.8	0.00	0.00
0.24	0.24	0.00	0.00	2.72	2.74	-0.02	-0.02	4.68	4.68	0.00	0.00
0.14	0.14	0.00	0.00	2.43	2.41	0.02	0.02	4.02	4.02	0.00	0.00
0.04	0.04	0.00	0.00	2.32	2.14	0.18	0.18	3.68	3.68	0.00	0.00
0.04	0.04	0.00	0.00	2.07	1.90	0.17	0.17	3.18	3.18	0.00	0.00
0.04	0.04	0.00	0.00	1.80	1.89	-0.09	-0.17	2.82	2.82	0.00	0.00
50K	5.24	-5.29	-0.05	16.5	16.71	-0.21	-0.21	28.3	27.64	0.66	0.66
4.44	4.78	-0.34	-0.34	14	14.19	-0.19	-0.19	24.1	23.64	0.45	0.45
3.79	3.91	-0.12	-0.12	12	12.04	-0.25	-0.25	20.8	20.07	0.73	0.73
3.19	3.18	0.01	0.01	10	10	0.00	0.00	18	18	0.00	0.00
2.77	2.98	-0.21	-0.21	8.66	8.68	-0.02	-0.02	15	14.79	0.21	0.21
2.41	2.44	-0.03	-0.03	7.25	7.31	-0.06	-0.06	12.8	12.16	0.62	0.62
2.18	2.12	0.06	0.06	6.3	6.35	-0.05	-0.05	11.1	10.58	0.42	0.42
1.92	1.84	0.08	0.08	5.49	5.53	-0.04	-0.04	9.8	9.22	0.58	0.58
1.7	1.61	0.09	0.09	4.8							

APPENDIX D

Legend

A	Illuminance values calculated by lighting software
B	Estimated Illuminance value from the reference indicated in bold = (A x 35000/Lumen) x Surface reflectance factor
C	Differences in % between A and B values = (A - B) / (A) x 100
D	Differences in Lux of the calculated values and the estimated values = A - B

12K	30				70				90			
	A	B	C	D	A	B	C	D	A	B	C	D
0.6	0.67	0.75	-0.17	-0.07	4.18	4.37	-0.19	-0.19	6.68	6.11	0.57	0.57
0.8	0.81	0.84	-0.03	-0.06	3.59	3.73	-0.14	-0.14	5.05	5.23	-0.18	-0.18
0.9	0.93	0.94	-0.01	-0.01	3.20	3.20	0.00	0.00	4.33	4.48	-0.15	-0.15
1.0	0.98	0.98	0.00	0.00	2.85	2.85	0.00	0.00	3.74	3.75	-0.01	-0.01
1.1	0.91	0.96	0.05	0.05	2.58	2.30	0.28	0.28	3.22	3.22	0.00	0.00
1.2	0.84	0.98	0.14	0.14	2.38	2.08	0.30	0.30	2.85	2.85	0.00	0.00
1.3	0.78	0.93	0.15	0.15	2.21	1.75	0.46	0.46	2.51	2.51	0.00	0.00
1.4	0.72	0.88	0.16	0.16	2.06	1.59	0.47	0.47	2.21	2.14	0.07	0.07
1.5	0.66	0.84	0.18	0.18	1.92	1.35	0.57	0.57	1.92	1.85	0.07	0.07
1.6	0.61	0.81	0.20	0.20	1.79	1.19	0.60	0.60	1.69	1.69	0.00	0.00
1.7	0.56	0.78	0.22	0.22	1.67	1.05	0.62	0.62	1.47	1.47	0.00	0.00
1.8	0.51	0.75	0.24	0.24	1.55	0.94	0.61	0.61	1.27	1.27	0.00	0.00
1.9	0.46	0.72	0.26	0.26	1.44	0.84	0.60	0.60	1.09	1.09	0.00	0.00
2.0	0.41	0.69	0.28	0.28	1.34	0.75	0.59	0.59	0.93	0.93	0.00	0.00
2.1	0.37	0.66	0.29	0.29	1.24	0.66	0.58	0.58	0.79	0.79	0.00	0.00
2.2	0.33	0.63	0.30	0.30	1.15	0.58	0.57	0.57	0.66	0.66	0.00	0.00
2.3	0.29	0.60	0.31	0.31	1.07	0.51	0.56	0.56	0.54	0.54	0.00	0.00
2.4	0.25	0.57	0.32	0.32	1.00	0.44	0.56	0.56	0.43	0.43	0.00	0.00
2.5	0.21	0.54	0.33	0.33	0.93	0.38	0.55	0.55	0.34	0.34	0.00	0.00
2.6	0.17	0.51	0.34	0.34	0.87	0.32	0.54	0.54	0.26	0.26	0.00	0.00
2.7	0.13	0.48	0.35	0.35	0.81	0.26	0.54	0.54	0.19	0.19	0.00	0.00
2.8	0.09	0.45	0.36	0.36	0.76	0.20	0.54	0.54	0.13	0.13	0.00	0.00
2.9	0.05	0.42	0.37	0.37	0.71	0.14	0.54	0.54	0.08	0.08	0.00	0.00
3.0	0.01	0.39	0.38	0.38	0.66	0.08	0.54	0.54	0.03	0.03	0.00	0.00
3.1	0.00	0.36	0.39	0.39	0.61	0.02	0.54	0.54	0.00	0.00	0.00	0.00
3.2	0.00	0.33	0.40	0.40	0.56	0.00	0.54	0.54	0.00	0.00	0.00	0.00
3.3	0.00	0.30	0.41	0.41	0.51	0.00	0.54	0.54	0.00	0.00	0.00	0.00
3.4	0.00	0.27	0.42	0.42	0.46	0.00	0.54	0.54	0.00	0.00	0.00	0.00
3.5	0.00	0.24	0.43	0.43	0.41	0.00	0.54	0.54	0.00	0.00	0.00	0.00
3.6	0.00	0.21	0.44	0.44	0.36	0.00	0.54	0.54	0.00	0.00	0.00	0.00
3.7	0.00	0.18	0.45	0.45	0.31	0.00	0.54	0.54	0.00	0.00	0.00	0.00
3.8	0.00	0.15	0.46	0.46	0.26	0.00	0.54	0.54	0.00	0.00	0.00	0.00
3.9	0.00	0.12	0.47	0.47	0.21	0.00	0.54	0.54	0.00	0.00	0.00	0.00
4.0	0.00	0.09	0.48	0.48	0.16	0.00	0.54	0.54	0.00	0.00	0.00	0.00
4.1	0.00	0.06	0.49	0.49	0.11	0.00	0.54	0.54	0.00	0.00	0.00	0.00
4.2	0.00	0.03	0.50	0.50	0.06	0.00	0.54	0.54	0.00	0.00	0.00	0.00
4.3	0.00	0.00	0.51	0.51	0.01	0.00	0.54	0.54	0.00	0.00	0.00	0.00
4.4	0.00	0.00	0.52	0.52	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
4.5	0.00	0.00	0.53	0.53	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
4.6	0.00	0.00	0.54	0.54	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
4.7	0.00	0.00	0.55	0.55	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
4.8	0.00	0.00	0.56	0.56	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
4.9	0.00	0.00	0.57	0.57	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
5.0	0.00	0.00	0.58	0.58	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
5.1	0.00	0.00	0.59	0.59	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
5.2	0.00	0.00	0.60	0.60	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
5.3	0.00	0.00	0.61	0.61	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
5.4	0.00	0.00	0.62	0.62	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
5.5	0.00	0.00	0.63	0.63	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
5.6	0.00	0.00	0.64	0.64	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
5.7	0.00	0.00	0.65	0.65	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
5.8	0.00	0.00	0.66	0.66	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
5.9	0.00	0.00	0.67	0.67	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
6.0	0.00	0.00	0.68	0.68	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
6.1	0.00	0.00	0.69	0.69	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
6.2	0.00	0.00	0.70	0.70	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
6.3	0.00	0.00	0.71	0.71	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
6.4	0.00	0.00	0.72	0.72	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
6.5	0.00	0.00	0.73	0.73	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
6.6	0.00	0.00	0.74	0.74	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
6.7	0.00	0.00	0.75	0.75	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
6.8	0.00	0.00	0.76	0.76	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
6.9	0.00	0.00	0.77	0.77	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
7.0	0.00	0.00	0.78	0.78	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
7.1	0.00	0.00	0.79	0.79	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
7.2	0.00	0.00	0.80	0.80	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
7.3	0.00	0.00	0.81	0.81	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
7.4	0.00	0.00	0.82	0.82	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
7.5	0.00	0.00	0.83	0.83	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
7.6	0.00	0.00	0.84	0.84	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
7.7	0.00	0.00	0.85	0.85	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
7.8	0.00	0.00	0.86	0.86	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
7.9	0.00	0.00	0.87	0.87	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
8.0	0.00	0.00	0.88	0.88	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
8.1	0.00	0.00	0.89	0.89	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
8.2	0.00	0.00	0.90	0.90	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
8.3	0.00	0.00	0.91	0.91	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
8.4	0.00	0.00	0.92	0.92	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
8.5	0.00	0.00	0.93	0.93	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
8.6	0.00	0.00	0.94	0.94	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
8.7	0.00	0.00	0.95	0.95	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
8.8	0.00	0.00	0.96	0.96	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
8.9	0.00	0.00	0.97	0.97	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
9.0	0.00	0.00	0.98	0.98	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
9.1	0.00	0.00	0.99	0.99	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
9.2	0.00	0.00	1.00	1.00	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
9.3	0.00	0.00	1.01	1.01	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00
9.4	0.00	0.00	1.02	1.02	0.00	0.00	0.54	0.54	0.00			

APPENDIX D

Legend

- A Illuminance values calculated by lighting software
- B Estimated illuminance value from the reference indicated in table = (A x 36000 Lumen) x Surface reflectance factor
- C Differences in % between A and B values = (A - B) / A x 100
- D Differences in Lux of the calculated values and the estimated values = A - B

	12K				30K				50K				70K				90K			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
10	0.51	0.62	-0.09	-0.04	1.8	1.04	-0.77	-0.14	3.13	3.23	-0.10	-0.10	4.41	4.02	-0.39	-0.11	6.71	5.81	-0.90	-0.10
15	0.30	0.35	-0.05	-0.14	1.0	1.04	-0.30	-0.04	2.5	2.73	-0.13	-0.13	3.6	3.83	-0.23	-0.03	4.92	4.92	0.00	0.00
20	0.21	0.25	-0.04	-0.14	0.7	0.7	-0.17	-0.04	1.6	1.6	0.00	0.00	2.35	2.35	0.00	0.00	3.28	3.28	0.00	0.00
25	0.16	0.19	-0.03	-0.14	0.5	0.5	-0.03	0.06	1.0	1.0	0.00	0.00	1.45	1.45	0.00	0.00	1.95	1.95	0.00	0.00
30	0.12	0.15	-0.03	-0.14	0.35	0.35	0.00	0.06	0.7	0.7	0.00	0.00	1.0	1.0	0.00	0.00	1.35	1.35	0.00	0.00
35	0.09	0.11	-0.02	-0.14	0.25	0.25	0.00	0.06	0.5	0.5	0.00	0.00	0.7	0.7	0.00	0.00	0.95	0.95	0.00	0.00
40	0.07	0.08	-0.01	-0.14	0.18	0.18	0.00	0.06	0.35	0.35	0.00	0.00	0.5	0.5	0.00	0.00	0.65	0.65	0.00	0.00
45	0.05	0.06	-0.01	-0.14	0.13	0.13	0.00	0.06	0.25	0.25	0.00	0.00	0.35	0.35	0.00	0.00	0.45	0.45	0.00	0.00
50	0.04	0.04	0.00	-0.14	0.1	0.1	0.00	0.06	0.18	0.18	0.00	0.00	0.25	0.25	0.00	0.00	0.3	0.3	0.00	0.00
55	0.03	0.03	0.00	-0.14	0.07	0.07	0.00	0.06	0.13	0.13	0.00	0.00	0.18	0.18	0.00	0.00	0.22	0.22	0.00	0.00
60	0.02	0.02	0.00	-0.14	0.05	0.05	0.00	0.06	0.1	0.1	0.00	0.00	0.13	0.13	0.00	0.00	0.16	0.16	0.00	0.00
65	0.01	0.01	0.00	-0.14	0.04	0.04	0.00	0.06	0.07	0.07	0.00	0.00	0.1	0.1	0.00	0.00	0.12	0.12	0.00	0.00
70	0.01	0.01	0.00	-0.14	0.03	0.03	0.00	0.06	0.05	0.05	0.00	0.00	0.07	0.07	0.00	0.00	0.09	0.09	0.00	0.00
75	0.01	0.01	0.00	-0.14	0.02	0.02	0.00	0.06	0.04	0.04	0.00	0.00	0.05	0.05	0.00	0.00	0.06	0.06	0.00	0.00
80	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.03	0.03	0.00	0.00	0.04	0.04	0.00	0.00	0.05	0.05	0.00	0.00
85	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.02	0.02	0.00	0.00	0.03	0.03	0.00	0.00	0.04	0.04	0.00	0.00
90	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.02	0.02	0.00	0.00	0.03	0.03	0.00	0.00
95	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.02	0.02	0.00	0.00
100	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
105	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
110	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
115	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
120	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
125	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
130	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
135	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
140	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
145	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
150	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
155	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
160	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
165	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
170	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
175	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
180	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
185	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
190	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
195	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
200	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
205	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
210	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
215	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
220	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
225	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
230	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
235	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
240	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
245	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
250	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
255	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
260	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
265	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
270	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
275	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
280	0.01	0.01	0.00	-0.14	0.01	0.01	0.00	0.06	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
285	0.01	0.01	0.00	-0.14	0.01	0.01	0.00													

APPENDIX D

Layend

A Illuminance values calculated by lighting software
 B Estimated illuminance value from the reference indicated
 in bold = (A x 3000/Lumen) x Surface reflectance factor
 C Difference in %, between
 A and B values = (A - B) / A x 100
 D Difference in Lux of the calculated values and
 the estimated values = A - B

10K				20K				30K				40K				50K				60K																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
1.8	2.17	-20.37	-0.37	5.77	6.05	-12.05	-0.73	10.2	10.83	-6.21	-0.63	14.4	15.17	-5.32	-0.77	18.6	19.50	-4.84	-0.90	22.8	23.82	-4.84	-1.04	27.0	28.22	-5.32	-1.18	31.2	32.72	-5.32	-1.32	35.4	37.22	-5.32	-1.46	39.6	41.72	-5.32	-1.60	43.8	46.22	-5.32	-1.74	48.0	50.72	-5.32	-1.88	52.2	55.22	-5.32	-2.02	56.4	59.72	-5.32	-2.16	60.6	64.22	-5.32	-2.30	64.8	68.72	-5.32	-2.44	69.0	73.22	-5.32	-2.58	73.2	77.72	-5.32	-2.72	77.4	82.22	-5.32	-2.86	81.6	86.72	-5.32	-3.00	85.8	91.22	-5.32	-3.14	90.0	95.72	-5.32	-3.28	94.2	100.22	-5.32	-3.42	98.4	104.72	-5.32	-3.56	102.6	109.22	-5.32	-3.70	106.8	113.72	-5.32	-3.84	111.0	118.22	-5.32	-3.98	115.2	122.72	-5.32	-4.12	119.4	127.22	-5.32	-4.26	123.6	131.72	-5.32	-4.40	127.8	136.22	-5.32	-4.54	132.0	140.72	-5.32	-4.68	136.2	145.22	-5.32	-4.82	140.4	149.72	-5.32	-4.96	144.6	154.22	-5.32	-5.10	148.8	158.72	-5.32	-5.24	153.0	163.22	-5.32	-5.38	157.2	167.72	-5.32	-5.52	161.4	172.22	-5.32	-5.66	165.6	176.72	-5.32	-5.80	169.8	181.22	-5.32	-5.94	174.0	185.72	-5.32	-6.08	178.2	190.22	-5.32	-6.22	182.4	194.72	-5.32	-6.36	186.6	199.22	-5.32	-6.50	190.8	203.72	-5.32	-6.64	195.0	208.22	-5.32	-6.78	199.2	212.72	-5.32	-6.92	203.4	217.22	-5.32	-7.06	207.6	221.72	-5.32	-7.20	211.8	226.22	-5.32	-7.34	216.0	230.72	-5.32	-7.48	220.2	235.22	-5.32	-7.62	224.4	239.72	-5.32	-7.76	228.6	244.22	-5.32	-7.90	232.8	248.72	-5.32	-8.04	237.0	253.22	-5.32	-8.18	241.4	257.72	-5.32	-8.32	245.6	262.22	-5.32	-8.46	249.8	266.72	-5.32	-8.60	254.0	271.22	-5.32	-8.74	258.2	275.72	-5.32	-8.88	262.4	280.22	-5.32	-9.02	266.6	284.72	-5.32	-9.16	270.8	289.22	-5.32	-9.30	275.0	293.72	-5.32	-9.44	279.2	298.22	-5.32	-9.58	283.4	302.72	-5.32	-9.72	287.6	307.22	-5.32	-9.86	291.8	311.72	-5.32	-10.00	296.0	316.22	-5.32	-10.14	300.2	320.72	-5.32	-10.28	304.4	325.22	-5.32	-10.42	308.6	329.72	-5.32	-10.56	312.8	334.22	-5.32	-10.70	317.0	338.72	-5.32	-10.84	321.2	343.22	-5.32	-10.98	325.4	347.72	-5.32	-11.12	329.6	352.22	-5.32	-11.26	333.8	356.72	-5.32	-11.40	338.0	361.22	-5.32	-11.54	342.2	365.72	-5.32	-11.68	346.4	370.22	-5.32	-11.82	350.6	374.72	-5.32	-11.96	354.8	379.22	-5.32	-12.10	359.0	383.72	-5.32	-12.24	363.2	388.22	-5.32	-12.38	367.4	392.72	-5.32	-12.52	371.6	397.22	-5.32	-12.66	375.8	401.72	-5.32	-12.80	380.0	406.22	-5.32	-12.94	384.2	410.72	-5.32	-13.08	388.4	415.22	-5.32	-13.22	392.6	419.72	-5.32	-13.36	396.8	424.22	-5.32	-13.50	401.0	428.72	-5.32	-13.64	405.2	433.22	-5.32	-13.78	409.4	437.72	-5.32	-13.92	413.6	442.22	-5.32	-14.06	417.8	446.72	-5.32	-14.20	422.0	451.22	-5.32	-14.34	426.2	455.72	-5.32	-14.48	430.4	460.22	-5.32	-14.62	434.6	464.72	-5.32	-14.76	438.8	469.22	-5.32	-14.90	443.0	473.72	-5.32	-15.04	447.2	478.22	-5.32	-15.18	451.4	482.72	-5.32	-15.32	455.6	487.22	-5.32	-15.46	459.8	491.72	-5.32	-15.60	464.0	496.22	-5.32	-15.74	468.2	500.72	-5.32	-15.88	472.4	505.22	-5.32	-16.02	476.6	509.72	-5.32	-16.16	480.8	514.22	-5.32	-16.30	485.0	518.72	-5.32	-16.44	489.2	523.22	-5.32	-16.58	493.4	527.72	-5.32	-16.72	497.6	532.22	-5.32	-16.86	501.8	536.72	-5.32	-17.00	506.0	541.22	-5.32	-17.14	510.2	545.72	-5.32	-17.28	514.4	550.22	-5.32	-17.42	518.6	554.72	-5.32	-17.56	522.8	559.22	-5.32	-17.70	527.0	563.72	-5.32	-17.84	531.4	568.22	-5.32	-17.98	535.6	572.72	-5.32	-18.12	539.8	577.22	-5.32	-18.26	544.0	581.72	-5.32	-18.40	548.2	586.22	-5.32	-18.54	552.4	590.72	-5.32	-18.68	556.6	595.22	-5.32	-18.82	560.8	599.72	-5.32	-18.96	565.0	604.22	-5.32	-19.10	569.2	608.72	-5.32	-19.24	573.4	613.22	-5.32	-19.38	577.6	617.72	-5.32	-19.52	581.8	622.22	-5.32	-19.66	586.0	626.72	-5.32	-19.80	590.2	631.22	-5.32	-19.94	594.4	635.72	-5.32	-20.08	598.6	640.22	-5.32	-20.22	602.8	644.72	-5.32	-20.36	607.0	649.22	-5.32	-20.50	611.2	653.72	-5.32	-20.64	615.4	658.22	-5.32	-20.78	619.6	662.72	-5.32	-20.92	623.8	667.22	-5.32	-21.06	628.0	671.72	-5.32	-21.20	632.2	676.22	-5.32	-21.34	636.4	680.72	-5.32	-21.48	640.6	685.22	-5.32	-21.62	644.8	689.72	-5.32	-21.76	649.0	694.22	-5.32	-21.90	653.2	698.72	-5.32	-22.04	657.4	703.22	-5.32	-22.18	661.6	707.72	-5.32	-22.32	665.8	712.22	-5.32	-22.46	670.0	716.72	-5.32	-22.60	674.2	721.22	-5.32	-22.74	678.4	725.72	-5.32	-22.88	682.6	730.22	-5.32	-23.02	686.8	734.72	-5.32	-23.16	691.0	739.22	-5.32	-23.30	695.2	743.72	-5.32	-23.44	699.4	748.22	-5.32	-23.58	703.6	752.72	-5.32	-23.72	707.8	757.22	-5.32	-23.86	712.0	761.72	-5.32	-24.00	716.2	766.22	-5.32	-24.14	720.4	770.72	-5.32	-24.28	724.6	775.22	-5.32	-24.42	728.8	779.72	-5.32	-24.56	733.0	784.22	-5.32	-24.70	737.2	788.72	-5.32	-24.84	741.4	793.22	-5.32	-24.98	745.6	797.72	-5.32	-25.12	749.8	802.22	-5.32	-25.26	754.0	806.72	-5.32	-25.40	758.2	811.22	-5.32	-25.54	762.4	815.72	-5.32	-25.68	766.6	820.22	-5.32	-25.82	770.8	824.72	-5.32	-25.96	775.0	829.22	-5.32	-26.10	779.2	833.72	-5.32	-26.24	783.4	838.22	-5.32	-26.38	787.6	842.72	-5.32	-26.52	791.8	847.22	-5.32	-26.66	796.0	851.72	-5.32	-26.80	800.2	856.22	-5.32	-26.94	804.4	860.72	-5.32	-27.08	808.6	865.22	-5.32	-27.22	812.8	869.72	-5.32	-27.36	817.0	874.22	-5.32	-27.50	821.2	878.72	-5.32	-27.64	825.4	883.22	-5.32	-27.78	829.6	887.72	-5.32	-27.92	833.8	892.22	-5.32	-28.06	838.0	896.72	-5.32	-28.20	842.2	901.22	-5.32	-28.34	846.4	905.72	-5.32	-28.48	850.6	910.22	-5.32	-28.62	854.8	914.72	-5.32	-28.76	859.0	919.22	-5.32	-28.90	863.2	923.72	-5.32	-29.04	867.4	928.22	-5.32	-29.18	871.6	932.72	-5.32	-29.32	875.8	937.22	-5.32	-29.46	880.0	941.72	-5.32	-29.60	884.2	946.22	-5.32	-29.74	888.4	950.72	-5.32	-29.88	892.6	955.22	-5.32	-30.02	896.8	959.72	-5.32	-30.16	901.0	964.22	-5.32	-30.30	905.2	968.72	-5.32	-30.44	909.4	973.22	-5.32	-30.58	913.6	977.72	-5.32	-30.72	917.8	982.22	-5.32	-30.86	922.0	986.72	-5.32	-31.00	926.2	991.22	-5.32	-31.14	930.4	995.72	-5.32	-31.28	934.6	1000.22	-5.32	-31.42	938.8	1004.72	-5.32	-31.56	943.0	1009.22	-5.32	-31.70	947.2	1013.72	-5.32	-31.84	951.4	1018.22	-5.32	-31.98	955.6	1022.72	-5.32	-32.12	959.8	1027.22	-5.32	-32.26	964.0	1031.72	-5.32	-32.40	968.2	1036.22	-5.32	-32.54	972.4	1040.72	-5.32	-32.68	976.6	1045.22	-5.32	-32.82	980.8	1049.72	-5.32	-32.96	985.0	1054.22	-5.32	-33.10	989.2	1058.72	-5.32	-33.24	993.4	1063.22	-5.32	-33.38	997.6	1067.72	-5.32	-33.52	1001.8	1072.22	-5.32	-33.66	1006.0	1076.72	-5.32	-33.80	1010.2	1081.22	-5.32	-33.94	1014.4	1085.72	-5.32	-34.08	1018.6	1090.22	-5.32	-34.22	1022.8	1094.72	-5.32	-34.36	1027.0	1099.22	-5.32	-34.50	1031.2	1103.72	-5.32	-34.64	1035.4	1108.22	-5.32	-34.78	1039.6	1112.72	-5.32	-34.92	1043.8	1117.22	-5.32	-35.06	1048.0	1121.72	-5.32	-35.20	1052.2	1126.22	-5.32	-35.34	1056.4	1130.72	-5.32	-35.48	1060.6	1135.22	-5.32	-35.62	1064.8	1139.72	-5.32	-35.76	1069.0	1144.22	-5.32	-35.90	1073.2	1148.72	-5.32	-36.04	1077.4	1153.22	-5.32	-36.18	1081.6	1157.72	-5.32	-36.32	1085.8	1162.22	-5.32	-36.46	1090.0	1166.72	-5.32	-36.60	1094.2	1171.22	-5.32	-36.74	1098.4	1175.72	-5.32	-36.88	1102.6	1180.22	-5.32	-37.02	1106.8	1184.72	-5.32	-37.16	1111.0	1189.22	-5.32	-37.30	1115.2	1193.72	-5.32	-37.44	1119.4	1198.22	-5.32	-37.58	1123.6	1202.72	-5.32	-37.72	1127.8	1207.22	-5.32	-37.86	1132.0	1211.72	-5.32	-38.00	1136.2	1216.22	-5.32	-38.14	1140.4	1220.72	-5.32	-38.28	1144.6	1225.22	-5.32	-38.42	1148.8	1229.72	-5.32	-38.56	1153.0	1234.22	-5.32	-38.70	1157.2	1238.72	-5.32	-38.84	1161.4	1243.22	-5.32	-38.98	1165.6	1247.72	-5.32	-39.12	1169.8	1252.22	-5.32	-39.26	1174.0	1256.72	-5.32	-39.40	1178.2	1261.22	-5.32	-39.54	1182.4	1265.72	-5.32	-39.68	1186.6	1270.22	-5.32	-39.82	1190.8	1274.72	-5.32	-39.96	1195.0	1279.22	-5.32	-40.10	1199.2	1283.72	-5.32	-40.24	1203.4	1288.22	-5.32	-40.38	1207.6	1292.72	-5.32	-40.52	1211.8	1297.22	-5.32	-40.66	1216.0	1301.72	-5.32	-40.80	1220.

APPENDIX D

Legend

- A Illuminance values calculated by lighting software
- B Estimated illuminance values from the reference indicated in bold = (A x adjustment) / Surface reflectance factor
- C Differences in % between A and B values = (A - B) / A x 100
- D Differences in Lux of the calculated values and the estimated values = A - B

	10K				20K				30K				50K				70K				90K			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
10	1.19	1.19	-0.00	0.00	3.2	3.2	-0.00	0.00	5.39	5.37	-0.02	0.00	7.7	7.7	-0.00	0.00	10.4	10.4	-0.00	0.00	13.3	13.3	-0.00	0.00
1.1	1.05	1.05	-0.00	0.00	2.9	2.9	-0.00	0.00	4.66	4.64	-0.02	0.00	6.57	6.57	-0.00	0.00	8.83	8.83	-0.00	0.00	11.5	11.5	-0.00	0.00
1.2	1.19	1.19	-0.00	0.00	3.2	3.2	-0.00	0.00	5.39	5.37	-0.02	0.00	7.7	7.7	-0.00	0.00	10.4	10.4	-0.00	0.00	13.3	13.3	-0.00	0.00
1.3	1.38	1.38	-0.00	0.00	4.4	4.4	-0.00	0.00	7.5	7.5	-0.00	0.00	10.4	10.4	-0.00	0.00	13.3	13.3	-0.00	0.00	17.4	17.4	-0.00	0.00
1.4	1.58	1.58	-0.00	0.00	5.6	5.6	-0.00	0.00	9.8	9.8	-0.00	0.00	13.3	13.3	-0.00	0.00	17.4	17.4	-0.00	0.00	21.5	21.5	-0.00	0.00
1.5	1.78	1.78	-0.00	0.00	6.8	6.8	-0.00	0.00	12.1	12.1	-0.00	0.00	16.5	16.5	-0.00	0.00	21.5	21.5	-0.00	0.00	25.6	25.6	-0.00	0.00
1.6	1.98	1.98	-0.00	0.00	8.0	8.0	-0.00	0.00	14.4	14.4	-0.00	0.00	19.8	19.8	-0.00	0.00	25.6	25.6	-0.00	0.00	29.7	29.7	-0.00	0.00
1.7	2.18	2.18	-0.00	0.00	9.2	9.2	-0.00	0.00	16.7	16.7	-0.00	0.00	22.5	22.5	-0.00	0.00	29.7	29.7	-0.00	0.00	33.8	33.8	-0.00	0.00
1.8	2.38	2.38	-0.00	0.00	10.4	10.4	-0.00	0.00	19.0	19.0	-0.00	0.00	25.6	25.6	-0.00	0.00	33.8	33.8	-0.00	0.00	37.9	37.9	-0.00	0.00
1.9	2.58	2.58	-0.00	0.00	11.6	11.6	-0.00	0.00	21.3	21.3	-0.00	0.00	28.1	28.1	-0.00	0.00	37.9	37.9	-0.00	0.00	42.0	42.0	-0.00	0.00
2.0	2.78	2.78	-0.00	0.00	12.8	12.8	-0.00	0.00	23.6	23.6	-0.00	0.00	30.1	30.1	-0.00	0.00	42.0	42.0	-0.00	0.00	46.1	46.1	-0.00	0.00
2.1	2.98	2.98	-0.00	0.00	14.0	14.0	-0.00	0.00	25.9	25.9	-0.00	0.00	32.4	32.4	-0.00	0.00	46.1	46.1	-0.00	0.00	50.2	50.2	-0.00	0.00
2.2	3.18	3.18	-0.00	0.00	15.2	15.2	-0.00	0.00	28.2	28.2	-0.00	0.00	34.7	34.7	-0.00	0.00	50.2	50.2	-0.00	0.00	54.3	54.3	-0.00	0.00
2.3	3.38	3.38	-0.00	0.00	16.4	16.4	-0.00	0.00	30.5	30.5	-0.00	0.00	37.0	37.0	-0.00	0.00	54.3	54.3	-0.00	0.00	58.4	58.4	-0.00	0.00
2.4	3.58	3.58	-0.00	0.00	17.6	17.6	-0.00	0.00	32.8	32.8	-0.00	0.00	39.3	39.3	-0.00	0.00	58.4	58.4	-0.00	0.00	62.5	62.5	-0.00	0.00
2.5	3.78	3.78	-0.00	0.00	18.8	18.8	-0.00	0.00	35.1	35.1	-0.00	0.00	41.6	41.6	-0.00	0.00	62.5	62.5	-0.00	0.00	66.6	66.6	-0.00	0.00
2.6	3.98	3.98	-0.00	0.00	20.0	20.0	-0.00	0.00	37.4	37.4	-0.00	0.00	43.9	43.9	-0.00	0.00	66.6	66.6	-0.00	0.00	70.7	70.7	-0.00	0.00
2.7	4.18	4.18	-0.00	0.00	21.2	21.2	-0.00	0.00	39.7	39.7	-0.00	0.00	46.2	46.2	-0.00	0.00	70.7	70.7	-0.00	0.00	74.8	74.8	-0.00	0.00
2.8	4.38	4.38	-0.00	0.00	22.4	22.4	-0.00	0.00	42.0	42.0	-0.00	0.00	48.5	48.5	-0.00	0.00	74.8	74.8	-0.00	0.00	78.9	78.9	-0.00	0.00
2.9	4.58	4.58	-0.00	0.00	23.6	23.6	-0.00	0.00	44.3	44.3	-0.00	0.00	50.8	50.8	-0.00	0.00	78.9	78.9	-0.00	0.00	83.0	83.0	-0.00	0.00
3.0	4.78	4.78	-0.00	0.00	24.8	24.8	-0.00	0.00	46.6	46.6	-0.00	0.00	53.1	53.1	-0.00	0.00	83.0	83.0	-0.00	0.00	87.1	87.1	-0.00	0.00
3.1	4.98	4.98	-0.00	0.00	26.0	26.0	-0.00	0.00	48.9	48.9	-0.00	0.00	55.4	55.4	-0.00	0.00	87.1	87.1	-0.00	0.00	91.2	91.2	-0.00	0.00
3.2	5.18	5.18	-0.00	0.00	27.2	27.2	-0.00	0.00	51.2	51.2	-0.00	0.00	57.7	57.7	-0.00	0.00	91.2	91.2	-0.00	0.00	95.3	95.3	-0.00	0.00
3.3	5.38	5.38	-0.00	0.00	28.4	28.4	-0.00	0.00	53.5	53.5	-0.00	0.00	60.0	60.0	-0.00	0.00	95.3	95.3	-0.00	0.00	99.4	99.4	-0.00	0.00
3.4	5.58	5.58	-0.00	0.00	29.6	29.6	-0.00	0.00	55.8	55.8	-0.00	0.00	62.3	62.3	-0.00	0.00	99.4	99.4	-0.00	0.00	103.5	103.5	-0.00	0.00
3.5	5.78	5.78	-0.00	0.00	30.8	30.8	-0.00	0.00	58.1	58.1	-0.00	0.00	64.6	64.6	-0.00	0.00	103.5	103.5	-0.00	0.00	107.6	107.6	-0.00	0.00
3.6	5.98	5.98	-0.00	0.00	32.0	32.0	-0.00	0.00	60.4	60.4	-0.00	0.00	66.9	66.9	-0.00	0.00	107.6	107.6	-0.00	0.00	111.7	111.7	-0.00	0.00
3.7	6.18	6.18	-0.00	0.00	33.2	33.2	-0.00	0.00	62.7	62.7	-0.00	0.00	69.2	69.2	-0.00	0.00	111.7	111.7	-0.00	0.00	115.8	115.8	-0.00	0.00
3.8	6.38	6.38	-0.00	0.00	34.4	34.4	-0.00	0.00	65.0	65.0	-0.00	0.00	71.5	71.5	-0.00	0.00	115.8	115.8	-0.00	0.00	119.9	119.9	-0.00	0.00
3.9	6.58	6.58	-0.00	0.00	35.6	35.6	-0.00	0.00	67.3	67.3	-0.00	0.00	73.8	73.8	-0.00	0.00	119.9	119.9	-0.00	0.00	124.0	124.0	-0.00	0.00
4.0	6.78	6.78	-0.00	0.00	36.8	36.8	-0.00	0.00	69.6	69.6	-0.00	0.00	76.1	76.1	-0.00	0.00	124.0	124.0	-0.00	0.00	128.1	128.1	-0.00	0.00
4.1	6.98	6.98	-0.00	0.00	38.0	38.0	-0.00	0.00	71.9	71.9	-0.00	0.00	78.4	78.4	-0.00	0.00	128.1	128.1	-0.00	0.00	132.2	132.2	-0.00	0.00
4.2	7.18	7.18	-0.00	0.00	39.2	39.2	-0.00	0.00	74.2	74.2	-0.00	0.00	80.7	80.7	-0.00	0.00	132.2	132.2	-0.00	0.00	136.3	136.3	-0.00	0.00
4.3	7.38	7.38	-0.00	0.00	40.4	40.4	-0.00	0.00	76.5	76.5	-0.00	0.00	83.0	83.0	-0.00	0.00	136.3	136.3	-0.00	0.00	140.4	140.4	-0.00	0.00
4.4	7.58	7.58	-0.00	0.00	41.6	41.6	-0.00	0.00	78.8	78.8	-0.00	0.00	85.3	85.3	-0.00	0.00	140.4	140.4	-0.00	0.00	144.5	144.5	-0.00	0.00
4.5	7.78	7.78	-0.00	0.00	42.8	42.8	-0.00	0.00	81.1	81.1	-0.00	0.00	87.6	87.6	-0.00	0.00	144.5	144.5	-0.00	0.00	148.6	148.6	-0.00	0.00
4.6	7.98	7.98	-0.00	0.00	44.0	44.0	-0.00	0.00	83.4	83.4	-0.00	0.00	90.0	90.0	-0.00	0.00	148.6	148.6	-0.00	0.00	152.7	152.7	-0.00	0.00
4.7	8.18	8.18	-0.00	0.00	45.2	45.2	-0.00	0.00	85.7	85.7	-0.00	0.00	92.3	92.3	-0.00	0.00	152.7	152.7	-0.00	0.00	156.8	156.8	-0.00	0.00
4.8	8.38	8.38	-0.00	0.00	46.4	46.4	-0.00	0.00	88.0	88.0	-0.00	0.00	94.6	94.6	-0.00	0.00	156.8	156.8	-0.00	0.00	160.9	160.9	-0.00	0.00
4.9	8.58	8.58	-0.00	0.00	47.6	47.6	-0.00	0.00	90.3	90.3	-0.00	0.00	96.9	96.9	-0.00	0.00	160.9	160.9	-0.00	0.00	165.0	165.0	-0.00	0.00
5.0	8.78	8.78	-0.00	0.00	48.8	48.8	-0.00	0.00	92.6	92.6	-0.00	0.00	99.2	99.2	-0.00	0.00	165.0	165.0	-0.00	0.00	169.1	169.1	-0.00	0.00
5.1	8.98	8.98	-0.00	0.00	50.0	50.0	-0.00	0.00	94.9	94.9	-0.00	0.00	101.5	101.5	-0.00	0.00	169.1	169.1	-0.00	0.00	173.2	173.2	-0.00	0.00
5.2	9.18	9.18	-0.00	0.00	51.2	51.2	-0.00	0.00	97.2	97.2	-0.00	0.00	103.8	103.8	-0.00	0.00	173.2	173.2	-0.00	0.00	177.3	177.3	-0.00	0.00
5.3	9.38	9.38	-0.00	0.00	52.4	52.4	-0.00	0.00	99.5	99.5	-0.00	0.00	106.1	106.1	-0.00	0.00	177.3	177.3	-0.00	0.00	181.4	181.4	-0.00	0.00
5.4	9.58	9.58	-0.00	0.00	53.6	53.6	-0.00	0.00	101.8	101.8	-0.00	0.00	108.4	108.4	-0.00	0.00	181.4	181.4	-0.00	0.00	185.5	185.5	-0.00	0.00
5.5	9.78	9.78	-0.00	0.00	54.8	54.8	-0.00	0.00	104.1	104.1	-0.00	0.00	110.7	110.7	-0.00	0.00	185.5	185.5	-0.00	0.00	189.6	189.6	-0.00	0.00
5.6	9.98	9.98																						

APPENDIX D

Legend

- A Illuminance values calculated by lighting software
- B Estimated Illuminance value from the reference indicated in table = (A x 3000/cumulative Surface reflectance factor)
- C Differences in % between A and B value = (A - B) / A x 100
- D Differences in Lux of the calculated values and the estimated values = A - B

10K				20K				30K				40K				50K				60K				70K				80K																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
0.78	0.87	-10.85	0.08	2.1	2.62	-22.2	-6.17	4.06	4.37	-7.62	-0.32	5.71	6.11	-7.00	-0.60	7.58	7.68	-1.30	-0.48	15.3	14.7	0.50	0.60	23.1	23.4	-0.30	-0.30	31.0	30.8	0.20	0.20	38.8	38.5	0.30	0.30	46.6	46.4	0.20	0.20	54.4	54.2	0.20	0.20	62.2	62.0	0.20	0.20	70.0	69.8	0.20	0.20	77.8	77.6	0.20	0.20	85.6	85.4	0.20	0.20	93.4	93.2	0.20	0.20	101.2	101.0	0.20	0.20	109.0	108.8	0.20	0.20	116.8	116.6	0.20	0.20	124.6	124.4	0.20	0.20	132.4	132.2	0.20	0.20	140.2	140.0	0.20	0.20	148.0	147.8	0.20	0.20	155.8	155.6	0.20	0.20	163.6	163.4	0.20	0.20	171.4	171.2	0.20	0.20	179.2	179.0	0.20	0.20	187.0	186.8	0.20	0.20	194.8	194.6	0.20	0.20	202.6	202.4	0.20	0.20	210.4	210.2	0.20	0.20	218.2	218.0	0.20	0.20	226.0	225.8	0.20	0.20	233.8	233.6	0.20	0.20	241.6	241.4	0.20	0.20	249.4	249.2	0.20	0.20	257.2	257.0	0.20	0.20	265.0	264.8	0.20	0.20	272.8	272.6	0.20	0.20	280.6	280.4	0.20	0.20	288.4	288.2	0.20	0.20	296.2	296.0	0.20	0.20	304.0	303.8	0.20	0.20	311.8	311.6	0.20	0.20	319.6	319.4	0.20	0.20	327.4	327.2	0.20	0.20	335.2	335.0	0.20	0.20	343.0	342.8	0.20	0.20	350.8	350.6	0.20	0.20	358.6	358.4	0.20	0.20	366.4	366.2	0.20	0.20	374.2	374.0	0.20	0.20	382.0	381.8	0.20	0.20	389.8	389.6	0.20	0.20	397.6	397.4	0.20	0.20	405.4	405.2	0.20	0.20	413.2	413.0	0.20	0.20	421.0	420.8	0.20	0.20	428.8	428.6	0.20	0.20	436.6	436.4	0.20	0.20	444.4	444.2	0.20	0.20	452.2	452.0	0.20	0.20	460.0	459.8	0.20	0.20	467.8	467.6	0.20	0.20	475.6	475.4	0.20	0.20	483.4	483.2	0.20	0.20	491.2	491.0	0.20	0.20	499.0	498.8	0.20	0.20	506.8	506.6	0.20	0.20	514.6	514.4	0.20	0.20	522.4	522.2	0.20	0.20	530.2	530.0	0.20	0.20	538.0	537.8	0.20	0.20	545.8	545.6	0.20	0.20	553.6	553.4	0.20	0.20	561.4	561.2	0.20	0.20	569.2	569.0	0.20	0.20	577.0	576.8	0.20	0.20	584.8	584.6	0.20	0.20	592.6	592.4	0.20	0.20	600.4	600.2	0.20	0.20	608.2	608.0	0.20	0.20	616.0	615.8	0.20	0.20	623.8	623.6	0.20	0.20	631.6	631.4	0.20	0.20	639.4	639.2	0.20	0.20	647.2	647.0	0.20	0.20	655.0	654.8	0.20	0.20	662.8	662.6	0.20	0.20	670.6	670.4	0.20	0.20	678.4	678.2	0.20	0.20	686.2	686.0	0.20	0.20	694.0	693.8	0.20	0.20	701.8	701.6	0.20	0.20	709.6	709.4	0.20	0.20	717.4	717.2	0.20	0.20	725.2	725.0	0.20	0.20	733.0	732.8	0.20	0.20	740.8	740.6	0.20	0.20	748.6	748.4	0.20	0.20	756.4	756.2	0.20	0.20	764.2	764.0	0.20	0.20	772.0	771.8	0.20	0.20	779.8	779.6	0.20	0.20	787.6	787.4	0.20	0.20	795.4	795.2	0.20	0.20	803.2	803.0	0.20	0.20	811.0	810.8	0.20	0.20	818.8	818.6	0.20	0.20	826.6	826.4	0.20	0.20	834.4	834.2	0.20	0.20	842.2	842.0	0.20	0.20	850.0	849.8	0.20	0.20	857.8	857.6	0.20	0.20	865.6	865.4	0.20	0.20	873.4	873.2	0.20	0.20	881.2	881.0	0.20	0.20	889.0	888.8	0.20	0.20	896.8	896.6	0.20	0.20	904.6	904.4	0.20	0.20	912.4	912.2	0.20	0.20	920.2	920.0	0.20	0.20	928.0	927.8	0.20	0.20	935.8	935.6	0.20	0.20	943.6	943.4	0.20	0.20	951.4	951.2	0.20	0.20	959.2	959.0	0.20	0.20	967.0	966.8	0.20	0.20	974.8	974.6	0.20	0.20	982.6	982.4	0.20	0.20	990.4	990.2	0.20	0.20	998.2	998.0	0.20	0.20	1006.0	1005.8	0.20	0.20	1013.8	1013.6	0.20	0.20	1021.6	1021.4	0.20	0.20	1029.4	1029.2	0.20	0.20	1037.2	1037.0	0.20	0.20	1045.0	1044.8	0.20	0.20	1052.8	1052.6	0.20	0.20	1060.6	1060.4	0.20	0.20	1068.4	1068.2	0.20	0.20	1076.2	1076.0	0.20	0.20	1084.0	1083.8	0.20	0.20	1091.8	1091.6	0.20	0.20	1100.0	1099.8	0.20	0.20	1108.0	1107.8	0.20	0.20	1116.0	1115.8	0.20	0.20	1124.0	1123.8	0.20	0.20	1132.0	1131.8	0.20	0.20	1140.0	1139.8	0.20	0.20	1148.0	1147.8	0.20	0.20	1156.0	1155.8	0.20	0.20	1164.0	1163.8	0.20	0.20	1172.0	1171.8	0.20	0.20	1180.0	1179.8	0.20	0.20	1188.0	1187.8	0.20	0.20	1196.0	1195.8	0.20	0.20	1204.0	1203.8	0.20	0.20	1212.0	1211.8	0.20	0.20	1220.0	1219.8	0.20	0.20	1228.0	1227.8	0.20	0.20	1236.0	1235.8	0.20	0.20	1244.0	1243.8	0.20	0.20	1252.0	1251.8	0.20	0.20	1260.0	1259.8	0.20	0.20	1268.0	1267.8	0.20	0.20	1276.0	1275.8	0.20	0.20	1284.0	1283.8	0.20	0.20	1292.0	1291.8	0.20	0.20	1300.0	1299.8	0.20	0.20	1308.0	1307.8	0.20	0.20	1316.0	1315.8	0.20	0.20	1324.0	1323.8	0.20	0.20	1332.0	1331.8	0.20	0.20	1340.0	1339.8	0.20	0.20	1348.0	1347.8	0.20	0.20	1356.0	1355.8	0.20	0.20	1364.0	1363.8	0.20	0.20	1372.0	1371.8	0.20	0.20	1380.0	1379.8	0.20	0.20	1388.0	1387.8	0.20	0.20	1396.0	1395.8	0.20	0.20	1404.0	1403.8	0.20	0.20	1412.0	1411.8	0.20	0.20	1420.0	1419.8	0.20	0.20	1428.0	1427.8	0.20	0.20	1436.0	1435.8	0.20	0.20	1444.0	1443.8	0.20	0.20	1452.0	1451.8	0.20	0.20	1460.0	1459.8	0.20	0.20	1468.0	1467.8	0.20	0.20	1476.0	1475.8	0.20	0.20	1484.0	1483.8	0.20	0.20	1492.0	1491.8	0.20	0.20	1500.0	1499.8	0.20	0.20	1508.0	1507.8	0.20	0.20	1516.0	1515.8	0.20	0.20	1524.0	1523.8	0.20	0.20	1532.0	1531.8	0.20	0.20	1540.0	1539.8	0.20	0.20	1548.0	1547.8	0.20	0.20	1556.0	1555.8	0.20	0.20	1564.0	1563.8	0.20	0.20	1572.0	1571.8	0.20	0.20	1580.0	1579.8	0.20	0.20	1588.0	1587.8	0.20	0.20	1596.0	1595.8	0.20	0.20	1604.0	1603.8	0.20	0.20	1612.0	1611.8	0.20	0.20	1620.0	1619.8	0.20	0.20	1628.0	1627.8	0.20	0.20	1636.0	1635.8	0.20	0.20	1644.0	1643.8	0.20	0.20	1652.0	1651.8	0.20	0.20	1660.0	1659.8	0.20	0.20	1668.0	1667.8	0.20	0.20	1676.0	1675.8	0.20	0.20	1684.0	1683.8	0.20	0.20	1692.0	1691.8	0.20	0.20	1700.0	1699.8	0.20	0.20	1708.0	1707.8	0.20	0.20	1716.0	1715.8	0.20	0.20	1724.0	1723.8	0.20	0.20	1732.0	1731.8	0.20	0.20	1740.0	1739.8	0.20	0.20	1748.0	1747.8	0.20	0.20	1756.0	1755.8	0.20	0.20	1764.0	1763.8	0.20	0.20	1772.0	1771.8	0.20	0.20	1780.0	1779.8	0.20	0.20	1788.0	1787.8	0.20	0.20	1796.0	1795.8	0.20	0.20	1804.0	1803.8	0.20	0.20	1812.0	1811.8	0.20	0.20	1820.0	1819.8	0.20	0.20	1828.0	1827.8	0.20	0.20	1836.0	1835.8	0.20	0.20	1844.0	1843.8	0.20	0.20	1852.0	1851.8	0.20	0.20	1860.0	1859.8	0.20	0.20	1868.0	1867.8	0.20	0.20	1876.0	1875.8	0.20	0.20	1884.0	1883.8	0.20	0.20	1892.0	1891.8	0.20	0.20	1900.0	1899.8	0.20	0.20	1908.0	1907.8	0.20	0.20	1916.0	1915.8	0.20	0.20	1924.0	1923.8	0.20	0.20	1932.0	1931.8	0.20	0.20	1940.0	1939.8	0.20	0.20	1948.0	1947.8	0.20	0.20	1956.0	1955.8	0.20	0.20	1964.0	1963.8	0.20	0.20	1972.0	1971.8	0.20	0.20	1980.0	1979.8	0.20	0.20	1988.0	1987.8	0.20	0.20	1996.0	1995.8	0.20	0.20	2004.0	2003.8	0.20	0.20	2012.0	2011.8	0.20	0.20	2020.0	2019.8	0.20	0.20	2028.0	2027.8	0.20	0.20	2036.0	2035.8	0.20	0.20	2044.0	2043.8	0.20	0.20	2052.0	2051.8	0.20	0.20	2060.0	2059.8	0.20	0.20	2068.0	2067.8	0.20	0.20	2076.0	2075.8	0.20	0.20	2084.0	2083.8	0.20	0.20	2092.0	2091.8	0.20	0.20	2100.0	2099.8	0.20	0.20	2108.0	2107.8	0.20	0.20	2116.0	2115.8	0.20	0.20	2124.0	2123.8	0.20	0.20	2132.0	2131.8	0.20	0.20	2140.0	2139.8	0.20	0.20	2148.0	2147.8	0.20	0.20	2156.0	2155.8	0.20	0.20	2164.0	2163.8	0.20	0.20	2172.0	2171.8	0.20	0.20	2180.0	2179.8	0.20	0.20	2188.0	2187.8	0.20	0.20	2196.0	2195.8	0.20	0.20	2204.0	2203.8	0.20	0.20	2212.0	2211.8	0.20	0.20	2220.0	2219.8	0.20	0.20	2228.0	2227.8	0.20	0.20	2236.0	2235.8	0.20	0.20	2244.0	2243.8	0.20	0.20	2252.0	2251.8	0.20	0.20	2260.0	2259.8	0.20	0.20	2268.0	2267.8	0.20	0.20	2276.0	2275.8	0.20	0.20	2284.0	2283.8	0.20	0.20	2292.0	2291.8	0.20	0.20	2300.0	2299.8	0.20	0.20	2308.0	2307.8	0.20	0.2

