

EVALUATING LIGHTSCAPE'S ACCURACY FOR PREDICTING DAYLIGHTING ILLUMINANCE COMPARED TO AN ACTUAL SPACE

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ABSTRACT

The purpose of this research is to evaluate the accuracy of Lightscape as a preliminary daylighting design tool and to calculate a correction coefficient factor that could be used in early design processes.

In preparation for this research, a pilot study was conducted to test Lightscape's ability to produce daylighting illuminance measurements that are close to measurements recorded from the actual space. The subsequent research analyzed Lightscape's performance on the Gainesville (Florida) Regional Utilities atrium space. Comparisons between both computer-generated models and the actual atrium space indicated that the Interior Solution – *one of Lightscape's preset Parameters* – provided the most accurate daylighting illuminance measurements. Measurements recorded were seventeen to thirty five percent (17-35%) of the illuminance measurements of the actual atrium.

Therefore, it was concluded that Lightscape is an accurate daylighting-predicting tool to be used in preliminary design process. Moreover, the correction coefficient factor for the measurements could be utilized to provide better estimates of daylighting illuminance in interior environments.

1. INTRODUCTION

Increasing productivity has become a compelling economic rationale for supplementing electric lighting with daylighting. The obstacle of incorporating daylighting in

design is the lack of procedures that help designers predict daylight in a simple, useful, and accurate manner. There are a multitude of calculations that must be performed in the daily work of designing lighting for interior environments. Some calculations are performed using a simple calculator. Others often involve complex geometry and intense calculations. Lightscape is useful in complex situation, because designers can create models to study both the visual effects of different lighting solutions and to gather illuminance data.

Although previous studies [1,2,3,4] give us valuable information about Lightscape's performance and accuracy, several questions are still unanswered. Most of the studies discussed above were performed to either test the impact of daylighting on the users, or test a group of computer simulation programs regarding their ability to convey a realistic image of the built environment. The only study that tested Lightscape's accuracy as a daylighting design tool was Renfro and Guglielmetti's study. However, their study was conducted using a simple physical model, to compare the illuminance data collected from the physical model with that of a computer-generated model (CGM). The purpose of this research is to analyze the accuracy of Lightscape in predicting and representing illuminance in interior environments. Understanding the accuracy of this design tool will assist and encourage designers who wish to incorporate daylighting design into their projects.

1.1 Pilot Study

A pilot study was performed to determine what structure and methods should be to evaluate Lightscape. The purpose

of the study was to test the effect of two factors on the accuracy of Lightscape. The two factors are:

- 1) Lightscape's Daylight Parameter with two levels:
 - a) Interior Space.
 - b) Exterior-Interior Space.
- 2) Model Complexity, which has three levels:
 - a) Simple model.
 - b) Moderate model.
 - c) Detailed model.

Testing two major factors resulted in a six factor-level combination. Measurements from all of those factor-level combinations were recorded and comparison analysis with measurements from the actual space tested the accuracy of Lightscape's data.

Process Parameters is a feature built into Lightscape that allows the user to instruct the software about what type of space it will simulate. In the Process Parameters there is the Quality Wizard, which runs the appropriate calculations and determines the spacing of the surface mesh units, and other information used for the model simulation. In the Quality Wizard, there are five different level selections that determine the quality of the simulation required, scaling from one: lower quality – *requires less time and memory*, to five: higher quality – *requires more time and memory*. Level three – *the default* – was used for this research's purposes. Once the quality level is chosen, it is required to identify whether daylighting is introduced into the space or not – *this is the first factor in the study which is called Daylight Parameter*. There are three selections in the Daylight Parameter, the first sets the model to be an Interior space, second sets the model to be an Exterior space and the third selection sets the model to be an Exterior-Interior space. This study tested two selections from the Daylight Parameters – a) Interior space, and b) Exterior-Interior space. These two parameters differ in regard to what part of the model they use to gather the data for the lighting calculation. The Interior space uses only the interior surfaces whereas the Exterior-Interior uses a combination of interior and exterior surfaces.

In the pilot study, Lightscape's performance – *accuracy of predicting daylight illuminance* – was tested in a classroom setting in the College of Design, Construction and Planning building at the University of Florida. Based on Renfro and Guglielmetti's [1] conclusion – *that Lightscape is inaccurate with indirect light from the north sky* – it was decided that the classroom should be located on the south façade of the building. Using a light meter and turning off the electrical lights in the classroom, illuminance data was recorded under clear sky condition at five different locations at a height of three feet. Measurements at these locations were recorded at three different times of the day.

Daylight measurement was recorded outside the building to establish the daylighting illuminance to be used in the CGM. Interior finish materials were also recorded for use in the CGM.

Then, three (CGM)'s of the classroom were constructed using CAD. The three models were then exported to Lightscape. Interior finish materials were specified in Lightscape using the material library provided with the software. A light meter was modeled using a 1"x ½" plane, in order to most accurately replicate light readings in the original space. These light meters were placed at the same measurement locations as in the actual classroom. They were also set to be non-occluding and non-reflecting surfaces. Daylight was introduced to the space using Lightscape's direct control daylight feature. The measurements recorded from outside the building plus information from sundesign.com [9] – *provides sun angles at a specific time*, were used to determine the daylight settings. Illuminance was measured in the same locations within each model.

Comparisons of the illuminance data collected from both the actual classroom and the different CGM's were recorded. Measurement of the Interior Solution ranged from thirty percent more (30%) to ninety percent less (-90%) than the actual space. The Exterior-Interior solution measurements differences ranged from two hundred and fifty percent more (250%) to sixty eight percent less (-68%) than the actual model measurements. However, when each model's five location measurements were averaged at the three different time frames, the difference between the average from the actual classroom and the CGM's became smaller.

After conducting the pilot study, it was discovered that measurements from Lightscape were not one hundred percent (100%) accurate. However, the averages of daylighting illuminance measurements from each model provided smaller differences. Comparing all factor level combinations within the pilot study, showed that the simple CGM simulated as an Interior Space in Lightscape, provided daylighting illuminance measurements closer to those from the actual classroom.

Concluding the pilot study with that: Simplified computer generated models simulated as an Interior Space in Lightscape can more closely predict the daylighting illuminance measurements of the actual space, than the measurements from moderate or detailed computer generated models. Moreover, it was evident from the data that there was a correlation between illuminance measurements from the computer generated models and the actual space.

1.2 Actual Research

The actual research succeeded the pilot study; it analyzed Lightscape's performance in a more complex space – *the atrium space at Gainesville Regional Utilities' (GRU) downtown office building*. Another factor to be considered in this study is that the pilot study introduced daylight through windows into the space, while in the actual research a skylight introduced daylight into the interior space.

Illuminance was first measured in the enclosed atrium area under clear sky condition at fifteen different locations within the atrium space – *five measurements within each of the three floors*. These measurements were recorded three times during the course of the day. Then, a simple CGM was generated of the atrium space in CAD. The CAD file was imported into Lightscape, and illuminance data was recorded and compared with data from the actual atrium space. On the other hand, another feature of Lightscape, which is LSRAD – *a DOS-based program in Lightscape* – that provides more control to how long the user wants to run the simulations. LSRAD has proven to be faster than Lightscape's regular simulation. Although both of them run the simulations in the same way, but probably the DOS-based program runs the simulation in the background, resulting in faster computations.

Comparison analysis showed that Lightscape is an accurate daylighting-predicting tool, for preliminary design process. Moreover, a correction coefficient was calculated for more accurate daylighting illuminance measurements.

2 REVIEW OF LITERATURE

2.1 Background

Prior to the invention of artificial lighting, designers made architectural environments illuminated primarily by sun and daylighting. After the invention of artificial light, the concern for daylighting's role in the design and function of architectural environments started to wane [5]. Engineers were primarily concerned with quantitative aspects of lighting interiors rather than the ambiance lighting provides an interior environment [4].

Currently knowledge about how daylight provides opportunities for energy conservations has renewed interest in daylighting. Also increased the design of lighting related architectural features, supplemental electric lighting systems, and lighting control systems that take advantage of daylight as a source of interior illumination [6].

2.2 Daylighting Tools

In general, there are four categories for the tools used to predict daylight distribution in a space. The first category uses calculation procedures formulated to show daylighting illuminance levels for rapid execution in early stages of design process. The most common calculation methods are Daylight Factor Method and the Lumen Method [7]. The second category of daylight prediction tools is called Elaborate Programs e.g. (Superlite, and DOE 2.1C), these simulation programs are capable of predicting light levels in relatively complex spaces under changing sky conditions [6]. Physical models are the third category. They provide information useful for evaluating the visual quality of daylighting. In general the main shortcomings of any of these three methods is that they are time consuming and some of them require extensive preparations before gathering daylight measurements [7].

Over the last decade a fourth category of light measurement and visualization systems have been developed. These new tools use computer-based computations to replicate the lighting design [8]. Lightscape belongs to this fourth category and is an advanced lighting and visualization application for creating a realistic three-dimensional model or a space. Lightscape provides instant visual feedback about lighting strategies, at any point in the design process. Primarily the advantage for using Lightscape instead of the other methods is that it presents both visual feedback and lighting calculations of the designed space at any time of year or day a user wishes.

2.3 Computer Graphics

The growth of computer technologies has lead to many developments in the field of electronic design assistants. Improvement of CG software provides invaluable service for most architectural and design professionals who use realistic images of the built environment, interactive animations, daylight studies and artificial lighting simulations to test design ideas within their design process. Also lighting manufacturers now have IES data online along with three-dimensional luminaire 'blocks' for three-dimensional rendering applications.

How a software renders a computer model is closely related to how it is created. Lightscape uses two general shading algorithms – *local and global illumination, to determine how model surfaces reflect and transmit light*.

3. MATERIALS AND METHODS

Similarly the same procedures in the pilot study were followed in the actual research. Measurements of

daylighting illuminance were taken at fifteen different locations within the building – *five measurements within each floor*. Another measurement was taken from outside of the building to be used in Lightscape’s simulation. All fifteen measurements and the one outside the building were taken three times during the day at each location; illuminance data was then entered into a spreadsheet. Also digital images of the materials in the atrium space were recorded and used in the material finishes in the CGM.

A three-dimensional simple CGM was constructed in CAD using construction documents provided by the GRU. Then the CGM was imported into Lightscape, materials were assigned to the surfaces in the atrium space, and glass surfaces were assigned as windows in Lightscape’s surface processing. Setting daylighting in Lightscape was performed in the same manner as in the pilot study.

The initial simulation, used Lightscape’s LSRAD. The simulation was run to two hundred and fifty iterations, which was almost ninety eight percent of the total energy distribution, for both factor levels. This was also performed for the different times during the day.

To test Lightscape’s visual accuracy, radiosity was performed using LSRAY this command was also used to test Lightscape’s visual ability. Measurements were recorded at the same location as in the actual atrium space from both CGM’s. Regression analysis was used to compare both the CGM’s and the actual spaces. The analysis compared the collected data from both CGM’s – interior space and exterior-interior space, and compared the relationship between the data recorded from the actual atrium space with data recorded from both CGM solutions.

4. RESULTS AND DISCUSSION

4.1 Results

Figure 1 presents the total average of measurements from the CGM’s using an Interior solution at the three different time frames – 11:00 am, 12:00 pm, and 1:00pm, compared to the actual measurements collected from the atrium space. As shown in the graph the lines are very close except at points K, L and M, and this is due to the presence of direct sunlight.

4.2 Discussion

In case of the Interior solution, the differences in daylighting illuminance measurement between Lightscape’s CGM and the actual atrium space ranged from seventeen percent (17%) and thirty five percent (35%). While illuminance differences in the Exterior-Interior solutions

ranged from forty nine percent (49%) to seventy percent (70%) of the measurements from the actual atrium space.

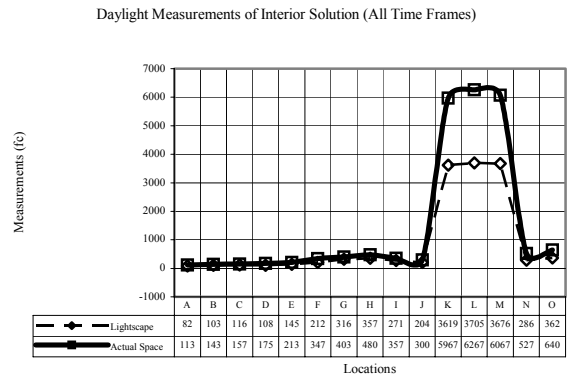


Fig. 1: Measurements from the CGM’s and the Actual Space using an Interior Solution. [10]



Fig. 2: A CGM image versus an actual photograph. [10]

According to Kaufman and Howard [11] in their illuminance values for general types of activities in interiors, the range of illuminance measurements for any specific tasks was always in a ratio of 1:2. Example: simple orientation for short temporary visits is five to ten footcandles of general lighting throughout the space. This was almost the same range provided from Lightscape’s illuminance data recorded when compared to the actual space.

For that reason, the variance in illuminance measurements recorded from Lightscape was acceptable. A regression analysis was performed to calculate a correction coefficient factor to assist in predicting daylighting illuminance. The results showed that there is a linear relationship between daylight illuminance measurements from Lightscape’s simulation and measurements from the actual space.

Since any daylighting illuminance measurements recorded from either Lightscape’s models or the actual space is a value greater than zero, the intercept was removed from the equation because it lies on the negative side of the Y-axis.

Therefore to approximate illuminance measurements that resemble measurements from the actual space, the X-coefficient was used as a correction coefficient factor for the daylight illuminance measurements recorded from Lightscape.

5. CONCLUSION

Daylighting is often proposed as an energy conservation strategy [7]. However the primary obstacle in utilizing daylighting is the lack of a simple method for predicting and visualizing light levels.

Both the Pilot Study and the Actual Research found that Lightscape's settings and the complexity of a model impact the accuracy of light illuminance measurements.

Lightscape has three Daylight Parameter Settings, Interior Solution, Exterior Solution and Exterior-Interior Solution. However, in this research only two features of the Daylight Parameter factor was tested – a) Interior Solution, and b) Exterior-Interior Solution. Comparing two types of CGM's with the actual atrium space, it was proven that Lightscape, using the Interior Solution, provides interior illuminance measurements close to those of the actual space, and provides no exterior illuminance measurements. While, simulating a model using Exterior-Interior Solution provides exterior illuminance measurements that are closer to measurements of the actual space's exterior light conditions. Nevertheless, interior measurements are not very close to the actual space's interior illuminance measurements.

A regression analysis was performed to calculate the correction coefficient factor for Lightscape's illuminance measurements. The analysis of multiple conditions showed that there is a linear relationship between illuminance measurements from Lightscape's model and the actual space.

Concluding the actual research with: Lightscape is an accurate daylighting-predicting tool. When using a simple computer generated model to replicate the interior environment, a correction coefficient factor of 1.67 is recommended to better estimate the actual daylighting illuminance in the interior space under consideration.

6. RECOMMENDATIONS

Recommendations are as follows:

6.1 Preparing The Model (.dwg):

When using CAD packages to construct three-dimensional models to be used in Lightscape:

1) Use basic three-dimensional modeling techniques in CAD, it is also recommended to minimize the amount of surfaces in generating the CGM. After the model is completed, it is required to explode all elements of the CGM in an axonometric view.

2) In case Architectural desktop is used, the CGM has to be exploded twice. However it is advised to use basic three-dimensional techniques instead of Architectural desktop tools, since it reduces time when simulated in Lightscape.

6.2 Lighting Preparation and Solution files (.lp - .ls):

When processing surfaces in the preparation files:

1) Surfaces that are not going to be used in the simulation or are not going to appear in portraying the interior environment, should either be set as non-occluding and non-reflecting or deleted – surfaces as: planes between floors in a multi-story space, roofing incase of interior simulations...etc.

2) It is recommended to use the DOS-based program in Lightscape - LSRAD, to calculate the radiosity in the model, since it saves time when running the simulation.

3) In using raytracing or rendering the model in Lightscape, it is recommended to also use the DOS-based programs – LSRAY, and LSRENDER.

7. FURTHER RESEARCH

Conclusions from this research suggest that performing similar tests on different architectural environments using Lightscape would refine our knowledge about the accuracy and application of the correction coefficient factor. Also, further tests should be conducted to compare Lightscape daylighting illuminance information with mathematical calculations to verify Lightscape's position among other daylight-predicting tools. Conducting such tests would provide the design community with simple and reasonably accurate methods for predicting and calculating daylighting measurements for their designs. Having useful and accurate daylight prediction tools will help encourage the design profession to integrate daylighting in interior lighting solutions. Furthermore, the improved and increased use of daylight in lighting design will also to reduce energy consumption and may improve user satisfaction and productivity.

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