



The Validation and Testing Study for Lighting Simulation Software

Engr. Syed Rizwan Ali¹, Azmat Khan², Bilal M. Iqbal³, Shujaat Butt⁴, Tanveer Zahid Khan⁵, & Ahmer Umer⁶
Department of Computer Science

Bahria University Karachi Campus, & Mohammad Ali Jinnah University
13 National Stadium Road, 75260, & 22-E Block-6 P.E.C.H.S, 75400, Karachi, PAKISTAN

Abstract: From last 10 years the lighting simulation software's demand are growing for testing and validation, lot of work has been done in research past 10 years but still a huge area needs to be covered. This study will discuss the most approved methodology used in practice for testing and validating lighting simulation software. In order to verify the accuracy of vender claims, selected research methods are used and presented. The current study used ECOTECT simulation software, to assist in the daylighting design of an actual building design.

Keywords: Accuracy; Testing; Validation; & Lighting Simulation.

I. Introduction

The use of lighting simulation software has increased in recent years due to the growing demands in energy crises, renewable energy resources, sustainability, and health by using daylight in space rather than artificial lights in commercial or institutional space with windows or skylights [1]. Lighting simulation plays a vital role to improve performance quality in built environment without assessing lighting simulation software testing and validation in buildings will be subject to the negative effects of daylights, whether or not they use its positive qualities because lighting effects may also be used to highlight changes in moods, atmosphere and it can be used for different purposes, by specifically focusing on it's current operation and implementation into the design process [2].

A set of validation methods is needed to validate the requirements of software, measuring its accuracy. Different methods are applied depending on the risks associated with the accuracy, and on the functions implemented by the software. [3] Suggest There is no single "silver bullet" suitable to solve any validation task.

II. Ligthing Simulation Software Validation & Testing Methods

There are different types of methods used for testing and validation in lighting simulation software, have introduced by the software engineering industry. A common frame of reference has to be established and recommendation for which test methods to use should be established [3] -[4]

The PASSYS project was developed in 1986 by the commission of the European communities with same objective to increase the confidence in environmental building performance simulation in solar system simulation. In this project the main aim was to validate every part of building in simulation software. [4] Suggests that validation is a very complex computational process which can be defined as follows:

- An accurate testing of program comparing its theoretical basis.
- Software implementation and user interface under a range of condition typically for the executed use of the program.

[4] Also recommended that as the validation is a complex process that's why practically it is not possible to perform complete validation of simulation software. So it is clear that empirical (IEA validation suite) methodology has been selected for this research. The IEA empirical validation package was developed in 1994. It contains detailed information for between two to ten days experiments. Those experiments are using three highly monitored test rooms, the IEA validation package suite mainly used in validating building lighting software [5].

According to [5] the validation methods may be grouped into following types of test:

- Analytical tests which compare against mathematical solutions.
- Comparative test which compare against other software.
- Sensitivity test which compare small input changes versus a base line run.
- Range test which exercise the program over wide ranges of input values.
- Empirical test which compare against experimental data.

The key standards for testing and validation publications are presented with their dates in the following list:

- Analytical, BEPAC/Bland conduction Test [6]-[7].
- Analytical, ASHARE 1052 - RP Building Fabric [8].
- Comparative, BESTEST/ASHARE standard 140P [8].
- Comparative/ Analytical, HVAC BESTNEST [9].
- Empirical, IEA validation suite [10].

These tests are used in a broad range of the lighting simulation software's capabilities. The architects or modelers community uses the results of these tests to judge and check the credibility, accuracy, integrity of their claim. The testing and validating lighting simulation used to analysis in laboratories but new era of technology has given such power, it can be performed by anyone, anywhere, and any time but the main concern was are some one using correct appropriate or correct methods or not.

A. Analytical, BEPAC/Bland conduction Test

BEPAC (the Building Energy Performance Analysis Club in the UK) has published a collection of conduction tests for validating building simulation software [6]-[7]. The validation, package includes FORTRAN routines for calculating results.

Advantages	Limitations
This test suite can be exercised for a broad range of material properties which are subjected to step, ramp, and sine changes in outdoor dry bulb temperatures [5]. This material was included in the BEPAC/Bland test suite to test, conduction calculations with thermal mass and near zero thermal resistance.	In an early Beta 1 version of EnergyPlus, this test case uncovered an accuracy problem with the conduction transfer function (CTF) calculations [5].

B. Analytical, ASHARE 1052 - RP Building Fabric

The American society of heating, refrigerating, and, air conditioning engineers (ASHRAE) sponsored research project 1052RP to develop analytical tests for the building fabric [8]. At the time of this writing, the project was nearly complete, including documentation describing 16 tests and a software toolkit to generate analytical results.

Advantages	Limitations
This test cover a variety of building envelope mechanisms including conduction, convection, solar gains, shading, infiltration, internal gains, radiant transfer, and ground coupling [5]. While a variety of analytical conduction tests have been published before, this is the first test suite to provide analytical solutions for the other areas.	These tests were applied to EnergyPlus as part of the review process for the research project. Several bugs were found in EnergyPlus while applying the tests, and the results of some of the tests have raised questions requiring further investigation [5]. The 1052RP toolkit allows the user of the test suite to generate results for a wide range of material properties. It is important to exercise the simulation tool for a wide range of combinations of mass, conductivity, and thickness in order to uncover hidden instabilities.

C. Comparative, BESTEST/ASHARE standard

The BESTEST suite developed through an International Energy Agency (IEA) project [9] is a comparative set of tests run on single zone and double-zone shoebox configurations with variations in mass, windows, overhangs, and fins. BESTEST has been restated as a Standard Method of Test in ASHRAE Standard 140-2001 [8].

Advantages	Limitations
For each test case, results for annual cooling load, annual heating load, peak cooling load, and peak heating load are compared. In addition, there are some free floating cases where maximum and minimum temperatures are compared instead of load, annual cooling results for low mass building [5].	EnergyPlus results are within the range of the other tested programs. Applying this test suite helped identify several bugs and documentation deficiencies, e.g. shade fin surface coordinates were inverted.

D. Comparative/ Analytical, HVAC BESTNEST

The HVAC BESTEST suite, in development through an IEA project, tests the cooling loads and electric power consumption for a single zone DX cooling system with a dry or wet coil under varying conditions of entering dry bulb, outdoor dry bulb, part load ratio (PLR), and sensible heat ratio (SHR) [5].

Advantages	Limitations
Consumption including indoor fan, compressor, and outdoor fan, comparisons for EnergyPlus versus other tested programs and three analytical solutions.	While EnergyPlus results are within the range of results from the other tested programs, there are some issues related to fan energy and humidity ratio which warrant further investigation. This test suite revealed several bugs during the validation.

E. Empirical, IEA validation suite

The IEA Empirical Validation Package [9] contains detailed information for two to ten days experiments using three highly monitored test rooms. The validation package was developed specifically for use in validating building energy simulation software [5].

Advantages	Limitations
This test contains detailed descriptions of the test rooms, heating equipment, and instrumentation and includes a data diskette. The three rooms were equipped with single glazing, double glazing, and an opaque insulated panel. Data for two tests are provided: heated. These test cases exercise the following components of the simulation: Opaque conduction and exterior solar gains, Simple glazing, conduction and solar gains, Zone heat balance without internal loads, & Simple heating system.	Input files have been developed for this test suite, but the meteorological data which comes with the test suite is not in a standard format. The data contains global and diffuse horizontal total radiation which must be converted to direct normal solar values for use with EnergyPlus [5].

According to [3] testing and validating of the lighting simulation software functionality measurement is not yet a mature discipline. Because of this modelers or architects wanted to increase the confidence in environmental building performance simulation systems. So software manufactures have to test quality before they can be put into serial production. Regarding the validation and testing for European (E.U) users, performed by the notified bodies to be exhaustive and high quality. That is true for many aspects, but the testing of functionality and software may not always be state of art. There are many different words used to describe the examination of software. So the each terms which being used it must be depending on the situation and on the established usage of language in each sector. That's whys developers may always check simulation software before its releases.

It's very important to know that difference between verification of the simulation software and validation of the simulation software. Verification and validation both are the processes which are being used to determine and making improvement in the reliability of simulation software.

Verification	Validation
Verification means the confirmation taken by the examination and requirements of objective evidence that the requirement have fulfilled [3] or in other words to determining the software function properly. For example if someone is going construct the building design, the software should conform to its specification [11].	It means confirmation and provision of objective evidence that the particular requirements for a specific intended use are fulfilled [3] or in other words validation determines accuracy that it function properly in a total system environment. For example if someone is going construct the building design, the software should do what the user really requires [11].

III. Testing and Validation of the ECOTECT

The use of computer aided design techniques for lighting design attracts great interest from architects and lighting designers [12]. ECOTECT is lighting simulation software which is quite unique amongst building analysis because it is entirely designed and written by architects and intended mainly for use by architects [13].

ECOTECT simulation software was developed in June 2001 and its author was Andrew Marsh, co-founder and head of research at Square One Company. He is well known around the world due to his architectural research. ECOTECT amongst other design tools, as a software package has a unique approach to conceptual building design [14]. ECOTECT enables accurate and physically valid lighting and daylighting design. It has been applied successfully to aid the design of many buildings, but notably and mainly new and unrealized designs with little existing contextual restrains [12].

This study has selected one of the most powerful computational lighting simulation software, ECOTECT, to assist in the daylighting design of an actual building design. The validation and testing studies, which were carried out in the UWE Bristol, showed that ECOTECT can be used to predict the accuracy in illuminance under the overcast sky conditions. The experimental application of ECOTECT to study the two separate days with

different sky condition reading, the three rooms will be selected in each room, we will calculate five readings but in this research article discusses only one medium Room [4q6] lecture room.

A. Experimental Design

Lighting simulation software is an attempt to provide an accurate simulation of a building design, and then it has to be mathematically and logically correct. As this study discussed in pervious chapters now a days there are many number of lighting simulation software and tools have been developed in the last 10 years (Edward, 2001). But only few of them are available and used in practice.

The experimental testing and validation ECOTECT has never been done in UWE Bristol, UK by climatic condition. Well testing and validation is a lengthy process, its necessary to make the experiment successful. That's why two different days were selected and with three different rooms into the UWE Q-block. Five reading were taken for each of the rooms, as previously discussed in this research article only one medium Room [4q6] lecture room. These experiments were conducted to investigate the validity of ECOTECT.

IV. The Measurement techniques for real world and virtual world environment

A. The Measurement for virtual world environment using ECOTECT LUX Meter

In ECOTECT the sky model to be used when determining natural lighting levels. The sky model is an algorithm describing the distribution of light over the entire sky dome. Choices are currently limited to the CIE Overcast and CIE Uniform sky models. Strictly speaking, however, the Daylight Factor method is only really valid for overcast sky conditions. This value represents a Lux value for the amount of light output from the sky. This is taken from the current weather data file but can be over ridden here. This value is derived from a statistical analysis of outdoor illuminance levels, based on the 15th percentile i.e. that illuminance level that is exceeded 85% of the time between the hours of 9am and 5pm throughout the working year. Thus it represents a worst case scenario that you can design to London 4000 LUX. Selecting this item calculates the design sky from the average diffuse sky illuminance formula given by Tregenza in 1986, as shown below:

Figure 4: The average diffuse sky illuminance formula

$$\begin{aligned} E &= 0.0105(Y^{\circ} + 5)^{2.5} & (-5^{\circ} < Y^{\circ} \leq 5^{\circ}) \\ E &= 48.8 \sin^{1.105}(Y^{\circ}) & (5^{\circ} < Y^{\circ} \leq 60^{\circ}) \end{aligned}$$

Figure 5: The ECOTECT 5 LUX Point

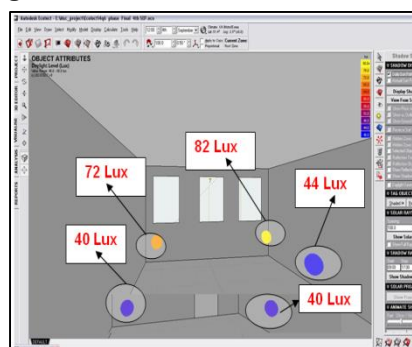
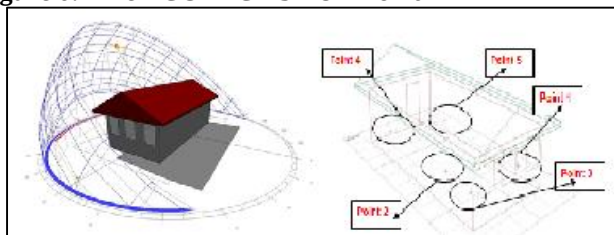


Figure 6: The ECOTECT 5 LUX Point



B. Measurement for the real environment using Hanger Digital LUX Meter

The Hanger Digital Luxmeter, Model EC1, is a precision pocket size instrument that will measure illuminance with in the range of 1 to 200,000 LUX. It dependability toughness and easy to use make it the ideal LUX Meter for use in the real environment.

This Luxmeter can distinguish by the following character tics:

- High accuracy
- Automatic zeroing
- Large measure range
- Easy to use and read
- Hold button
- Three measurement ranges

A completely new electronic design an automatic zero control for all operating temperature from 0° - +50° C. The instrument can do work for short periods, be used at very low temperature say - 20° C. below figure shows its more functionality.

Figure 7: The Hanger Digital LUX Meter

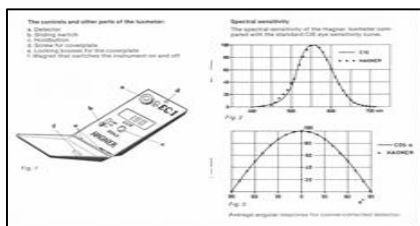
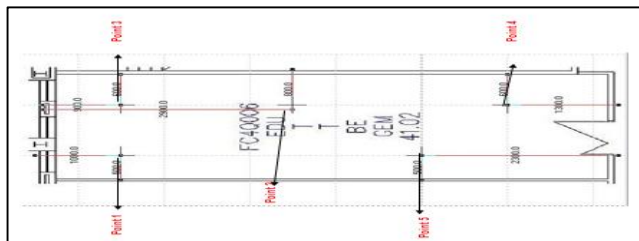


Figure 8: The Schematic illustration of Room 2- 4q6



Medium Room 2 will be lecture hall, to measure its height and length of walls, windows, doors and will take five different reading in different place by Hanger digital Luxmeter.

Figure 9: The Real Building of Medium Room 2 – [4q6] 5 points location with LUX values



V. Conclusion

In ECOTECT, there are a number of different methods that can be used to calculate natural light levels in buildings, all of which vary in their complexity, accuracy, calculation time and application. To accommodate different situations and requirements, Ecotect implements a range of these methods but here in this study using natural lighting, the calculation of illuminance levels. The UWE Bristol buildings represents a challenge to the application of advance lighting simulation; the new technology to building design, in this case lighting simulation technology is used to study lighting design of existing UWE institutional building. The validation studies demonstrated that ECOTECT is reasonably good in simulating the light environment in the under overcast sky without any external obstruction. When ECOTECT was applied to assist in daylighting design of UWE, the software further indicated that it is an effective lighting design tool. The research results showed that lighting simulation technology is particularly useful when a large number of options have to be considered during the scheme design stage of the design process.

VI. References

- [1] Engr. Syed Rizwan Ali, Lamine Mahdjoubi., & Azmat Khan. JMEST, *The Comparison Study Between UK Daylighting Simulation - Malaysia Daylighting Simulations Due To Overcast Sky Conditions*, Available from: <http://www.jmest.org/wp-content/uploads/JMESTN42350862.pdf> [Accessed by 15 July 2015]
- [2] Engr. Syed Rizwan Ali, Azmat Khan, et al, IJSER, *Injecting Quantifiability to Promote Software Maintenance*, Available from: <http://www.ijser.org/onlineResearchPaperViewer.aspx?Injecting-Quantifiability-to-Promote-Software-Maintenance.pdf> [Accessed by 15 July 2015].
- [3] Jacobson J. & Jacobson B, MID-Software WP2 Testing and Validation. *Methods for Validation and Testing of Software* [Online] Available from: http://www.welmecw7.ptb.de/Guides/MID-SW-Report-Validation_Testing.pdf [Accessed 2 May 2015]
- [4] J. Mardaljevic, (1995) *Validation of a lighting simulation program under real sky conditions*, *Lighting Res. Technol.* 27 (4).pp 181–188
- [5] Crawley, D. B (2001) Testing and Validating types. *Testing and Validating of a New Building Energy Simulation Program*. In Seventh International IBPSA Conference, Brazil 13 1 August 2001. UAS: Learned information, pp 353 to 355.
- [6] BEPAC (1993). B.H. Bland, *Conduction tests for the validation of dynamic thermal models of buildings*, Technical Note 93/1, August 1993.
- [7] Bland (1992). Bland, B.H. "Conduction in dynamic thermal models: Analytical tests for validation", *Building Services Engineering Research and Technology*, 13(4), pp 197-208.
- [8] ASHRAE, (2000). ANSI/ASHRAE Standard 140-2001, *Analytical Test Suite Building Fabric, 1052RP Draft Final Report*, December, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.
- [9] IEA . J. Neymark, and R. Judkoff, International Energy Agency, *Building Energy Simulation Test and Diagnostic Method for HVAC Equipment Models (HVAC BESTEST)* Vol. 1: Cases E100-E200 (Draft), November 2000.
- [10] IEA. Building Energy Simulation Test (BESTEST) and Diagnostic Method, National Renewable Energy Laboratory, Golden, Colorado, February 1995.
- [11] Sommerville, I (2004) *Software Engineering.. Def of Validation & Verification* [Online] Available from: <http://www.atilim.edu.tr/~dmishra/se112/ch22.ppt> [Accessed 1 July 2015].
- [12] Edward Yan-Yung Ng, Lam Khoo Poh, Wu Wei, Takehiko Nagakura, (2001). Elsevier Science, *Automation in Construction*. Advanced lighting simulation in architectural design in the tropics. 10. pp 365–379.
- [13] Square 1, (2008). ECOTECT Guide. Daylighting [Online] from: www.philiplo.com/architecture/daylighting [Accessed 30 July 2015]
- [14] MARSH, A & ROBERTS, A (2015) Basic theory. ECOTECT: Environmental Prediction in Architectural Education. [Online] Available from: www.ecaade.org/prev-conf/archive/ecaade2001/site/.../13_03_roberts.pdf [Accessed 13 July 2015].