Simulation Tools usage in Building's Indoor Artificial Lighting

Ashfaque Ahmed Baloch[1, 2], Pervez Hameed Shaikh[2], Zeeshan Anjum Memon[2, 3],

Zohaib Husain Leghari[2, 3]

[1]Ziauddin University, Faculty of Engineering, Science and Technology, Karachi
[2]Mehran University of Engineering and Technology, Jamshoro
[3]Universiti Teknologi Malaysia (UTM), Malaysia

Abstract: **While addressing the buildings' sustainability, the lighting system design is considered as major component. The energy conservation and waste savings can be tackle through buildings' sustainability. Indoor artificial lighting pays significant contribution in industrialized countries' rising energy costs. Thus the energy-saving strategies could affect the visual comfort within indoor environment. This paper comprises a systematic advanced review of the simulation tools for indoor lighting of building research. To optimize utmost usage of building's lighting systems, the artificial material and dynamical part deviations are offered by simulation. Thus the synthetic environment and equivalent lighting system design in virtual world is allowed. Therefore, to find out the widely used tools for simulation of lighting in building prototypes among the researcher is the main objective of this paper. Hence the simulation platforms are categorized in lone and cohesive tools used by the researchers. The survey is comprised of the seventy papers where were thoroughly reviewed. It has been observed that different researchers has carried out various relevant studies in the lighting in buildings and energy savings. This research can aid positively to the energy managers and researchers to decide the feasible simulation tool for the simulating their respective prototypes.**

Keywords: *Visual Comfort; Artificial Lighting; Simulation Design; Energy; Sustainability*

I. INTRODUCTION

World's one third of primary energy is consumed in buildings. Occupant's indoor comfort is the core concern within the buildings. Due to this, maintenance of indoor comfort environment is in contradict to the energy conservation strategies. The descending order of equipment responsible for energy consumption in buildings are plug in loads, entertainment devices, kitchen appliances, lightings, and HVAC systems. 19% of world's electricity is consumed by buildings' lighting [1]. The quality of visual consciousness is the lighting index in buildings. The European standard EN 12665:2011 of visual comfort is, a well-being state of visibility to individual induced by the visual comfort in buildings. It is be subject to the physiology of individual human eye, quantity and quality of light in rendering colors, light source spectral emissions, its planetary distribution and risk of glare, etc. [2] While addressing the buildings sustainability, lighting design is considered as on the significant challenge and essential element of building design [3]. It is therefore, significant to analyze several effecting inputs, outputs and processes to understand the complexities of actual and theoretical building lightings. To optimize the building's utmost usage of lighting system, the mock objects and dynamic role variations are permissible in simulations. Thus allowing lighting system design and artificial environment in virtual world. In the past one decade, the simulations for complex engineering systems have been arisen as a favorable method. It provides the faster and enhanced techniques obtain the more refined results that would have taken long time spans.

Different simulating tools has been used by various researchers for simulation of their prototypes and modules has been given in this review paper. To find out the most popular and dominant simulation tool adopted by the researchers to simulate the lighting in buildings. The researchers, scientist, industrialist would get help by this article to consider numerous simulation tools existing and the most commonly been employed for the scattering the lighting simulation in buildings. The systematic ascending order literature search starts over a decade, in which Ashfaque et al. [4] has reviewed the Simulation tools application for artificial lighting in buildings. Marler and Arora [5] reviewed multi objective methods, Roy et al. [6] reviewed wider area methods of optimization of engineering design. the implementation of computional optimization methods on sustainable building design has been reviewed by R. Evins [7]. P.H. Shaikh et al. [8] has reported for comfort management and building energy in sustainable and smart buildings using optimized control systems. Visual comfort indices evaluation through the point to their use in optimization processes by integrated design of buildings was presented by S. Carlucci et al. [9].

For this review, seventy papers of last two decades have been reviewed thoroughly (due to limited space the table of reviewed paper has not been included in this paper). 74.29% of the peer-reviewed article and 25.71% conference papers of highly relevant to building and energy sector have been considered as shown in fig. 1. Office buildings were the main concentration of the research; however, commercial, residential, industrial and office buildings' general models were observed as shown in fig. 2. The profound understanding into the literature as shown in fig. 3, suggests that the most of researchers have considered general building models, and some have built their test chambers as a physical model. The remaining paper is comprised of; individual and integrated simulation tools used by the researchers. 2nd section describes the findings of this review paper. Whereas the section 3 gives recommendations for future work and paper is concluded in section 4.

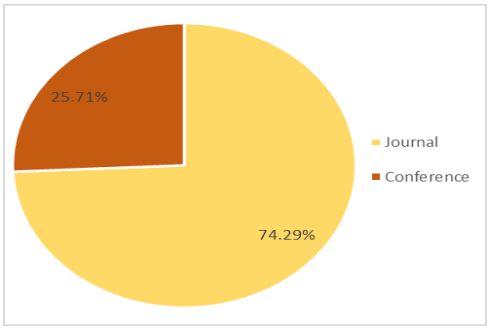

Fig. 1. Conference papers and journal publications division.

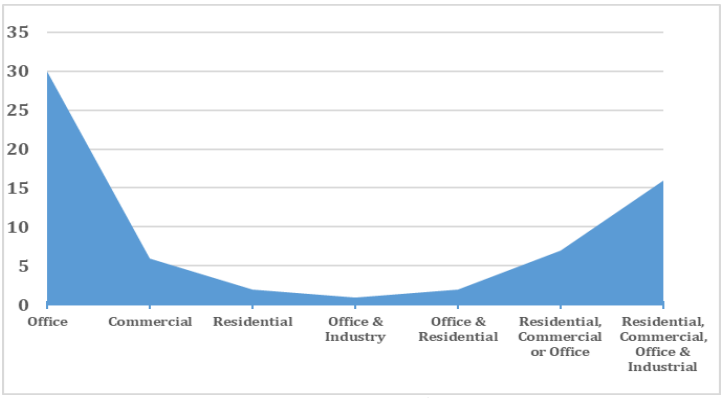

Fig. 2. Building area types considered for study in literature.

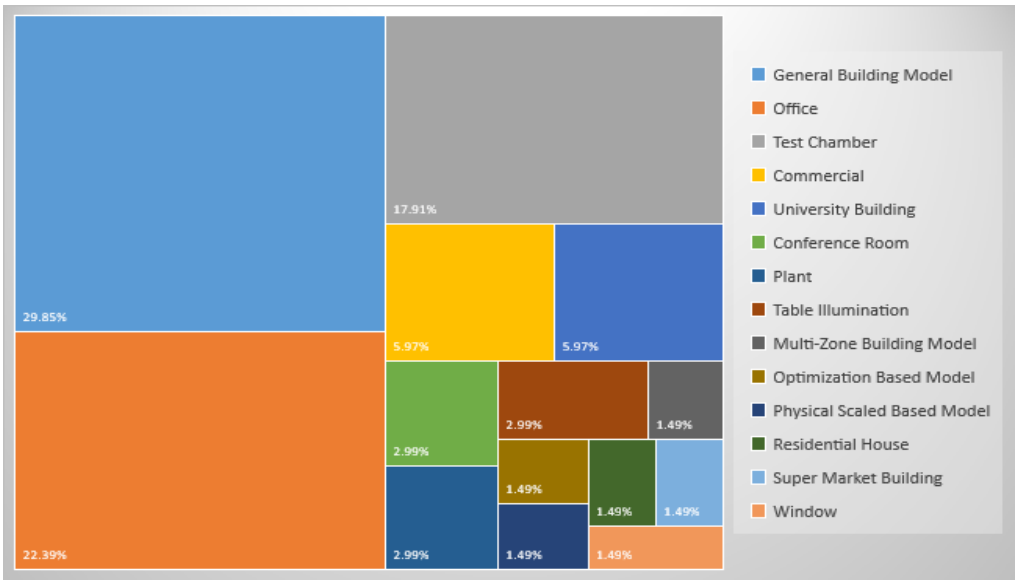

Fig. 3. Adopted models found in survey of literature.

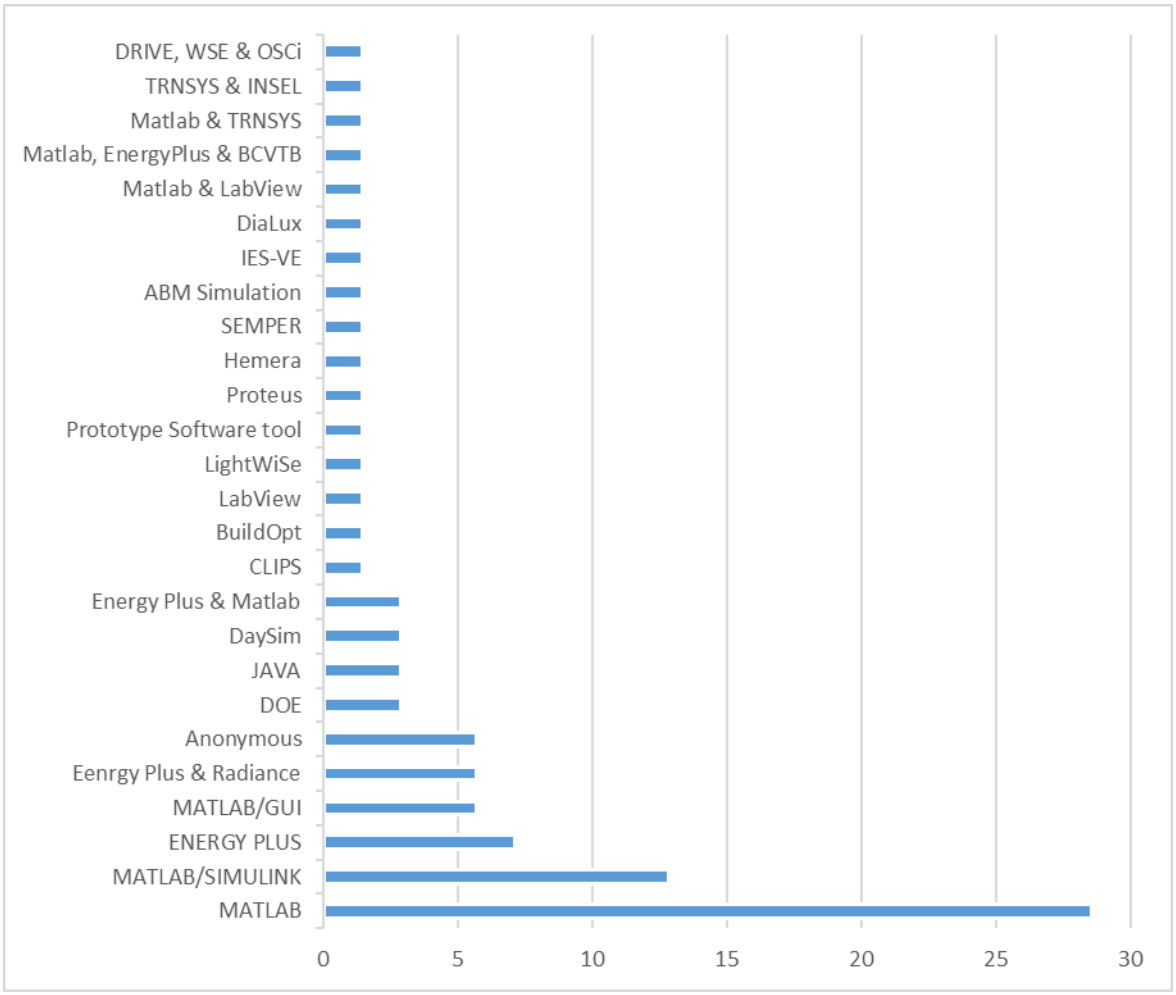

Fig. 4. Frequency of building's simulation tools for lighting design

II. SIMULATION TOOLS AND APPROACHES

Overall seventy research papers based on simulation for lighting in buildings has been reviewed for this review paper. All the papers were thoroughly studied, and focused to find out the simulation tools used for lighting simulation. It has been found that the MATLAB, MATLAB-GUI, EnergyPlus, Design of Experiments, JAVA, LabVIEW, DaySim, C-Language Integrated Production System (CLIP) BuildOpt are the ones which were used as single tools for simulation of building models. The integrated simulation tools used for the simulating building models are EnergyPlus/Radiance, EnergyPlus/MATLAB

MATLAB/LABVIEW, MATLAB/Transient System Simulation (TRNSYS), and TRNSYS/Integrated Simulation

Environment Language (INSEL). The accumulated retrived information has been shown in percentage in fig. 4.

III. DISCUSSION AND RECOMMENDATION

MATLAB has been found a general purpose simulation tool in this survey. The capability of MATLAB allows it to combine a tuned desktop environment with high level language for iterative engineering and scientific workflows. The simultaneous use of different tools, provides an approach that lead to qualitative and quantitative evaluation process that assures reliability of the research results [10]. Among seventy papers four papers found without identified simulation tools. Common lighting metrics were investigated by Den and Inanici [11], energy saving lighting control system was presented by Galadiu et al. [12] and claimed that occupancy sensors control, individual control and lighting sensor control can help reducing the light installation by 42% and can save energy up to 47% using these controls and over 67% - 69% of overall saving as compared to conventional lighting system. Lee and Selkowitz [13] presented the monitored based performance of daylighting control system. Another one Singhvi et al. [14] reported the intelligent lighting control system.

The researchers has proposed prototype and potential for optimization of lighting and daylight elements can be considered by lighting simulation packages and to fulfil the required flow of information the interaction between various users should be linked. The Radiance simulation tool facing the trouble in dealing with very high or very small sources of flux light, to overcome the problem the one may apply the forwarded ray tracer or substantially test the sample of complex fenestration systems (CFS) and map the resultant enactment [15]. Genuinely, the simulations of building energy has become limited due to deficiency of mature, comprehensive and wide ranging interfaces of users. Consequently, EnergyPlus is more helpful than

DOE-2 in complicated systems designing but need more time. A user friendly environment is expected from the EnergyPlus in its present advancements [16].

Despite the fact that simulation tools are easy to use, they do have weaknesses. There is need to improve the vigorous problems' calculations faced during the simulation of lighting. The institution of heuristics or simple assumptions can help in reducing the platform complexity. Furthermore the simulation time would be reduced and the accuracy of results would also be assured.

Therefore, the much better visual comfort's occupancy and exploration is needed [17]. For further research, the essential challenges may involve expression exploration with incorporative effectual computational language and modern light technology and transport models. Systematizing simulation, enhanced tools for statistical outputs and advancement of conceptual frameworks are the some recommendations drawn through the broad survey. Relating to common tasks and research technologies the investigational setups would be modeled that could enhance understanding of simulation results.

IV. CONCLUSIONS

In this study a comprehensive evaluation of several simulation tools for lighting in buildings have been studied and found the most widely held tool for building's lighting simulation by the researchers. It is found that tools of simulation that were used individually were slightly more adopted by researchers than combined simulation tools.

As per this survey, the most widely used tool of building's lighting simulation MATLAB trailed by MATLAB/Simulink, MATLAB/GUI, EnergyPlus, DOE, JAVA, LabVIEW, DaySim. Whereas, the most widespread integrated simulation tools found are MATLAB-SIMULINK/LABVIEW followed by the DRIVE/OSGi, MATLAB/EnergyPlus/BCVTB, MATLAB/TRNSYS, TRNSYS/INSEL, EnergyPlus/Radiance, EnergyPlus/MATLAB, and EnergyPlus/MATLAB/GPE. It has been observed in this survey that various researchers has carried out studies in energy savings and lighting in buildings. For the simulation of energy savings and lighting in the buildings prototype, several individual along with combined tools of simulation were suggested. The energy managers and researchers can get positive aid through this survey for determining the viable building's lighting simulation tool for their respective prototype.

REFERENCES

[1] Nardelli Andrei, Deuschle Eduardo, de Azevedo Leticia Dalpaz, Pessoa João Lorenço Novaes, Ghisi Enedir. Assessment of light emitting diodes technology for general lighting: a critical review. Renew Sustain Energy Rev 2017;75:368–79.

[2] BSI. BS EN 12665:2011. Light and lighting. Basic terms and criteria for specifying lighting requirements. British Standards Institute; 2011.

[3] Liu G, Nolte I, Potapova A, Michel S, Ruckert K. Longlife comparison of worldwide certification systems for sustainable building. In: Proceedings of the 9th international conference on Sustainable Energy Technologies SET 2010, Shanghai, China; 2010, p. 7.

[4] Baloch, Ashfaque Ahmed, et al. "Simulation tools application for artificial lighting in buildings." Renewable and Sustainable Energy Reviews 82 (2018): 3007-3026.

[5] Marler R, Arora J. Survey of multi-objective optimization methods for engineering. Struct Multidiscip Optim 2004;26(6):369–95.

[6] Kumar Roy Raj, Hinduja Srichand, Teti Roberto. Recent advances in engineering design optimisation: challenges and future trends. CIRP Ann-Manuf Technol 2008;57(2):697–715.

[7] Evins Ralph. A review of computational optimisation methods applied to sustainable building design. Renew Sustain Energy Rev 2013;22:230–45.

[8] Shaikh Pervez Hameed, et al. A review on optimized control systems for building energy and comfort management of smart sustainable buildings. Renew Sustain Energy Rev 2014;34:409–29.

[9] Carlucci Salvatore, Causone Francesco, De Rosa Francesco, Pagliano Lorenzo. A review of indices for assessing visual comfort with a view to their use in optimization processes to support building integrated design. Renew Sustain Energy Rev 2015;47:1016–33.

[10] Tuan AN, Marco A. Energy intelligent buildings based on user activity: a survey. Energy Build 2013;56:244–57.

[11] Van Den Wymelenberg Kevin, Inanici Mehlika. A critical investigation of common lighting design metrics for predicting human visual comfort in offices with daylight. Leukos 2014;10(3):145–64.

[12] Galasiu Anca D, Newsham Guy R, Suvagau Cristian, Sander Daniel M. Energy saving lighting control systems for open-plan offices: a field study. LEUKOS 2007;4(1):7–29.

[13] Lee Eleanor S, Selkowitz Stephen E. The New York Times Headquarters daylighting mockup: monitored performance of the daylighting control system. Energy Build 2006;38(7):914–29.

[14] Singhvi Vipul, Krause Andreas, Guestrin Carlos, James H. Garrett Jr., Matthews HScott. Intelligent light control using sensor networks. In: Proceedings of the 3rd international conference on Embedded networked sensor systems. ACM; 2005. p.218–29.

[15] Rob Guglielmetti, Pless Shanti, Torcellini Paul A. On the use of integrated daylighting and energy simulations to drive the design of a large net-zero energy office building. IBPSA-USA J 2010;4(1):301–9.

[16] Sree Rallapalli Hema. A comparison of EnergyPlus and eQUEST whole building energy simulation results for a medium sized office building [PhD diss.]. Arizona State University; 2010.

[17] Ochoa Carlos E, Aries Myriam BC, Hensen Jan LM. State of the art in lighting simulation for building science: a literature review. J Build Perform Simul 2012;5(4):209–33.