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REVIEW ON MEASURING TOOLS FOR ENERGY EFFICIENT SOLAR SHADING STRATEGIES IN TROPICAL CLIMATE

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ABSTRACT: *Solar shading is an important architectural element not only for the purpose of reducing direct solar heat gain, but also for controlling the indoor environment quality of day-lighting and associated glare. The balance between the prevention of heat gains and natural day-light penetration is crucial for energy saving in building cooling and lighting. This paper is part of an initial research work towards designing energy efficient solar shading devices in hot humid tropics. It is mainly a critical review of measuring tools used in solar shading design. The availability and performances of computer simulation tools are presented as they can provide more accurate results to assist in designing and towards achieving optimum cooling and lighting energy. The review concludes that the understanding of the characteristics of different types of shading devices and the methods of shading design is crucial for architects to design energy efficient solar shading. However, the present methods of shading design require detailed data input or expert knowledge that is impractical during early design stage. Hence, further research is needed to develop a simplified design tool for solar shading towards energy efficiency in tropical climate.*

Keywords: *Solar shading, measuring tools, energy efficient, tropical climate*

Introduction

From the traditional Malay houses to the contemporary high-rise offices, windows are one of the most significant elements; act as openings for daylight penetration, natural ventilation and visual interaction. However, windows also allow the unwanted solar heat gain into the buildings, which causes energy consumption for building cooling. Thus, the need to reduce unwanted heat gain has been the major energy-related issue in window design (Carmody *et al.*, 2004). This situation is more critical in hot humid tropical climate where the intensity of solar radiation is high and uniform throughout the year. In Malaysia, record shows that the annual maximum intensity of solar radiation falling on horizontal is about 1000 W/m2 and on vertical surface is about 850 W/m2 for east and west facing surfaces (Ossen, 2005). One of the common solutions given by the architects is through the use of solar shading.

Solar shading is not merely an esthetical element but rather be a climatic-functional device for buildings. The main role of solar shading is to act as a spatial insulator against the radiant heat wave penetrating into the building internal space through the windows (Olgyay and Olgyay, 1957; Ossen, 2005). However, admissive use of solar shading will reduce the daylight penetration through windows and extensive use of artificial lighting is required (Baker and Steemers, 1996; Lim *et al.*, 2008). The use of artificial lighting not only consumes energy but also causes waste heat into the building space, increasing the cooling demand (Zain-Ahmed, 2002). The abundance of daylight in the tropics that has not been utilized to the maximum since it is usually concurrent with intense solar heat gain (Ahmad, 1996; Zain-Ahmed, 2002; Ossen, 2005). Hence, the balance between the prevention of heat gains and natural day-light penetration is very crucial in order to propose optimum shading strategies as energy efficient design solutions (Sharifah and Sia, 2004; Tzempelikos and Athienitis, 2007).

Generally, solar shading can be divided into two main categories: natural devices and solar control devices. Natural devices are the vegetation and building orientation (Olgyay and Olgyay, 1957; Ossen, 2005). According to Emmanuel (1993), the purpose of natural elements such as vegetation is not so much to ameliorate negative aspects of tropical climate but to enhance the cooling potentials of shading. It is very critical for the architects to understand the types of solar shadings and their characteristics; and also to utilize the methodology of shading design (Lim *et al.*, 2008).

Computer Simulation Tool

With the increased computer capacity during the last 30 years, architects and engineers have more and more relied on building energy simulation programs to achieve energy efficiency in buildings (Loutzenhiser *et al.*, 2007). Nowadays, some detailed simulation programs such as ECOTECT and IES Virtual Environment (VE) integrate daylight and thermal simulation (Lim *et al.*, 2008). Athienitis and Tzempelikos (2002) developed an integrated model based on clear and overcast sky formulations for external illuminances and radiosity for internal illuminances. Franzetti *et al.* (2004) implemented a day-lighting software module with a thermal model which its validity was restricted to internal working plane illuminances below 1000 lux. Hviid et al. (2008) developed a simplified tool which employs the radiosity method for internal daylight reflections, which gives a reasonable balance between accuracy and time of calculation.

Goulding (1992) suggests that the "best opportunities for improving a building's energy performance occur early in the design process". Balcomb (1998) also asserted that the most critical phase to reach optimum energy performance is in pre design. However, review has found that in the current practice, architects prefer to analyze the energy performance in the later stages, usually by consulting an engineer (Pedrini and Hyde, 2001). Although there are varieties of integrated building simulation tools available today, detailed input data is required in order to run even the simplest simulation. Therefore, these tools are commonly used to evaluate the overall energy performance of existing buildings or in the design development stage, rather than being used in the early design stage. Hence, the selection of final design solutions for window system and shading strategies are often influenced by architects' subjective factors in the early stage (Tzempelikos and Athienitis, 2007). According to Pedrini and Hyde (2001), there are many reasons for this situation:-

a. the misunderstanding of building performance;
b. the absence of methods suitable for architects;
c. the lack of scientific knowledge by the architect;
d. the complexity of energy tools and many other intrinsic limitations;
e. the abstracted and personal design approach by the architect;
f. the different language used by architects and engineers;
g. insufficient governmental incentives.

It is essential for architects to have exposure towards the available computer simulation tools today. Appropriate selection of the tools is important to optimize the process and output performance. In general, the selection of the tools is depended on several criteria (Lim *et al.*, 2008) as shown in Fig. 1.

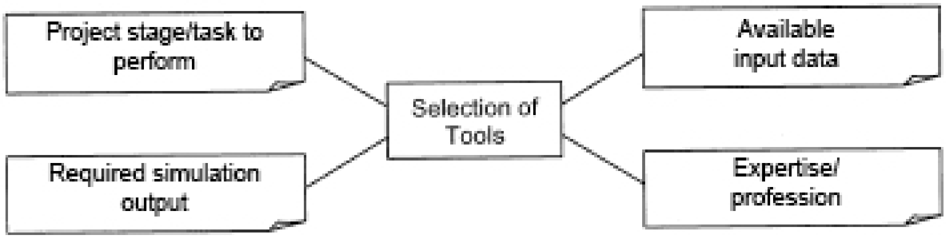

Figure 1: Criteria for selection of tools

Finding and Discussion

For the comparison of various computer simulation tools, 6 tools are selected as shown in Table 1. These tools are selected due to the different outputs and disadvantages of the tools, in order to give a clearer picture of the various current available computer simulation tools. These tools are commonly used by designers and engineers for building performance simulation. Besides, the tools are suitable for various climates including tropical climate, provided that the climatic weather files are available.

Table 1: Review on computer simulation tools (Crawley *et al.*, 2005, Ossen, 2005, Lim *et al.*, 2008)

Name & Software Developer	Advantages	Disadvantages
BLAST (Building Load Analysis and System Thermodynamics) *Building System Laboratory. University of Illinois. USA.*	-Provides hourly simulation of building energy consumptions heating and cooling	-High level of expertise required to develop custom system and plant model. -No detail output of interior illuminance from window & skylight. -No lighting control system applied. -Payment required for software package and license.
DOE-2.2 *Berleley, CA, USA. & James J, Hirseh & Associate, CA, USA.*	-Uses a room weighting factor approach to calculate load. -DOE 2.2 is a freeware.	-High level of expertise required.

ECOTECT *Square One research Pty Ltd. c/o Centre for Research in the Built Environment. Cardiff University. U.K*	-Complete environmental design tool which couples an intuitive 3D modeling interface with extensive solar, thermal, lighting, acoustic and cost analysis functions. -User friendly and easy to operate -Can export file to other software such as RADIANCE, AutoCAD DXF, Energy Plus, ESP-r, etc. for more specific analysis or validation	-No HVAC systems are integrated for energy calculations. -Required another program for energy calculations. -Payment required for software package and license.
Energy Plus *US Department of Energy, USA.*	-Based on features and capabilities of BLAST and DOE-2 -Include solar thermal, multi-zone airflow, and electric power simulation including PV systems and fuel cells. -Energy Plus is a freeware.	-Difficult to use without graphical interfaces.
e-QUEST-3 *Berleley, CA, USA. & James J, Hirseh & Associate, CA, USA.*	-Is a user interface Based on new calculation engine DOE 2.2 -Easy to use and detailed analysis without requiring extensive experience in DOE-2 modeling for eQUEST. -e-QUEST-3 is a freeware.	-Limitation in shading device options; only horizontal and vertical fins can be modeled. -Daylight reading at reference point is limited to a depth of three times as the height of floor to ceiling. Deep plans cannot be model for day-lighting. -Use only imperial scale measurement for calculation.
IES Virtual Environment (VE) *Integrated Environmental Solution Ltd. U.K*	-Built around the concept of single-Integrated Data Model. -Create 3D date model. -Evaluate the performance of a building throughout design process.	-Training required mastering the interfaces prior to use the software. -Payment required for software package, training and license.

Comparison of the various simulation tools with the project stages shows that different tools have their advantages for different steps according to the task, provided input and required output. Therefore, understanding of the project stages and the ability of the tools is very critical for effective and accurate building simulation. Table 2 shows the criteria for the project stages in pre-design, sketch, detail and final evaluation, and the recommended simulation tools.

Table 2: Project steps and recommended simulation tools (Pedrini and Hyde, 2001; Lim *et al.*, 2008)

	Criteria			**Simulation Tools**					
Step	**Task**	**Input**	**Output**	**BLAST**	**DOE-2.2**	**ECOTECT**	**Energy Plus**	**e-QUEST-3**	**IES <VE>**
Pre-design	Investigation Hypothesis formulation	Client's briefing Site & Weather Codes, Guidelines, Building "templates"	Potential savings Strategies definition			•			
Sketch	Base case diagnostics Test alternatives Conceptualization	Base case and possible alternatives	Energy performance Alternatives proposition Diagnostics	•				•	•
Detail	Identify main parameters Optimize the design Realization	Base case Detailed solutions (resulted from diagnostics)	Detailed design parameters alternatives Tactics		•			•	•
Final evaluation	Energy simulation Benchmarks Code compliance	Defined parameters	Final performance		•		•		•

Not all kinds of solar shadings design or performance variables are available in the simulation tools. Each of them has their limitations. Hence, it is essential to select suitable tools that are able to provide the required design variables and performance variable. Table 3 shows the summary of the variables for the selected simulation tools.

Table 3: Summary of solar shading design and performance variables of simulation tools

			Design Variable																Performance Variable										
			External					Internal			Natural		Geometry						Thermal				Visual						
Simulation Tools	Climate zone	Graphical Interface	Horizontal	Vertical	Egg-crate	Awnings	Active automatic	Louvers	Blinds	Glazing	Orientation	Vegetation	Depth	Width	Angle	Window-to-wall	Spacing	Color	Solar radiation	Solar transmit	Temperature	Ventilation	Illuminance	Glare	View	Optimized shading	Energy	HVAC	License Fees
BLAST	W	P	•	•						•	•					•			•	•	•						•	•	•
DOE-2.2	W		•	•						•	•		•	•	•	•	•		•	•	•		•	•			•	•	
ECOTECT	W	•	•	•	•			•	•	•	•		•	•	•	•	•		•	•	•		•		•	•			•
Energy Plus	W	P	•	•					•	•	•					•			•	•	•	•	•	•			•	•	
e-QUEST-3	W	•	•	•					•	•	•		•	•	•	•	•		•	•	•		•	•			•	•	
IES <VE>	W	•	•	•	•			•	•	•	•		•	•	•	•	•		•	•	•	•	•	•			•	•	•

W = Weather file; P = Plug-in available

The review shows that all of the 6 computer simulation tools have their own strengths and limitations. BLAST uses a heat balance approach while DOE–2.2 uses a room weighting factor approach for load calculation (Crawley *et al*, 2001). ECOTECT is more suitable for architect or designer to simulate the building performance in early design stage. It is also possible to have ECOTECT self-generate an optimized shading device. It uses the solar profiles to generate the exact shape required to shade any given rectangular window given a start and stop time and a cut-off date. However, this tool does not integrate HVAC systems for energy calculations. Hence, it requires another program for energy calculations. e-QUEST-3 is a free download software based on calculation engine DOE 2.2. Only horizontal and vertical fins can be modeled in this tool. Energy Plus integrates the capabilities of BLAST and DOE-2 but it is more suitable for final evaluation simulation which requires high expertise. For IES <VE>, more complete simulation can be performed, including indoor glare and energy consumption. The new development of IES VE-Ware and IES VE-toolkits provides connectivity to Revit Architecture 2008/09 or Revit MEP 2008/09. However, training is needed to master the IES VE due to the complicated data input and interfaces. From all the selected tools, none of them is able to perform simulation for awning, active automatic shading device and vegetation shading. Besides, no tool is available to perform simulation on colour design. This has constrained the use the simulation tools for the research on solar shading strategies. Due to the different constraints of the tools, sometimes combination of different tools is required in order to perform a better simulation results (Lim *et al.*, 2008).

Conclusion

This paper concludes that the understanding of the characteristics of different types of shading devices and the methods of shading design is crucial for architects to design energy efficient solar shading. This is because the balance between the prevention of heat gains and natural day-light penetration is required, especially in tropical climate with high solar radiation. However, the present available methodologies of shading design are limited due to the needs of detailed data input or complicated procedures. Development of simplified design tools for energy efficient solar shading in tropical climate is demanded. This is to allow the architects to take shading strategies into consideration in early design stage, without requiring detailed data input or complicated procedure, while providing data for optimum solar shading design towards building energy efficiency. Hence, more researches, simulations and validations are needed.

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References

Ahmad, M.H. (1996). *The Influence of Roof Form and Interior Cross Section on Daylighting in the Atrium Spaces in Malaysia*. Ph.D., University of Manchester.

Athienitis, A.K. and Tzempelikos, A. (2002). A methodology for simulation of daylight room illuminance distribution and light dimming for a room with a controlled shading device. *Solar Energy*. 72 (4), 271–281.

Baker, N. and Steemers, K. (1996). LT Method 3.0 - a strategic energy-design tool for Southern Europe. *Energy and Buildings*. 23, 251-256.

Balcomb, D. (1998). The coming revolution in building design. *Environmentally Friendly Cities - PLEA'98*. Lisbon: James & James Science Publishers Ltd.

Carmody, J., Selkowitz, S., Lee, S. E., Arasteh, D. and Willmert, T. (2004). Window Systems for High Performance Buildings. (1st ed.) New York: W.W.Norton & Company, Inc.

Crawley, D.B., Hand, J.W., Kummert, M. and Griffith, B.T. (2005). Contrasting the capabilities of building energy performance simulation programs. (1st ed.) Joint Report by US Department of Energy, USA, University of Strathclyde, UK, University of Wisconsin-Madison, USA and National Renewable Energy Laboratory, USA.

Crawley, D.B., Winkelmann, F.C., Lawrie, L.K. and Pedersen, C.O. (2001). Energyplus: new capabilities in a whole-building energy simulation program. 7th International IBPSA Conference. 13-15 August. Rio de Janeiro, Brazil, 51-58

Emmanuel, R (1993). A hypothetical 'Shadow Umbrella' for thermal comfort enhancement in the equatorial urban outdoors. *Architectural Science Review*, 36:173-184

Franzetti, C., Fraisse, G. and Achard, G. (2004). Influence of the coupling between daylight and artificial lighting on thermal loads in office buildings. *Energy and Buildings*. 36 (2), 117–126. doi:10.1016/j.enbuild.2003.10.005

Goulding, J. R. and Lewis, J. O. (1992). *Energy Conscious Design - A Primer for European Architects*. London: Batsford.

Hviid, C.A., Nielsen, T.R. and Svendsen, S. (2008). Simple tool to evaluate the impact of daylight on building energy consumption. *Solar Energy*. doi:10.1016/j.solener.2008.03.001

Lim, Y.W., Ahmad, M.H. and Ossen, D.R. (2008). Review on solar shading strategies and measuring tools for building energy efficiency in tropical climate. *Proc. 9th SENVAR + 2nd ISESEE, International Seminar in Sustainable Environment & Architecture + International Symposium & Exhibition in Sustainable Energy & Environment.* 1-3 December. Universiti Teknologi Mara, UiTM, Shah Alam, Malaysia, 239-248.

Loutzenhiser, P.G., Maxwell, G.M. and Manz, H. (2007). An empirical validation of the daylighting algorithms and associated interactions in building energy simulation programs using various shading devices and windows. *Energy.* 32, 1855-1870. doi:10.1016/j.energy.2007.02.005

Olgyay, V. and Olgyay, A. (1957). *Solar Control and Shading Devices.* New Jersey: Princeton University Press.

Ossen, D.R. (2005). *Optimum Overhang Geometry for High Rise Office Building Energy Saving in Tropical Climates.* Ph.D., Faculty of Built Environment, Universiti Teknologi Malaysia.

Pedrini, A. and Hyde, R. (2001). A database energy tool for design-phase assessment of office buildings. *The 18th Conference on Passive and Low Energy Architecture (PLEA 2001).* 7-9 November. Florianópolis, Brazil, 1-8.

Sharifah, F.S.F and Sia, S.J (2004) Sunlight control and daylight distribution analysis: The KOMTAR case study. *Building and Environment*, 39: 713-717. doi:10.1016/j.buildenv.2003.12.009

Tzempelikos, A. and Athienitis, A.K. (2007). The impact of shading design and control on building cooling and lighting demand. *Solar Energy.* 81, 369-382. doi:10.1016/j.solener.2006.06.015

Zain-Ahmed, A., Sopian, K, Othman, M.Y.H, Sayigh, A.A.M and Surendran, P.N. (2002). Daylighting as a passive solar design strategy in tropical buildings: A case study of Malaysia.*Energy Conversion and Management*, 43:1725-36.