A STUDY ON COMPUTER PROGRAMMES APPLIED FOR SOLAR SIMULATION IN ARCHITECTURE AND URBAN DESIGN

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ABSTRACT: This paper conducts a study on the computer programmes which are applied to simulate solar radiation in research area of urban development and architecture. These programmes are useful to simulate thermal behaviour of a building or its envelope when they are exposed to the sun. The other benefit in application of these programmes is to understand influence of solar irradiation on energy efficiency for buildings as well as identifying comfort level for pedestrians walking in cities. Since these programmes are released in an immense range, hence this paper attempts to introduce several of well-known programmes that are available in the market and widely used by those involved in related research with this study. In addition, the paper's effort is not only introducing the simulator, but also to clarify the strong and weak points of the programmes. Subsequently, limitation in terms of availability of either programme is shown and rate of required expertise is discussed in its relevant section of this paper. At the end their capabilities are compared together and comprehensiveness of alliances within programmes is pointed out.

Keywords: software programmes, solar simulation, building and its envelopes, architecture and urban development.

1. INTRODUCTION

Simulation programmes are burgeoning in almost all areas of knowledge. They are capable to prognosticate which is considered the main reason of their every day thriving. These programmes facilitate and shorten long procedures in both terms of time and calculation. Even in cases that research or computation confronts difficulties; for instance pecuniary issues; simulation is the only solution. The other motivation of their popularity is the daily base advancement in those programmes per se. Computer literacy associated with all mentioned reasons result in ongoing exploitation of simulation programmes in different fields of knowledge inwhich architecture and urban design are not exceptions.

The objective of this paper is to introduce several well-known and reliable simulation programmes in architecture and urban design. This objective is accompanied with highlighting necessity of simulation approach especially in developing countries in both level of practice and education.

2. SIMULATION PROGRAMMES IN ARCHITECTURE AND URBAN DSIGN

In architecture and urban design simulation programmes are widely used. Designers and engineers apply simulators to understand behaviour of studying

objects. In relevance with ability of software, simulators in this area can be classified in two major categories: qualitative and quantitative.

2.1. Qualitative simulation programmes

These types of programmes are useful to study qualitative behaviour of users in a space, so-called qualitative simulation programmes. Studying the behaviour of visitors gathered in an arena in case of fire is exemplifying of these simulators' usage. Utilising traditional approaches are rough assumptions that sometimes are not even close to reality. Since these programmes are not of this paper discourse, we do not debate anymore and start introducing the other type which is quantitative programmes.

2.2. Quantitative simulation programmes

These are programmes that deal with physical aspects such as structure, temperature and so on. In spite of being applied in architecture and urban design, these aspects are derived from physics and hence they have physical definitions and units. It is the extent that engineers are more familiar with them. In order to solve this problem, recent programmes are integrated with user interface capabilities that enable architects and designers to utilise them. It brings another imperative advantage that significantly augments efficacy of project to be designed. Dealing with design stage, these software programmes address efficacy of project from the preliminary stage that usually designers are involved in.

One may find energy and subsequently thermal concern among those which attracts designers and engineers from city scale to single room. Due to recent increment in fuels price, this issue is also attractive to clients. In the other hand, governments and ecology activists concern about it because world threatening catastrophes such as global warming and climate change are explicitly addressable throughout energy. Therefore, thermal simulators that encompass focus of this paper are selected and introduced in following with particular spotlight on solar thermal simulation programmes.

3. METHODOLIGY

Selection of simulation programmes are based on reliability of their output and results. In this regard points delivered by US Department of Energy, unit of Energy Efficiency and Renewable Energy (EERE) has been deemed. In integration with

recommendation of this department as one of the most harbingers in thermal simulation, delineation of the releasing company of each software is pointed out. In addition published papers in association with the programmes are cited as well. It has been attempted to avoid personal views of authors in detail data except of comparison part of this paper. Only very general information from personal viewpoints of authors has been mentioned wherever necessary.

The effort of this paper is also to introduce the latest version of programmes with additional information about the availability of software and market issues.

4. THERMAL SIMULATION PROGRAMMES

The most recognised thermal simulation programmes particularly integrated with solar irradiation simulation are pointed out below as follows:

3.1. Ecotect

It is one of the most popular simulators among its own types, however its daylighting evaluation can be considered as the most consistent application (Khaled, 2007). The publisher describes the ECOTECT as a complete building design and environmental analysis tool that covers the full range of simulation and analysis functions required to truly understand how a building design will operate and perform (*Ecotect*, 2008). US department of energy accentuates that it provides essential analysis feedback from even the simplest sketch model (US Department of Energy, 2008). ECOTECT progressively guides the user as more detailed design information becomes available. It is available through its website: http://www.squ1.com .

3.2. Energy plus:

Energyplus has released by US Department of Energy based on *BLAST* and *DOE-2.1E* programmes (Crawley, et.al., 2005). Regarding its strength points US department of energy has mentioned that it has accurate, detailed simulation capabilities through complex modelling capabilities (US Department of Energy, 2008). One of the most advantages of applying this simulator is that Weather data for more than 1250 locations worldwide available on its web site. The software has won different awards namely R&D 100 awards, Awards for Excellence in Technology Transfer (2times) and IT Quality Award for Technical Excellence (*EnergyPlus*, 2008). The URL http://www.energyplus.gov is its website.

3.3. IES

IES is a wide-ranging tool for simulating and cost calculating for thermal management and illuminating as well (*IES*, 2008). It is an integrated collection of application which is linked by a single Integrated Data Model and Common User Interface (Muhaisen and Gadi, 2006). Having another name as VE (Virtual Environment), it consists of different simulators, each for different purposes. It is one of the most comprehensive programmes for understanding the thermal loads (US Department of Energy, 2008). Entire the programme is available via its website: http://www.iesve.com .

3.4. LESO-SHADE

It calculates shading factor on any facade or surface of a building caused by any obstacles. According to US department of energy, the scenes are easy to define and the user can get very easily and in a short time both a 3-dimensional view of the scene and the shading factors that can be taken into account as its advantages whereas disadvantages are: there is no possible connexion to a standard CAD package, the number of possible geometric shapes is rather limited and the geometric elements cannot be rotated of an arbitrary angle which makes this software not fitted into this (US Department of Energy, 2008). Its website http://lesowww.epfl.ch/ provides more information.

3.5. ParaSol

Suitable for designing sun shading devices, Parasol accepts input data in 3 separate segments: room, window and sunshade (*ParaSol*, 2008). According to US department of energy it is a design tool to study the potential of solar protection for different types of sunshades and glazing systems and their influence on the building energy performance at an early design stage (US Department of Energy, 2008). Having more inquiries, http://www.parasol.se should be visited.

3.6. RadTherm

It is a tool for heat management. US department of energy explains that *RadTherm* has powerful capabilities to solve transient solutions for 2D or 3D models in a natural environment, including the effects of direct, diffuse, and reflected solar radiation, thermal radiation, natural or forced convection, and conduction, but as a points of weakness it needs high level of knowledge, an engineering background which makes it difficult for those who are novice but interested (US Department of Energy, 2008). It is a professional thermal modelling to predict the full temperature distribution of a product or system, e.g. active and passive cooling can be tested for the cost-benefit analysis

(RadTherm, 2008). *RadTherm* is obtainable through http://www.thermoanalytics.com .

3.7. Shadow FX

Shadow FX is a useful software for architects and town planners for shading calculations, sun modelling and solar shading. US department of energy accentuates that the program is user-friendly and highly graphic where shadow profiles are output in the form of AutoCAD DWG and DXF files (US Department of Energy, 2008). The software can be reached via http://www.shadowfx.co.uk . It is designed to deal with small scaled 2D shadow analysis since the overhang and fin diagrams provide fast, simple sun-screening design solutions (*ShadowFX*, 2008).

3.8. Sombrero 3.01

Sombrero 3.01 is a design tool to calculate shading on any arbitrary surfaces surrounded by shanding elements as a function of time and location (Niewienda and Heidt, 1996). It provides quantitative results for shading of collectors or windows by buildings, overhangs, trees or the horizon (US Department of Energy, 2008). It adds: these results can be used either directly for visualization or as input for other thermal simulation programmes. Either for active use of solar energy (domestic hot water, photovoitaics) or for passive solar architecture (shading or lighting of planes), *Sombrero 3.01* can provide quantitative results (*Sombrero*, 2008). It is obtainable via http://nesa1.uni-siegen.de/ .

3.9. SUNDI

A simple analysis can be done with sun orbit diagrams. The results can be presented graphically. The *SUNDI* simulation programme can be used for calculating the irradiance losses due to shading (*SUNDI*, 2008). The irradiance losses can be also calculation for long periods of time US department of energy (US Department of Energy, 2008). Programme is user friendly and calculations are very quick. To access for more information, http://emsolar.ee.tu-berlin.de/simulation/sundi.html is useful.

3.10. TownScope II

TownScope II is among those few simulators which supports urban designers and decision makers as well (Teller and Azar, 2001). It supports urban design decision-making in a "responsive environment" perspective (*TownScape II*, 2008). According to US department of energy it combines a user-friendly graphical interface with powerful analysis tools (US Department of Energy, 2008). Thermal comfort, critical wind discomfort risk and perceptive qualities of

urban open spaces can be assessed very quickly via *TownScope II*. Additionally, the software provides an integrated multi-criteria decision module to rank various alternative proposals. Regretfully dimensioning, optimisation or detailed simulations are not afforded by the software. It is obtainable via http://www.ulg.ac.be/lema/ . Recently its website address has moved to http://www.lema.ulg.ac.be/tools/townscope/ .

3.11. TRNSYS

Transient simulation programme links the components of the grid connected PV system together (Abdullah, et.al., 2002). It is also useful for energy savings calculation by daylighting (Schweizer, et.al., 1998) as well as thermal simulation (Flor, et.al., 2005). Recently the programme has been developed in terms of external shading and internal insulation calculation of building which called *TRNSHD* (Hiller, et.al., 2000). It also benefits of a graphical interface (*TRNSYS*, 2008). The input data must be in very detailed information because the programme is not provided any assumption (US Department of Energy, 2008). It is available from: http://www.trnsys.com .

5. SIMULATORS JAXTAPOSITION

A juxtaposition is provided in table 1 containing all introduced programmes. Glossary of abbreviation as follows:

Glossary:

●: available
_: not available
D: Day
Dcp: descriptive manner
F: Free
H: Hour
L: limited
M: Min
MI: Manual Input
Mth: monthly
N/A: Not Applicable
TMY: Typical Meteorological Year data set
TS: Technical Support

Table 1: simulation programmes and their capabilities.

	Released	open source		Climatic data			Modelling capability		Sun path		Shadow cast		Thermal calculation		Other capabilities			Expertise requirement		
	Date	Trial version	Full version	Particular area	Data bank	World climate	Model maker	Compatibility to other programme	Certain periods	Accuracy	Outside	Inside	Heat gain	Temperature	ventilation	Luminance	others	Low	High	Training course
Ecotect 5.50	Jun 2006	L	100$	●	●	_	●	●	●	M	●	●	●	●	●	●	●	●	_	_
EnergyPlus	Apr 2008	_	F	_	1250	_	Des	_	●	N/A	_	_	●	●	●	●	●	_	●	_
IES 5.8.2	Apr 2008	L	8000$	●	L	_	●	●	●	M	●	●	●	●	●	●	●	●	●	●
LESO-SHADE	1999	_	CHF 200	L	_	_	L	_	●	H	●	_	_	●	_	_	_	●	_	_
RadTherm9	Jan 2008	L	$1000	L	_	_	●	L	_	_	●	_	●	●	●	●	●	_	●	●
Shadow FX 1.08b	Jul 2000	L	$99	L	_	_	L	●	L	H	●	_	●	_	_	_	_	●	_	_
Sombrero 3.01	N/A	L	€220	200	_	_	L	_	●	H	●	_	●	_	_	_	●	●	_	_
SUNDI	N/A	_	F	●	_	_	N/A	N/A	●	D	N/A	N/A	●	●	_	_	_	●	_	_
TownScape II 3.0.1	Nov 2007	L	€450	L	Mth	_	L	L	●	H	●	_	_	●	●	●	●	●	_	●
TRNSYS 16	Oct 2004	●	4200$	_	_	TMY	DCP	_	●	N/A	●	●	●	●	●	●	A	●	_	TS

6. OUTCOME

In this paper, the top 11 most recognised thermal simulation programmes are introduced. They are useful in architecture and urban design particularly in solar irradiation simulation. They effectively can underpin strength points of design even in very early stage of design when project is not more than a concept. Nonetheless in developing countries utilisations of simulators are still in process, undoubtedly next decade will be dominated by them and in all schools of design; architecture or urban design; they will be applied widely. It is the process that leading universities have already commenced within last ten years.

7. REFERENCES

Sallal, A. Khaled, (2007). *Testing Glare in Universal Space Design Studios in Al-Ain, UAE Desert climate and Proposed Improvements*: Renewable Energy, 32, pp.1033-1044.

Official website of *Ecotect*, retrieved 7-March-2008, available through http://www.squ1.com

Official website of *US Department of Energy*, retrieved 2-Febraury-2008, available through http://www.eere.energy.gov

Crawley, B. Drury and et.al.,(2005). Contrasting the Capabilities of Building Energy Performance Simulation Programs. *Building Simulation 2005: Ninth International IBPSA Conference*, ____, Montreal, Canada.

Official website of *Parasol*, releaser retrieved 6-March-2008, available through http://www.parasol.se

Official website of *RadTherm*, retrieved 17-March-2008, available through http://www.thermoanalytics.com

Official website of *ShadowFX*, retrieved 3-April-2008, available through http://www.shadowfx.co.uk/shadowfx.htm

Official website of *EnergyPlus*, retrieved 28-March-2008, available through http://www.energyplus.gov

Official website of *IES*, retrieved 29-Febraury-2008, available through http://www.iesve.com

Muhaisen, S. Ahmad and Gadi, B. Mohamed, (2006). Effect of Courtyard Proportions on Solar Heat Gain and Energy Requirement in the Temperate Climate of Rome: *Building and Environment*, 41, pp.245-253.

Niewienda, A. and Heidt, D. F. (1996). SOMBRERO: A PC-Tool to Calculate Shadows on Arbitrarily Oriented Surfaces: *Solar Energy*, 58(4), pp.253-263.

Official website of *Sombrero*, retrieved 21-March-2008, available through http://nesa1.uni-siegen.de

Official website of *SUNDI*, retrieved 2-March-2008, available through http://emsolar.ee.tu-berlin.de/simulation/sundi.html

Teller, J. and Azar, S.(2001).TownScape II-A Computer System to Support Solar Access Decision-Making: *Solar Energy*, 70(3), pp.187-200.

Official website of *TownScape*, retrieved 26-March-2008, available through http://www.lema.ulg.ac.be/tools/townscope [26-3-2008].

Abdullah, H. Ali, Ghoneim, A. Adel and Al-Hasan, Y. Ahmad (2002). Assesment of Grid-connected Photovoltaic Systems in the Kuwaiti Climate: *Renewable Energy*, 26, pp. 189-199.

Schweizer, C., Eicker, U. and Lomas, K.(1998). Dynamic Calculation of Daylighting in Urban Structures: *Renewable Energy*, 15, pp.360-363.

Flor, J. Francisco, Cebollar, O. Rafael, Felix, L. Jose(2005). Solar Radiation Calculation Methodology for Building Exterior Surfaces: *Solar Energy*, 79, pp.513-522.

Hiller, D.E. Marion, Beckman, A. William, and Mitchell, W. John, (2000). TRNSHD_ A Program for Shading and Insulation Calculations: *Building and Environment*, 35, pp.633-644.

Official website of *TRNSYS*, retrieved 26-March-2008, available through http://www.trnsys.com