EXPLORING THE AVAILABILTY AND USABILITY OF WEB-BASED BUILDING PERFORMANCE SIMULATION TOOLS

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ABSTRACT

In the last two decades web-based simulation (WBS) has become increasingly available. In the process, it has also become relevant for building performance simulation (BPS). After discussing the present state of web-based BPS tools, a framework is offered to categorize the currently available tools. In order to address usability issues, selected tools (in thermal and energy domain) are considered in more detail. A sub-set of these tools are subsequently tested by a small user group.

INTRODUCTION

During the last decade, web-supported tools for knowledge inquiry and problem solving have been increasingly become popular. The growing availability of web-based sources of advisory information and decision-making support tools "anywhere and anytime" holds a promising future for professionals and stakeholders in many different domains. The ease of use and instantly distributed updates to the applications are amongst the features that enhance the pervasive use of such resources and tools (Byrne et al. 2009). Particularly in engineering fields, expenses associated with acquiring and maintaining conventional software applications often represents a detriment and an obstacle to users with limited resources (for example potential users in the developing countries). Thus, in the area of building design and construction too, free (or low-cost), low-maintenance, and easy to use web-based tools could provide an effective alternative to users (students, architects, engineers, etc). The present contribution focuses on an assessment of web-based computational applications in the field of building (thermal) performance analysis. An overview is provided, and priliminary usability tests are undertaken. Specifically, the usability of web-based tools in the context of conceptual design stage (Zhu et al. 2007) is explored.

The contribution briefly enumerates, classifies, and compares some 24 available web-based simulation (WBS) tools. A small subset of these tools is subsequently presented to a small group of potential users within the framework of a usability assessment session (Nielsen 1995). Moreover, suggestions are made toward further development and subsequent improvement of such tools.

Augenbroe (2003) has assessed the role of "e-simulation" in the future context and its potential benefits over the traditional BPS applications. There are several prior studies about WBS on Building Science field. Mills 2002 discussed (for USA and Canada) the current state of residential energy analysis for both web-based and conventional tools. The review consisted of 50 web-based tools, which was narrowed down to 21 tools and compared with 6 conventional tools. A large number of WBS tools were found to lack updates or inaccessible altogether.

SURVEY

We selected a number of tools from (Crawley 1998). The rest was identified based on internet and literature search. The tools were classified in two dimensions: 1) the simulation domain, 2) the tool type (see Table 1). Six simulation domains were distinguished: i) thermal/energy performance, ii) code compliance, iii) cost analysis, iv) active energy systems, v) lightning, and vi) others. The type dimension involves 3 categories: a) remote simulation and visualization (RSV), indicating tools that are entirely internet driven; b) hybrid simulation and visualization (HSV), in which the simulation runs remotely on a simulation server and visualization engine is downloaded to the client side via a web-browser; c) local Simulation and visualization (LSV), where both the simulation engine and visualization components are downloaded to the client server (Byrne et al. 2009). We included LSVs, since they can be employed without a charge. A total of 136 tools were mapped onto the framework, namely 51 RSVs, 6 HSVs, and 79 LSVs.

PRELIMINARY EVALUATION

We conducted a preliminary assessment of selected WBS tools in the thermal and energy domain. Thereby, usability problems were the starting point for the development of a questionnaire (see Figure 1) including of 11 items. We evaluated 24 tools (see Table 2) in view of the issues addressed in this questionnaire.

Table 1 Categorization of the 136 surveyed WBS tools (note that certain tool are categorized in more than one category)

DOMAIN	RSV	HSV	LSV
Thermal/energy	19	5	18
Cost analysis	5	-	4
Code Compliance	9	1	14
Lighting	3	-	19
Active systems	10	1	13
Others	13	-	25

Table 2 List of tools for preliminarily evaluation

CODE	TOOL NAME	SIMULATION DOMAIN
A	Acuity Energy Platform	Energy management tool
B	Appliance Calculator	Appliances' cost/energy estimation
C	Home Energy Saver	Cost/energy and saving estimation
D	Home/ Commercial Energy Suite	Cost/energy estimation
E	ArchiPHYSIKweb pro	Energy estimation and code compliance
F	Building/ Green Energy Performance Compass	Energy use and savings, CO2 emissions
G	Cal- Arch	Energy use
H	Clariti	Energy management
I	MIT Design Advisor	Energy use, daylight
J	EnergyCAP Energy Benchmark	Energy use
K	Energy Profile Tool	Energy use, cost estimation, CO2 emissions
L	foAudits	Energy use (PDA or Palms)
M	My e-Home	Energy use
N	Rehab Advisor	Energy saving
O	Smeasure	Energy use and green house gas emissions
P	Building Advice	Energy use and savings, code compliance
Q	Building Green House Rating	Energy use and savings, code compliance
R	Energy Work Site	Energy use, cost estimation, code compliance
S	Green Quest	Energy use, cost estimation, CO2 emissions, code compliance
T	H1 Compliance Calculator	Energy use, code compliance
U	COM Check Web	Code compliance
V	Energy Star Home Advisor	Energy saving
W	IC3	Code compliance
X	RES Check Web	Code compliance

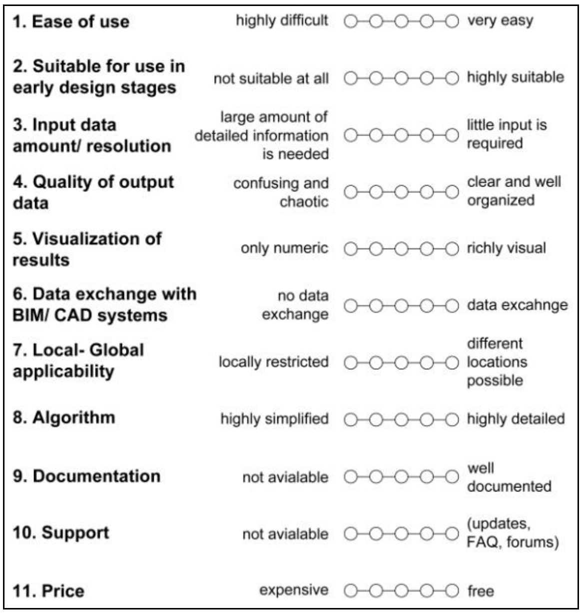

Figure 1 Questionnaire for tool assessment

To aggregate the 11 items of the questionnaire into a simple single-number indicator, a weighting scheme would be necessary. For the purpose of the present study, the weighting scheme of Table 3 was applied. In this scheme, weights associated to each question are expressed in percentage adding up to 100%.

Authors' preliminary evaluation of the 24 tools mentioned in Table 2 resulted in the total scores depicted in Figure 2. From this set, 3 tools were selected (***I***, ***M***, and ***T***) for further evaluation by a small group of users. ***I*** had the highest value (Figure 2) in the authors' evaluation. ***M*** supports the construction of 2D and 3D geometric building models. Lastly, ***T*** possesses data exchange capability.

Table 3: Evaluation of the Questionnaire

	QUESTIONNAIRE ITEM	WEIGHT (%)
1	Ease of use	10
2	Suitable for use in early design stages	12.5
3	Input data amount/ resolution	7.5
4	Quality of output data	10
5	Visualization of the results	7.5
6	Data exchange with BIM/ CAD systems	7.5
7	Local- Global applicability	12.5
8	Algorithm	12.5
9	Documentation	7.5
10	Support	5
11	Price	7.5
	TOTAL	**100**

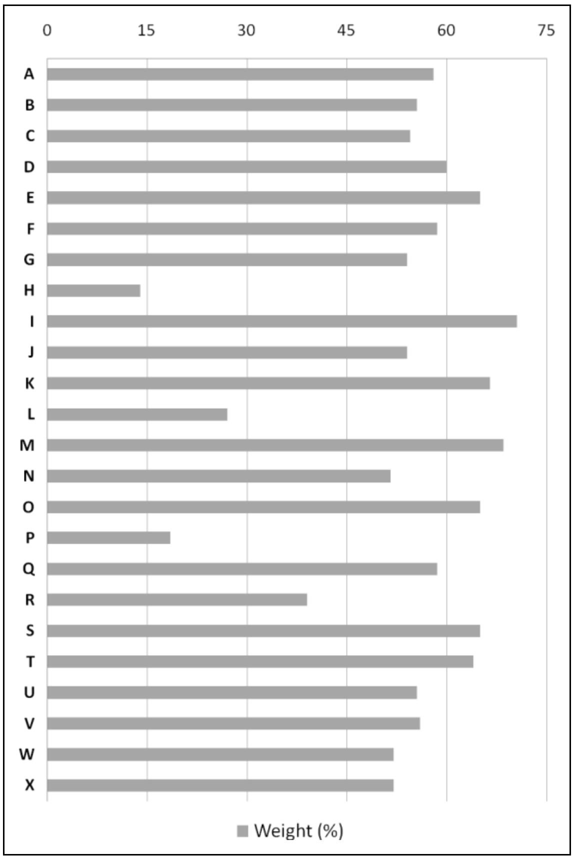

Figure 2: Preliminary Evaluation for Thermal-Energy Calculators

TEST WITH A SMALL GROUP

The test was conducted with a small group of potential users (16 architecture and engineering students). A specific task (evaluation of the energy performance of a small building) was given to the participants, for which the 3 above mentioned tools were to be used. Before conducting the test with the participants, we formulated our expectations (conjectures as to how the participants would evaluated the tools) based on our own evaluation. These formulations are summarized in Table 4 in terms of 12 hypotheses.

The participants' evaluations of the 3 tools are summarized in Figure 3 in terms of mean values. The general trend in the evaluations of the authors and the participants are similar (see Figure 4). ***I*** ranks, in both cases, ahead of ***M***, followed by ***T***.

A more detailed analysis of the results is provided in Table 4, which includes remarks concerning the authors' conjectures (see Table 5) and the participants' views (see Figure 3) on a question by question basis.

Table 4 A summary of the authors' conjectures regarding tools T, I, and M, as formulated prior to the test with a small group of users

QUESTION	HYPOTHESIS
1. Ease of Use	Selected tools are generally easy to use. ***T***'s GUI is deficient, making navigation difficult.
2. Early design stage suitability	***T*** and ***I*** do not support schematic design stage effectively.
3. Input data amount/ resolution	***T*** requires large amount of input data. ***I*** requires the least amount of input data.
4. Quality of output data	***M*** and ***I*** provide clear and well-organized output. ***T*** appears rather confusing.
5. Visualization of results	Except ***T***, tools provide effective visualization.
6. Data exchange with BIM or CAD	***I*** does not support data exchange. ***M*** exports and imports only *.meh extensions. Tool ***T*** imports *.gbxml and *.xml extensions.
7. Local – Global applicability	***M*** and ***T*** are locally restricted. ***I*** offers multiple locations.
8. Algorithm	***T*** is most detailed, followed by ***M.***
9. Documentation	All tools are well documented.
10. Support	***M*** offers only an email contact. ***I*** provides FAQ and email support. ***T*** provides these features plus a forum.
11. Price	All tools are free, but ***T***'s report must be purchased.
12. Satisfaction	***I*** is easier to use and requires less input data. ***M*** provides better visualization, and does not require deep technical background, but is limited concerning building types. ***T***'s GUI is deficient, but appears to be more detailed and reliable.

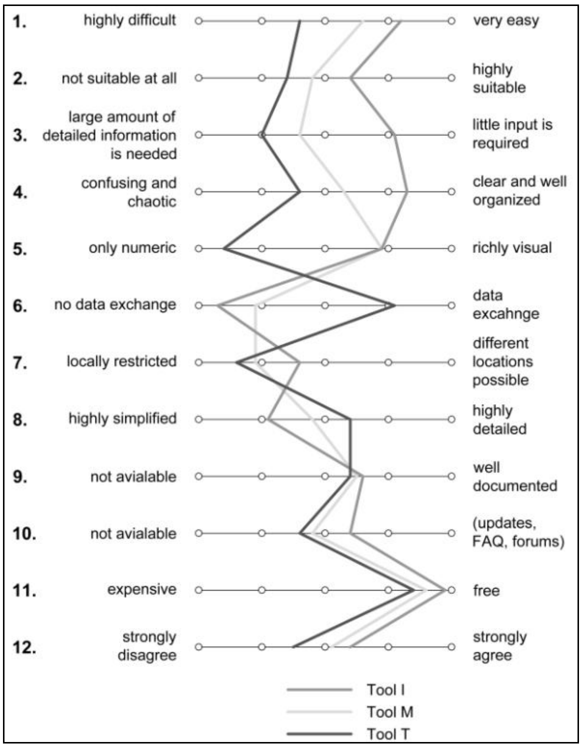

Figure 3 Mean values of the user group evaluation

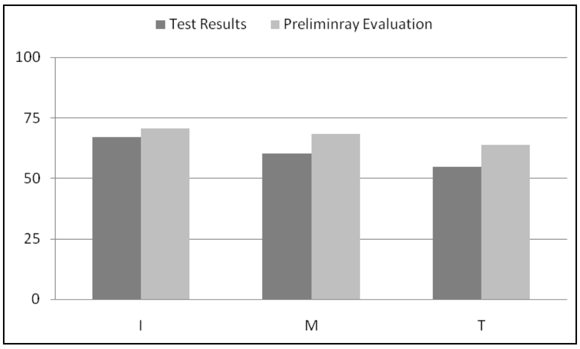

Figure 4 Comparison between the participants' test results and the authors' preliminary evaluation

Table 5Analysis of the test results

QUESTION	ANALYSIS
1. Ease of Use	***I*** requires less input data and provides default settings, hence it was found easy to use. ***M*** has a friendlier user interface as compared to ***T***.
2. Early design stage suitability	Contrary to the authors' conjectures, they found ***I*** more suitable then the other two. The reason seems to be that users focused on the fact that ***I*** requires less information, not that this information is not necessary available at the early stages of design.
3. Input data amount/ resolution	Similar to authors' conjecture, ***I*** was seen as requiring the least amount of data input and ***T*** has the highest.
4. Quality of output data	***I*** offers users a combined view of the results of different design alternatives, explaining users' preference. Users agreed with the preliminary evaluation in finding ***T***'s output confusing.
5. Visualization of the results	Since ***T*** does not provide charts or graphs for results, it received the lowest evaluation.
6. Data exchange with BIM or CAD	***T*** was the only tool that enables the users to import files with BIM extensions.
7. Local – Global applicability	Even though ***I*** offers a variety of locations, it received a lesser evaluation than expected: users implied that the locations were not distributed well enough. ***M*** is available only in Denmark and ***T*** in New Zealand.
8. Algorithms	Users' views confirm the preliminary evaluation.
9. Documentation	Users' views confirm the preliminary evaluation.
10. Support	As opposed to our conjecture, ***T***'s support function was not considered high, as the users could not access forum, due to the tool's GUI.
11. Price	All tools are free in principle. But the registration requirement of ***M*** and the report cost for ***T*** appear to have affected participants' judgment.
12. Satisfaction	All tools were found modestly satisfactory.

CONCLUSION

Web-based BPS tools have the potential to reach a large and diverse range of users from architects to facility owners. As participants in our small experiment suggest, the ease of use, instant accessibility, effective visualization, and low cost of the tools represent the main advantages of such tools. However, participants in our test commented that they expected more efficient data management and exchange capabilities so that building models (including geometry and material information) may be reused, thus saving time. Moreover, most tools are applicable only for limited locations, mostly due to the lack of pertinent weather information and local building materials and systems data.

Generally speaking, most WBS tools do not offer the possibility of collective developments and enhancements. If an open-source mentality would prevail in the BPS community, such tools could be developed by larger groups of collaborators, leading to richer and more widely applicable tools. Likewise, supporting functionalities such as data bases for weather information as well as materials and systems information could be more efficiently developed.

To maintain the advantages of WBS tools in terms of instant accessibility, simple user interaction features, low costs but provide, at the same time, sufficiently detailed and reliable results, tools with a hybrid structure may offer the best opportunity: they combine the best features of local and remote simulation (Byrne et al. 2009). The workload on the server is reduced (as compared to conventional WBS approaches) by exporting the animation/visualization functionality to the client side (Myers 2004). Thus, BPS tools with hybrid approach could offer the same features as the conventional tools in terms of data interoperability and provision of a database.

In conclusion, it must be stated, that while the increased application of web-based BPS tools is highly desirable, it may also contain a risk: the authors as well as the users with some technical background question the reliability of the underlying abstractions, data bases, and computational algorithms of currently available simplistic tools. Users lacking a sufficient technical background in building physics and technology may use tools in an inappropriate manner, arrive at mistaken results, or interpret results wrongly. It would be thus important (as one of the many possible and necessary measures); to augment WBS tools availability with effective online courses and curricula in the relevant areas of building physics.

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APPENDIX

URL information for the WBS tools considered in the preliminarily evaluation

CODE	TOOL NAME	WEB SITE
A	Acuity Energy Platform	www.agentisenergy.com
B	Appliance Calculator	www.energynewengland.com/old%20energynewengland /softapps.htm
C	Home Energy Saver	homeenergysaver.lbl.gov/
D	Home/ Commercial Energy Suite	www.apogee.net/
E	ArchiPHYSIKweb pro	www.web-planquadrat.at/de/planquadrat.html
F	Building/ Green Energy Performance Compass	www.abgr.com.au
G	Cal- Arch	poet.lbl.gov/cal-arch/start.html
H	Clariti	www.energyclariti.com
I	MIT Design Advisor	designadvisor.mit.edu/design/
J	EnergyCAP Energy Benchmark	www.energycap.com/benchmark/
K	Energy Profile Tool	www.energyprofiletool.com/subscription
L	foAudits	www.foaudits.com
M	My e-Home	www.savingtrust.dk/consumer/tools-and-calculators/my-home/myhome-register-profile-cookies
N	Rehab Advisor	www.rehabadvisor.pathnet.org/index.asp
O	Smeasure	www.smeasure.org.uk
P	Building Advice	www.airadvice.com
Q	Building Green House Rating	www.abgr.com.au
R	Energy Work Site	www.energyworksite.com/corporate
S	Green Quest	www.mygreenquest.com
T	H1 Compliance Calculator	www.design-navigator.co.nz/ DNProcessProject.php
U	COM Check Web	energycode.pnl.gov/COMcheckWeb/
V	Energy Star Home Advisor	www.energystar.gov/index.cfm?fuseaction=home_energy_advisor.showGetInput
W	IC3	ic3.tamu.edu/login
X	RES Check Web	energycode.pnl.gov/REScheckWeb/