"ARCHITECT FRIENDLY": A COMPARISON OF TEN DIFFERENT BUILDING PERFORMANCE SIMULATION TOOLS

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ABSTRACT

A wide range of scientifically validated Building Performance Simulation tools BPS is available internationally. The users of those tools are mainly researchers, physicists and experts who value empirical validation, analytical verification and calibration of uncertainty as defined by e.g. BESTEST. However, literature and comparative surveys indicate that most architects who use BPS tools in design practice are much more concerned with the (1) Usability and Information Management (UIM) of interface and (2) the Integration of Intelligent design Knowledge-Base (IIKB). Those two issues are the main factors for identifying a building simulation program as "*Architect Friendly*". Now, with the advancement of BPS tools and the recent announcements of direct links between BIM or non-BIM modeling tools and BPS tools it is important to compare the existing programs. Based on an online survey, this paper presents the results of comparing ten major BPS tools. The following programs are compared: ECOTECT, HEED, Energy 10, Design Builder, eQUEST, DOE-2, Green Building Studio, IES VE, Energy Plus and Energy Plus-SketchUp Plugin (OpenStudio). With 249 valid responses, the survey ranked the tools in three classes and revealed that architects seek the IIKB above the UIM of the interface. Finally, the paper summarizes the key findings and underlines the major requirements for future improvement and development of BPS tools, mainly from an architectural perspective.

INTRODUCTION

Building simulation as a discipline can be traced back to the 1960's when the US government was involved in projects to evaluate the thermal environment in fallout shelters [1]. Since its inception, building simulation has been constantly evolving as a vibrant discipline that produced a variety of BPS tools that are scientifically and internationally validated. Realizing the increasing importance of the decisions made early in the design process and their impact on energy performance and cost, several BPS tools have been developed during the 80's to help architects perform early energy analysis, and create more energy efficient more sustainable buildings [2]. It was not until the 90's, that architects and designers got more and more encouraged to join the building simulation field. The architecture discipline started to integrate building simulation, similar to the integration of CAAD and virtual environment (VE) tools into practice. However, despite the proliferation of many building simulation/energy analysis tools in the last ten years, architects and designers are still finding it difficult to use even basic tools [3]. Findings confirm that most these BPS tools are not compatible with architects' working methods and needs [4-6]. From the perspective of many architects, most BPS tools are judged as too complex and cumbersome [7].

In fact, it is repeatedly reported in literature that a growing gap exists between architects as users and BPS tools [8]. Most BPS tools, are of necessity developed by technical researchers, building scientist or HVAC engineers. During development they are mainly concerned with empirical validation, analytical verification and calibration of uncertainty as defined by IEA BESTEST [9].In order to bridge this gap we have to recognize that building simulation is also a human, psychological and social discipline because it directly involves man-computer interaction and human knowledge processing, while enriching human experience. Therefore, we have to comprehend architects' problems in interacting with such tools because architects have a different background; different knowledge processing methods and they are visually oriented.

Now, there is a chance to bridge this gap. The advent of Building Integrated Modeling (BIM) and the recent announcements of direct links between BIM and non-BIM modeling tools and BPS tools in addition to the waves of energy codes and rating systems such as LEED, AHRAE 90.1 etc., are proving that disciplines are merging. There is a common objective and chance to improve the integration and alliances between engineers, architects and even constructers to create realistically integrated projects together and overcome the differences between the logical model and the realities of AEC industry practice. Therefore, the aim of this study is to compare and evaluate existing tools, from an architectural point of view to provide

guidance to BPS tool developers, with particular focus on existing challenges and the criteria of 'Architect Friendly' BPS tools.

This paper reports a survey that is dedicated to gathering information from beginner simulation tools users such as architects, designers and fresh graduate students who want to become sustainability oriented architects and designers in the USA. The survey probes the users' perception of the most important criteria of the usability of ten major USA market tools and how they use, and benefit from the tools associated with their design decisions. The survey investigated (1) the usability and information management of interface and (2) the integration of intelligent design knowledge-base. The objectives of the study are as follows:
•To identify the basic criteria for BPS tools that can support architects and designers making sustainable design more efficient, and cost effective.
•To compare the potential challenges and opportunities of using existing BPS tools
• To understand the architects' perceptions about existing tools and the importance of using them during design phases

METHODOLOGY
The research has been carried out in two parts. The first part consisted of a literature review on BPS tools, necessary to understand the tools' usefulness. Also the review assisted in defining a set of criteria for 'Architect Friendly' tools that are used in daily architecture design practice. The second part is based on an online survey.

Part 1:"Architects Friendly" tools and criteria
The architecture and simulation community at large have identified a number of criteria for 'Architects Friendly' BPS tools [10-12]. Among them, the following criteria are the most reiterated: (1) Usability and information management (UIM) of interface, (2) integration of intelligent design knowledge-base (IIKB), (3) interoperability of building modeling (IBM), and finally (4) the accuracy of the tool and its ability to simulate complex and detailed building components (AASDC). But, some recent publications claim that point (3) and (4) seem to be fading and getting less important [13]. Probably as a result of researchers publishing real-world validation studies and recent announcement of direct links between BIM or non-BIM modeling tools, such as the plug-in of IES and Energy PLUS for Google SketchUp. Similar to the Revit Architecture plug-in IES and ECOTECT in addition to EnergyPlugged that enables AutoCAD to create and edit EnergyPlus input files. However, in order to guarantee plausible and persuasive research, this paper presents the results of an online survey that

focused only on criteria (1) UIM and (2) IIKB. As future work, a second survey will include criteria (3) IBM and (4) AASDC.
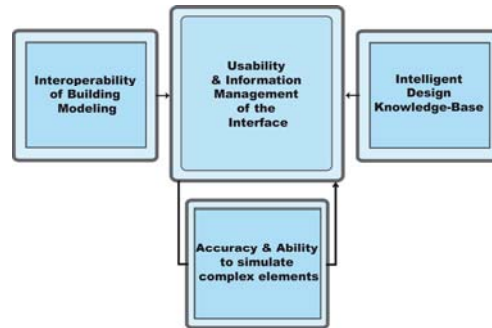

Fig. 1. Criteria for 'Architect Friendly' tools

Part 2: Survey
The online survey aimed to compare different BPS tools. Prior to launching the survey the authors conducted a literature review of other recent surveys [5, 11-17]. Comments and suggestions were requested from peers at X. The peers were asked to:
• Screen and list their top-ten BPS tools, from the U.S. DOE Directory. The selection had to represent an overview of state of the art BPS tools used by architects in the USA [18].
• Revise the questionnaire and provide critical feedback in order to optimize the structure, clarity and relevance of the questionnaire before posting the final version online.
As a result eight tools, ECOTECT, HEED, Energy 10 (E10), Design Builder (DB), eQUEST, Green Building Studio (GBS), IES VE and EnergyPlus SketchUp (EPSU) plug-in were selected plus 'raw' DOE-2 and Energy Plus (EP). The reviewers suggested adding DOE-2 and Energy PLUS to broaden the range of examined tools. First, to allow comparing tools that are capable of making overall energy analysis in the early design phase, versus tools capable of making detailed analysis in later design phases. Secondly, to allow comparing the sensible use of tools versus the amount of knowledge requested for each tool. Most significantly, to compare tools with developed graphical user interface (GUI) versus tools with text based user interface.
The questionnaire targeted beginner simulation tools users such as architects, designers, architecture educators and fresh graduate students who want to become sustainable architects or designers in the USA. Participants were recruited through email invitations to the mailing lists and forums of the ten above mentioned tools, in addition to the AIA Committee on the Environment (COTE), USGBC and the building performance simulation mailing lists (Bldg-SIM, Bldg-RATE, IBPSA-USA). Environmental architecture

departments, students' chapters, blogs and architecture firms in the USA were approached. The survey included 22 questions and the average duration for taking the survey was approximately 8 to 12 minutes. A welcome page explained the objective of the survey, informed participants of the approximate survey duration, and expected target group. Including the above mentioned issues the survey listed the tools that will be inquired. The questionnaire was structured into 4 parts:

- The first part, started with some basic information collection concerning respondent's current position, types of software used for energy simulation and CAD/3D modeling.
- The second and third parts of the survey focused on the following key criteria. (1) The usability and information management (UIM) of interface and (2) the integration of intelligent design knowledge-base (IIKB). The respondents were asked not only to judge the relevant importance of the above mentioned criteria, but also to share their experience by comparing longitudinally the ten selected tools.
- In the fourth part, and prior to the closing message, respondents were asked to rank the most important criteria for a BPS tool to be considered as 'Architect Friendly'.

An open question followed every part of the questionnaire in order to allow respondents to share their thoughts and comments. At the end of the survey respondents were invited to post their ideas about current limitations or improvements that should be avoided or integrated in the future development of BPS tools.

RESULTS

Hosted at eSurveyPro.Com, the survey was available online from mid December 2008 until mid January 2009. With the assistance of AIA-COTE, the survey attracted over 481 interested visitors with over 249 eligible respondents. Researchers and engineers were excluded to avoid bias in the responses. Despite hat, the results cannot be proven to be representative of any given population, but with an adequate amount of responses, patterns can be identified and cross-discipline analysis is possible[19].

Part 1: Basic Information
How do you describe your current position?
Figure 2 shows the six available categories from which respondents could chose. The majority of respondents were architects (38.5%) and designers (19.2%). Architecture educators were about 16.8% of respondents, architecture graduate students 12% and architecture undergraduate students 6%, while 4.8% of the respondents were intern-architects. Moreover, half of the respondents were LEED accredited

professionals and almost a quarter of respondents (24%) were AIA accredited architects. The survey sampled the architects' community with a prior interest in green building design and energy performance. Participants that did not fall into the above mentioned criteria were excluded in order to assure cross-discipline benchmarking.
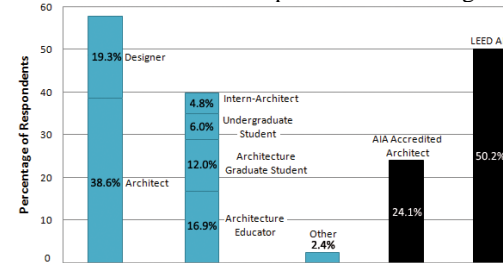

Fig. 2. Respondents' current position & affiliation

What of the following BPS tools do you use?
Next, respondents were asked what BPS tool they constantly used during all different design phases. Respondents could choose more than one tool. Figure 3 shows respondents' choices. Over 64% (159 individuals) of the respondents reported they use ECOTECT. The figure reveals that ECOTECT is the most commonly used tool among respondents. 123 individuals responded that they use eQUEST corresponding to 49% of all respondents. Surprisingly, both EP and EPSU plug-in were used by 32% of the respondents. IES VE was used by 24% of all respondents, E10 22.6%, DB 21.6%, DOE-2 19.2%, HEED 18% and GBS 10.8%. Although, those figures cannot be an indicator for market penetration they reflect at least these respondents' preference towards simulation tools.
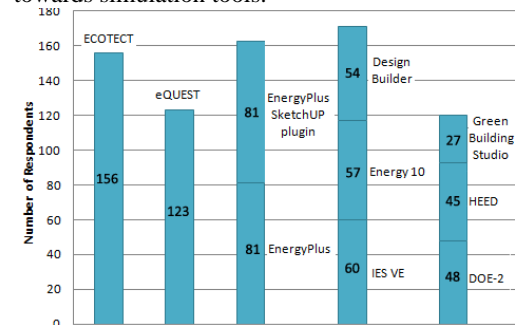

Fig. 3. BPS tools used by respondents

For which design phase would you use the following programs?
In a follow up question, respondents were asked to justify the design phases for every tool they use. Figure 4 indicates the typical usage phase for the ten tools according to the respondents' pattern. GBS, E10, HEED and DB were considered as tools that are used in early design phases. ECOTECT, eQUEST and IES VE were considered as tools that can be used during the conceptual and design development phase. Finally, DOE-2, EP and EPSU were considered

as extensive tools that are used for detailed analysis during the design development and design optimization phase.
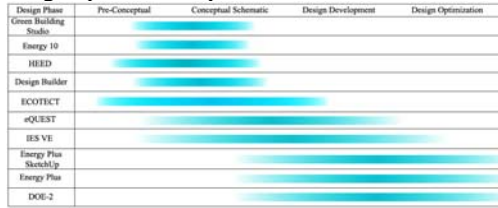

Fig. 4. Tools usage in different design phases

What CAD/3D modeling software do you use?
As seen in the comparison in Figure 5, the surveyed respondents used more than one program for CAD drawing/drafting and 3D modeling. The most frequently mentioned tools for CAD are shown in Figure 5. Together, AutoCAD and SketchUP outpace the rest. Revit comes in third. Notably absent are ArchiCAD and Vectorworks, which can be used for both 2D and 3D but are evidently not being used much by this group for 2D drawing/drafting. The top-ranked 3D modeling tool used most often for 3D modeling tasks is SketchUP.
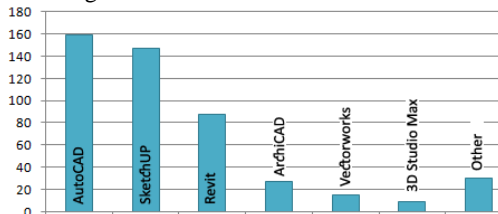

Fig. 5. CAD/3D modeling software usage pattern

Part 2: Usability and Information Management of Interface

UIM of the interface are two very important attributes of '*Architect Friendly*' tools. The term usability incorporates better graphical representation of simulation input and output, simple navigation and flexible control. For example, architects would like to see results presented in a concise and straightforward way, with a visual format or 3D spatial analysis preferred to numerical tabulation. Additionally, usability includes the ability to learn easily and quickly and to support the user with training, on-line help, look-up tables and error-traps. Similarly, information management is becoming a growing concern for tool users. There is a need for quality control of simulation input and the ability to evaluate alternatives quickly, accurately, and provide complete analysis for a design. Also, the ability to allow assumptions and to use default values and templates to facilitate data entry [14].

a. What are your priorities concerning USABILITY and GRAPHICAL VISUALIZATION of the interface?
As shown in Figure 6, respondents' top priorities concerning the usability and graphical

visualization of an interface where the graphical representation of output results (22.9%) followed by the flexibility of use and navigation (17.3%). The other three criteria were considered still important but with less agreement and with the same relative importance (15.5%). Learning how to use the tool easily and quickly was the least important feature (13.7%) among the 6 criteria. Except the graphical representation of output, the difference between the responses is small. This indicates that respondents want it all.

In the comments box, most respondents stressed the importance of graphical output and input features. Also several respondents criticized the wizard approach and expressed their interest in a more flexible and customizable approach. One interesting concept that came from a respondent was the ability to build a simulation in a 3D environment where users can "pick and place" different building, HVAC and load components into a space and simulate their performance and visualize it in 3D.
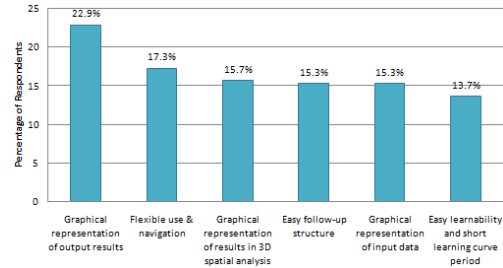

Fig. 6. Criteria concerning usability and graphical visualization usage pattern

Which tool(s) fulfill the following criteria?
Next, respondents were asked to compare the tool(s), concerning the usability and graphical visualization of their interfaces. Six sub-criteria, shown in table 1, were used to compare the ten different tools. The raw votes of respondents were normalized and plotted as a percentage in the table. Respondents' top ranking was for IESVE (87%), followed by ECOTECT, DB, eQuest and GBS (85%). There was less agreement on HEED and E10; but they were still considered as friendly (70%).

Table. 1. Ranking the tools according to usability and graphical visualization

	IES VE	ECOTECT	Design Builder	eQUEST	Green Building Studio	HEED	Energy 10	Energy + SketchUp	DOE-2	Energy +
Graphical representation of output results	✔	✔	✔	✔	✔	✔	✔	☒	☒	☒
Flexible use & navigation	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Graphical representation of results in 3D spatial analysis	✔	✔	☒	☒	☒	☒	☒	✔	☒	☒
Easy follow-up structure	✔	☒	✔	✔	✔	✔	✔	☒	✔	✔
Graphical representation of input data	✔	✔	✔	✔	✔	☒	☒	✔	✔	☒
Easy learnability and short learning curve period	☒	✔	✔	✔	✔	✔	✔	✔	☒	☒
USABILTIY & GRAPHICAL VISUALISATION OF THE TOOL (%)	87%	85%	85%	85%	85%	70%	70%	63%	50%	35%

b. What are your priorities concerning INFORMATION MANAGEMENT of the interface?

Figure 7 plots respondent's top priorities concerning information management of an interface. First, 28% of the respondents considered the ability to create comparative reports for multiple alternatives, as a priority. Second, 23.7% of the respondents favored the ability to assure quality control for the simulation input parameters. The third preferred criterion (17.7%) was the ability to allow assumption and default values to facilitate simulation data entry. Flexible data storage and user customizable features (16.1%) in addition to simple input and reviewing options (14.5%) were the least important among the 5 criteria.

In the comments box, most respondents stressed flexibility and the ability to accommodate beginner and advanced users concurrently. For beginner users, the interface should facilitate quick, transparent and simple entry values (debugging) next to default templates and libraries. Simultaneously, the interface should allow advanced users to create and modify their own customizable building types, systems, components/features, templates and output reports.
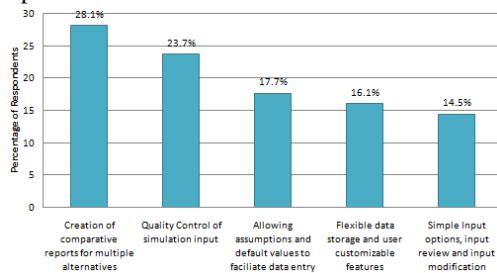

Fig. 7. Criteria concerning information management

Which tool(s) fulfill the following criteria?
Next, respondent were asked to compare the tool(s), concerning the information management of their interfaces. Six sub-criteria, shown in table 2, were used to compare the ten different tools. The raw votes of respondents were normalized and plotted as percentage in the table. Respondents' top ranking concerning information management of interface was for IES VE, HEED and eQUEST (100%), followed by GBS, DB and E10 (77%). There was less

Table. 2. Ranking the tools according to information management

agreement on ECOTECT (72%), while EP, EPSU and DOE-2 did not meet the user's

expectations (42%). One interesting idea came from a respondent who wanted to combine IES VE, ECOTECT and Radiance.

Part 3: Integration of Intelligent Design Knowledge-base
The integration of a design knowledge-base in the tools is required to support decision making under risk and uncertainty. Architects are looking for tools that can support sustainability design decisions and make detailed comparisons between different building design and equipment measures [7, 20]. In order that the design advances, the designer has to increase the input in the design with a higher level of knowledge and details. Therefore, it is essential that the simulation tools include an interface that supports such a knowledge-base. A knowledge-base that contains descriptive explanations, examples and procedural methods for determining appropriate installation and systems, e.g. guidelines, case studies, strategies etc. In this part of the survey, the questionnaire was designed to investigate '*Architect Friendly*' tools that can support the designer to comply with building codes and to be consistent with the rating systems, in addition to be able to assist in adjusting the design parameters to the needs within the framework of existing codes. The questionnaire also investigated the ability of the tools to allow the examination of sensitivity and uncertainty of key parameters in relation to design-decisions. Already, significant application of knowledge-based tools is present in intelligent computer-aided-architectural instruction or intelligent tutoring systems that support the architect's intuition or assists in solving a problem [17, 21].

a. What are your priorities concerning INTEGRATION OF KNOWLEDGE-BASE?
As shown in Figure 8, respondent's top priority concerning the integration of knowledge-base in an interface was the ability to provide guidelines for building codes and rating systems compliance (35%). The next priority was the ability to provide case studies databases for decision making (28%) followed by the ability to provide weather data and extensive libraries of building components and systems (25%). The fourth and last chosen criterion was the ability to support online user help and training courses.

In the comments box, most respondents stressed the importance of integrating a knowledge-base, that supports the compliance with LEED, baseline standards such as ASHRAE 90.1 and even the 2030 Challenge benchmarks. One interesting concept that came from a respondent was the development of a genuine overall architectural design development toolkit that calculates LEED credits and also offers the

calculation of energy, water savings, renewable energy and carbon foot-printing. Also seen as useful was, offering manufacturers' information about certain components such as windows and mechanical and electrical equipment that can be imported directly online and simulated. Another interesting comment was about the lack of information and ability to simulate sophisticated and detailed components such as double-skin facades, photovoltaics, electro-chromic glazing, green roofs etc... Similarly important, the absence of guidelines and ability to simulate passive systems such as, thermal mass, Trombe walls, passive cooling and heating etc…, was repeatedly reported.
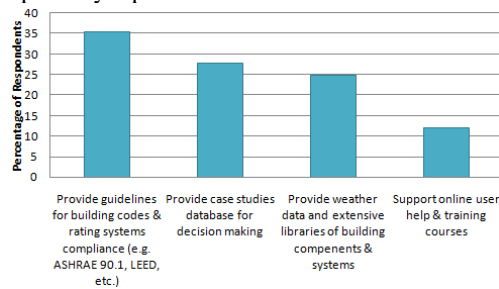

Fig. 8. Criteria concerning integration of knowledge-base

Which tool(s) fulfill the following criteria?
Next, respondents were asked to compare the tools, concerning the integration of a knowledge-base in their interfaces. Six sub-criteria, shown in table 3, were used to compare the ten different tools. The raw votes of respondents were normalized and plotted as a percentage in the table. Respondents' top ranking concerning integration of a knowledge-base in the interface was for, HEED (75%), followed by DB, IES VE and eQUEST (72%). The integration of a knowledge-base in the rest of the tools was unsatisfactory as shown in table 3.

Table. 3. Ranking the tools according to integration of knowledge-base

	HEED	IES VE	eQUEST	Green Building Studio	Energy 10	Design Builder	Energy +	ECOTECT	Energy + Sketchup	DOE-2
Provide guidelines for building codes & rating systems compliance	✓	✓	✓	☒	☒	☒	☒	☒	☒	☒
Provide case studies database for decision making	✓	☒	☒	☒	☒	☒	☒	☒	☒	☒
Provide weather data and extensive libraries of building compenents & systems	☒	✓	✓	✓	✓	✓	✓	✓	☒	✓
Support online user help & training courses	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
INTEGRATION OF KNOWLEDGE-BASE (%)	75%	72%	72%	37%	37%	37%	37%	37%	25%	12%

b. What are your priorities concerning the INTELLIGENT KNOWLEDGE-BASE and DESIGN PROCESS?
As shown in Figure 9, respondent's top priority, concerning the integration of the intelligent knowledge-base and compatibility with design process, was the ability to provide quick energy analysis that supported their decision making (33%). The next priority was the ability to examine sensitivity and uncertainty of key design parameters (29%) followed by the ability to

analyze weather characteristics and suggest suitable climatic design strategies (20%). The fourth and last criterion was the overall embracement of design during most design stages.
In the comments box, most respondents pointed out the importance of the ability of the tools to match the fast, fluid and iterative nature of the design process regarding the different design phases and the ability and flexibility to revise and update the design variables. Additionally, some respondents expected that the tools should be more intelligent keeping a balance between the amounts of requested input variables vis-à-vis the different design phases.
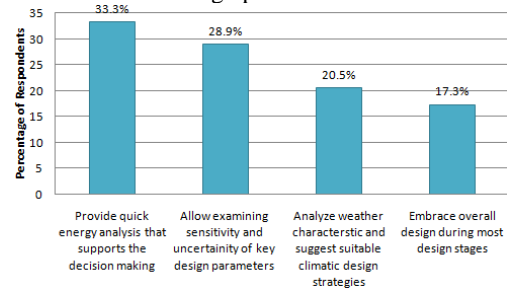

Fig. 9. Criteria concerning intelligent knowledge-base and design process

Which tool(s) fulfill the following criteria?
Next, respondent were asked to compare the tool(s), concerning the intelligence of the knowledge-base and compatibility with design process. Four sub-criteria, shown in table 4, were used to compare the ten different tools. The raw votes of respondents were normalized and plotted as a percentage in the table. Respondents' top ranking was for HEED (100%), followed by IES VE and eQuest (80%). There was less agreement on E10 (63%), DB (51%) and ECOTECT (51%).

Table. 4. Ranking the tools according to the intelligence of knowledge-base & design process

	HEED	IES VE	eQUEST	ECOTECT	Energy 10	Green Building Studio	Design Builder	DOE-2	Energy +	Energy + Sketchup
Provide quick energy analysis that supports the decision making	✓	✓	✓	✓	✓	✓	✓	☒	☒	☒
Allow examining sensitivity and uncertainty of key design parameters	✓	✓	☒	☒	✓	☒	☒	✓	✓	✓
Analyze weather characterstic and suggest suitable climatic design strategies	✓	☒	☒	☒	☒	☒	☒	☒	☒	☒
Embrace overall design during most design stages	☒	✓	✓	✓	☒	☒	☒	☒	☒	☒
INTELLIGENT KNOWLEDGE-BASE & DESIGN PROCESS (%)	83%	80%	51%	51%	44%	13%	13%	29%	29%	29%

Part 4: MOST IMPORTANT features of a simulation tool
What are the MOST IMPORTANT features of a simulation tool?
In part 4, respondents were asked to rank the most important features of a simulation tool. Figure 10 shows the results of this question. Almost one third (31%) of the respondents, indicated that the integration of an IIKB, that assist designers in decisions-making, is the most important feature of a BPS tool. This finding underlines the significance of an IIKB for

respondents. The friendliness of the interface concerning UIM came in second place (28%). In the third place, selection was made for the IBM. Finally, AASDC came in last place (18%). These results reveal a very interesting finding. Respondents prioritize the IIKB over the UIM of the interface and even the AASDC. We believe architects need consistent information that assist the design optimization process and guide them into building science designs. However, the small difference between the respondents' preferences requires an analysis of significance.
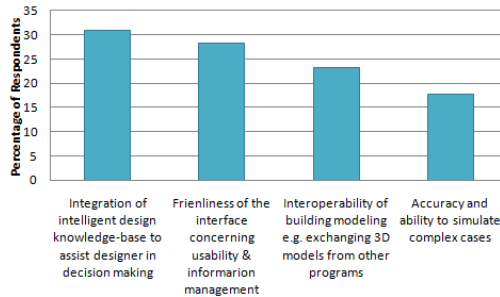

Fig.10 Criteria ranking of 'Architect Friendly' tools

DISCUSSION AND CONCLUSIONS

With 249 valid responses, this survey collected a reasonably plausible pattern of surveyed respondents. The significance of the results was not calculated and the results cannot be proven as representative of the architects community but at least are showing interesting findings.

Comparing the tools

In this survey, ten tools were compared by architects, designers, architecture educators and students according to the (1) UIM of interface and (2) IIKB. The final results of comparing the ten tools are illustrated in Figure 11. The ten tools can be grouped into three categories.
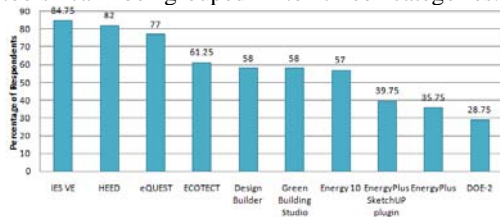

Fig. 11. Ranking the ten tools

IES VE (85%), HEED (82%) and eQuest (77%) came in the first category. Respondents strongly agreed that those three tools are '*Architect Friendly*'. The strength of IES VE lays in its user friendly GUI and its template driven approach. The tool offers default values and templates that facilitate quick entry and supports a progression in thermal performance analysis from getting quick answers in early design to detailed analysis in later design phases. HEED's strength is not only related to its strong GUI and ease of use, but also its ability to compare multiple design alternatives and above all, its ability to consistently provide the design guidelines for

different climate zones. eQUEST has many common strong points with IES VE, in particular its extensive capabilities in modeling conventional components or systems, however it is very constrained when it comes to unconventional building components or systems.

In the second category, comes ECOTECT (61%), DB (58%), GBS (58%) and E10 (57%) with less agreement among respondents. Although these four tools are popular and are known for having friendly GUI and varied graphical output features, respondents reported a common weakness: mainly, the difficulty to integrate the tools with the architectural design process. The tools lack the flexibility to facilitate the design process moving from conceptual to detailed design. Additionally, they lack the extensiveness, which make them always used with at least one or more other tool.

EPSU (40%), EP (36%) and DOE-2 (29%) came in the third and last category. This result was expected. Many respondents criticized the EPSU because it works well only for fairly simple geometry and building description (wall, roof, floor, etc.).

Apart from that, it should be noted that in this paper the tools were ranked against criteria (1) and (2). In the second phase of the research, the ten tools will be compared against (3) IBM and (4) AASDC.

Integration of Intelligent Design Knowledge-Base

This survey revealed that architects want the IIKB BPS tools. There is no doubt that using BPS tools requires analysis, technical savvy and the ability to interpret results. But most architects need consistent information that assist the design optimization process and guide them into building science designs. A design tool for an architect should educate as well as inform the architect on the assumptions that are behind the results. In contrast, the examined tools are far from the integration of an intelligent knowledge-base and do not embrace an integrated design approach that include architects, engineers and constructors.

Usability and Information Management of Interface

Respondents identified the UIM of the interface as the second important priority for an 'Architect Friendly' tool. This survey showed that respondents are looking towards a greater ease of use of GUI. Architects need a tool that provides graphical representation of simulation input and output, simple navigation, flexible and customizable control, in addition to intelligent default features. They would like to build their simulation in a 3D environment, to be able to create comparative reports for multiple

alternatives, and to assure quality control for the simulation input parameters.

To sum up, architects and designers are aspiring to create sustainable built environment for the future and taking it serious considering the use of effective BPS tools that improves design reliability of energy efficiency and passive design. However, we have to apprehend architects' problems in interacting with such tools because architects have a different knowledge background; knowledge processing methods and above all they are visually oriented.
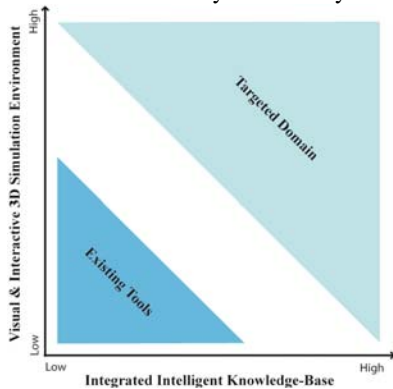

Fig. 12. The gap between wishes and existing tools

FUTURE WORK

The findings of this survey show that further research is needed to develop genuine overall environmental building design development toolkit that first of all integrates an intelligent knowledge-base, which comply with codes and rating systems, and do embrace an integrated multidisciplinary design approach including the whole design team. In the future BPS tools should develop more visual and interactive tools to allow simulating in 3D environment. In the second phase of the research, the authors will analyze the significance of different responses of user groups and launch the second part of the survey to compare the same tools against (3) the IBM and (4) the AASCC.

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