PLACING USER NEEDS AT THE CENTER OF BUILDING PERFORMANCE SIMULATION (BPS) TOOL DEVELOPMENT: USING ‘DESIGNER PERSONAS’ TO ASSESS EXISTING BPS TOOLS

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ABSTRACT

This paper explores the development of ‘building designer personas’ to illustrate how Building Performance Simulation (BPS) can engage with Human Computer Interaction (HCI) knowledge and methods to place its users at the centre of development of new tools. It explains this concept and sets up the fundamentals to develop it further based on previous work on meaningful information for design decision making (Bleil de Souza and Tucker 2014 and 2015). An example of a building designer ‘provisional persona’ in a specific scenario is developed in detail. This example is then used to assess how current BPS tools satisfy this user’s needs and to identify what is missing from BPS development through not carefully considering those needs. This concept can be applied to different types of BPS users and this paper briefly mentions how to explore it in future work.

INTRODUCTION

The aim of this paper is to provoke the Building Performance Simulation (BPS) community to think about what would be an ‘ideal’ BPS user interface to building designers. It attempts to do so by borrowing the concept of ‘personas’ from the field of Human Computer Interaction (HCI).

In the field of Human Computer Interaction (HCI) and Interaction Design, ‘personas’ are archetypal characters who describe and represent the different types of users that the software is designed for. They are formulated from significant and meaningful patterns that have been observed in user behaviour generally collected from a mixture of interviews and direct observations.

This study uses the concept of ‘personas’ from HCI to explore how building designers want to make use of BPS tools to support their professional practice. The fundamentals to develop building designer ‘provisional personas’ are explored based on previous work (Bleil de Souza and Tucker 2014 and 2015) comprising a blend of literature review on Design Research, an online survey, interviews and discussions with building designers plus the analysis of 140 diaries of designers narrating how they a solved design problem.

An example of a ‘provisional persona’ is provided within a ‘scenario’, another HCI method used to clarify how the interface to be designed could best help this user to achieve her/his goals (Cooper 2007). This ‘provisional persona’ is then ‘placed in front of’ four mainstream user-friendly BPS tools. A step-by-step description of how these tools can be used by this ‘provisional persona’ within the scenario provided illustrates how well those tools satisfy this user’s needs, and triggers a discussion on what is missing in current BPS interface development.

As ‘personas’ essentially summarise patterns of user behaviour, they provide a user-centred approach to analyse existing tool capabilities while at the same time enabling different proposals to emerge. Thus, using ‘personas’ to improve BPS tool interface development means moving from research findings, which simply illustrate building designers’ dissatisfaction with current tools to a collection of criticism accompanied by proposals which address their needs.

BACKGROUND THEORY: PERSONAS IN HCI

Introduced by Cooper, ‘personas’ are a descriptive model of users, a “composite archetype based on behavioural data gathered from the many actual users encountered in ethnographic interviews” (Cooper 2007 pp. 76). I.e. “they represent a synthesis from a number of real users who have been involved in data gathering” (Rogers, Sharp and Preece 2015 pp.357). They should be typical and believable, but not stereotypes as stereotypes are based on assumptions rather than factual data (Cooper 2007). ‘Personas’ are represented as individual human beings, fictional characters, and encapsulate a set of behaviour patterns in using a product (Cooper 2007). They must have motivations expressed in terms of goals related to using the product being developed.

‘Personas’ bring user profiles to life as they are “rich descriptions of typical users of the product under development that the interface/software designers can focus on and design the product for (Rogers, Sharp and Preece 2015 pp. 357). They are an extremely useful concept because they define a “precise way of thinking and communicating about how users behave, how they think, what they wish to accomplish and why" (Copper 2007 pp.75). They are widely used in industry and can also contribute to marketing and sales plans.

Even if the construction of rigorous personas is not possible (no extensive ethnographic study), "provisional personas can be useful rhetorical tools to clearly communicate assumptions about who the important users are and what they need, to reinforce rigorous thinking about serving specific user needs" (Cooper 2007 pp.86). This is because "using provisional personas yields better results than no user models at all" (Cooper 2007 pp. 87).

Provisional or not, 'personas' help interface/software designers staying focused on the user (Tidwell 2011) preventing self-referential design, in which interface/software "designers or developers project their own goals, motivations, skills and mental models into a product's design" (Cooper 2007 pp.80). Most of all, "design and choices can be tested on personas the same way that they can be shown to real users during the formative design process" (Cooper 2007 pp.79).

'Personas' are frequently used together with scenarios, because descriptions of their skills, attitudes, tasks and environment should be provided as examples in narratives. Scenarios make use of narratives, one of the most powerful creative methods, to imagine a new and better future for users (Cooper 2007). They describe the use of a product through examples of goals being achieved (Rogers, Sharp and Preece 2015 and Cooper 2007). They create "stories for design: rich stories of interaction" (Dix et al 2004). They are "a method of design problem solving by concretization: making use of a specific story to both construct and illustrate design solutions" (Cooper 2007 pp.111).

Initially, scenarios should be abstract, describing high-level actions from a user perspective, representing a goal-oriented product. They should encourage 'what if?' questions and "permit the articulation of possibilities without undermining design innovation" (Carroll as cited in Cooper 2007 pp.111). This means, scenarios should initially be used to "define what the product will do before you design how the product will do it" (Cooper 2007 pp.114).

Scenarios can also be further developed to reach a very practical / implementation level to "be used as a script to act out potential patterns of use" (Dix et al. 2004). i.e. combining user interaction with implementation, as the narrative enables interface/software designers to ask step-by-step "What is the user intending now? and what is the system doing now?" (Dix et al. 2004).

Scenarios are a very important interaction design tool as they force interface/software designers to think about use in detail and notice potential problems before they happen.

> *"Because interaction design is first and foremost the design of behaviour that occurs over time, a narrative structure, combined with the support of fast and flexible visual tools, is perfectly suited for motivating, envisioning, representing and validating interaction concepts. (…) By focusing on the narrative, we are able to quickly and flexibly arrive at high-level design solutions without getting bogged-down by the inertia and expense inherent to high-production-value renderings"* (Cooper 2007 pp. 110).

> *"Scenarios are a resource that can be used and revised throughout the design process: helping us see what is wanted, suggesting how users will deal with the potential design, checking that the proposed implementation will work, and generating tests cases for final evaluation"* (Dix et all 2004).

METHODOLOGY: CONSTRUCTING 'PROVISIONAL PERSONAS' AND SCENARIOS

Since in this research no extensive ethnographic study was undertaken, a building designer 'provisional persona' is developed based on the previous work of Bleil de Souza and Tucker 2014 and 2015. In this previous work, a blend of literature review on Design Research, an online survey, interviews and discussions with building designers plus the analysis of 140 diaries of designers narrating how they a solved design problem were used to develop a framework and a conceptual data model to produce and present meaningful information for design decision making.

The framework and conceptual data model provide information to understand building designers – i.e. the user. From the framework and conceptual data model, one can identify a series of users' goals, what they wish to accomplish and the tasks for BPS to undertake throughout the building design process.

Once the basis for understanding the user is established, one can construct 'provisional personas' within specific building design problem solving scenarios by, for instance, extracting goals and tasks from practice cases reported in interviews or observations.

'Provisional personas' and their goals

From this previous work, five main aims/goals building designers have in using BPS tools were identified:

(i) *"Understanding a specific performance result: Understanding where a specific performance result is happening and what building elements are responsible for causing it.*

(ii) *Exploring a specific design strategy: Undertake a specific design action and assess the consequences of this action in the overall performance*

(iii) *Meeting a target: Quantify how far a specific type of performance result is from a prescribed benchmark and inform the user which building design variables are the responsible for this mismatch.*

(iv) *Assessing a specific product: Assess the performance result of integrating a specific system or product in the design of a building.*

(v) *Optimizing: Find the optimum quantities for a specific set of parameters to achieve a best performance target."* (Bleil de Souza and Tucker 2014 pp.64)

These aims are generic and were extracted from the 140 diaries of designers narrating how they a solved design problem, and confirmed by a survey and interviews with building designers.

Motivations, aspirations and subtle differences each user attributes to these aims were visible in the interviews undertaken with five UK building design practices. In interviews, one could see these aims in specific contexts: including different types of practice and different types of building design problem-solving. When in context, aims are enriched and provide extra information in terms of how building designers wish to use and interact with BPS tools.

'Provisional personas' and what they wish to accomplish

This previous work also discusses and illustrates how building designers think and design, i.e. their 'modus operandi', concluding that Schon's description of the design process is an accurate portrait of what happens in practice. For Schon (1983, 1984 and 1991), design is seen as a sequence of experiments "generally used to transform the situation from 'what it is' to something the designer likes better" (Schon in Bleil de Souza and Tucker 2015). Design experiment can be:

> *"(i) exploratory experiments, in which action is undertaken only to see what follows;*
>
> *(ii) move-testing experiments, used to assess moves depending on the changes produced and whether the designer likes the changes produced; and*
>
> *(iii) hypothesis-testing experiments, used to discriminate among competing alternatives generally not used to reach a final solution but to constantly reframe the problem through a new hypothesis to be tested"* (Bleil de Souza and Tucker 2015 pp.227).

Design experiments provided the background for the development of a structure to predict what building design 'provisional personas' wish to accomplish and why when using BPS tools throughout the design process: tools should be semi-automatically embedded in the different 'what if' situations generated within design experiments.

Tasks for BPS tools to undertake throughout the design process

'What if' situations provide an opportunity to ask questions about performance. Tasks for BPS to undertake throughout the design process were then summarised in a finite list of questions about performance. A full list of question, which are either design queries or provide design advice, is presented in Bleil de Souza and Tucker 2014.

Examples of these questions are:

(i) How does this building perform in relation to target 'X'?

(ii) What is causing the performance of this building?

(iii) How does this building perform with this product?

(iv) What is causing the performance of this building not to meet the target 'X'?

(v) What is the effect on performance when action 'X' is undertaken?, etc.

Again drawing from the interviews, questions can be put in context enriching the construction of potential scenarios in which building designers interact with BPS tools.

From questions to scenarios

All questions fit a template in which there is:

(i) a standard part containing 'personas' aims/goals, defining what building designers want to use BPS for, followed by analysis processes, defining how BPS should be used to answer the question, and

(ii) a custom based part in which design actions, changes in design parameters, are defined by the 'persona'

Thus semi-automating the use of BPS throughout the design process can be linked to the development of a question/answering system, which recognizes a design input question as an instance of the template:

<Design aims> <Analysis Process> < Design Action>

Since the number of aims, analysis processes and questions are limited (Bleil de Souza and Tucker 2014 and 2015), question interpretation could be hand-coded on a natural language type of interface. "Once the system has found a matching template, it could recall a specific script to run simulations and the necessary ancillary tools (e.g. optimization routines) and /or procedures (e.g. automatic elimination parametric tests) to generate data to answer the question automatically" (Bleil de Souza and Tucker 2015 pp.245).

As suggested by Dix et al. 2011, one can imagine a set of scenarios emerging when looking at each different question about performance. Considering the way these questions are structured, scenarios can be quite practical in terms of what the system should do to embed BPS tools throughout the design process.

Once a set of questions has been defined, it becomes simpler to propose a structure to organise BPS outputs meaningful to design decision making as these outputs need to properly answer design questions. Bleil de Souza and Tucker 2015 provide an in depth discussion of what kind of BPS outputs would be meaningful for building designers to answer these questions. They propose a database/database management system to record and retrieve preferred combinations of metrics (energy use for heating, cooling, etc.), types of interaction with data (overviews, zooms into different building locations, etc.) and displays (graphs, tables, drawings, etc.). Essentially a hierarchical data structure with lists, this database was built based on what 140 designers proposed as suitable outputs to answer their questions when narrating how they a solved design problem. It replaces currently non-user friendly BPS post-processing by a customizable environment to record and recall effective representation systems to aid design decision making and provides the basis to define what would be the 'ideal' BPS outputs for building designers to act upon.

EXPLORING AN EXAMPLE USING FOUR USER FRIENDLY BPS TOOLS

Once the basis for understanding the user is established, an example of a 'provisional persona' within a specific building design problem-solving scenario is presented by decomposing goals and tasks from a practice case reported in one of the interviews undertaken in previous work (Tucker and Bleil de Souza 2015).

Firstly, the practice case is described to provide the context for the development of the scenario and 'provisional persona'. The case is then examined in terms of the aims and questions proposed in Bleil de Souza and Tucker's (2014) framework. Motivations and aspirations in terms of what building designers want BPS tools to do for them in the wider context of their practice are inferred from lessons learned from the interview.

One single question with its respective answer is used as an example to demonstrate what building designers really want out of BPS. The answer covers not only what could be 'ideal' for building designers but also unfolds how it could be provided via scripts.

A step-by-step report about how this question could be answered using current BPS user friendly tools is presented to contrast how far software development can be from responding to users' needs.

From the practice case to the ideal scenario:

In this practice case, John (fictitious name) and his team who have very basic knowledge of building physics, are designing a series of retirement living homes and need to comply with a specific performance target. They outsource compliance checks and advice with consultants because they are not good 'at speaking science' and cannot manipulate BPS tools.

The report from their consultants states the design work does not comply without providing information about why this is happening. John and his team request design advice and receive recommendations for a series of design changes, which should enable the design to achieve compliance.

It can be inferred from this interviews that, in reality, these users are requesting consultants information about what is causing the performance of their buildings not to comply with the target so they could decide by themselves which design changes should be appropriate to reach it. They know well that any design change will have implications not only in performance and therefore they need to be in control of this decision. They also know the design process is based on experimentation, which does not support delays in waiting for consultants to run simulations and analyse results every time a change needs to be made to assess how far they are from complying. "*Timing of decision making is important, as design costs money*" (interview quote)

John and his team want to "*bring this analysis process back into the hands of their practice*" but "*they want to speak English, they don't want to speak science*" (interview quote). From this interview finding one can predict that a 'provisional persona' constructed based on this practical case wants performance analysis to be integrated within his/her design experiments so he/she understands cause and effect and is in control of the design changes to improve performance. This includes integrating performance analysis within building design software (CAD or BIM) from input to output, having answers to specific design questions provided in a format building designers understand.

In this particular case, the 'provisional persona' is after the answer to a very common question many building designers have when trying to improve performance, to reach a target or test specific products: "What is causing the performance of this building?"

He/she wants to know as an answer: where a specific performance result is happening and what building elements are responsible for causing it so he/she can decide how to proceed with design changes once knowing where to act.

Even though consultants and experts will claim this question can be answered in multiple ways, a route to automate an answer to this type of question could be set up through elimination parametric tests. SERI 1985 discusses this route when presenting a method to better support environmental design decision making. Overviews of what is causing the performance of a building could be provided from eliminating main building variables one at a time ranking the ones with higher impact on results (internal gains, ventilation losses and gains, solar gains, fabric conduction losses or gains and fabric storage). Further detailed information could be provided from eliminating usage related variables (people, lighting, small power) and / or building related variables (window conduction, wall conduction, roof conduction, floor conduction, window mass, wall mass, roof mass, floor mass, solar, infiltration) one-by-one again ranking them in order of importance.

Thus, in an 'ideal world', building designers would query within a BIM environment using natural language, what is causing the performance of the building they are designing. They would then get a direct answer at an overview level about what are the main causes of this specific performance behaviour (list of features, pointers in drawings, etc.). They would also be provided with the possibility to further zooming into where are the best/worst performance results in the building (potentially in plans) and which design parameters are causing them (pointers in drawings, etc.).

Contrasting the ideal scenario with how it can be achieved using current user friendly BPS tools

Table 1 provides a summary illustrating how the aforementioned 'ideal' scenario can be achieved with four user-friendly mainstream BPS tools. It contains a succinct description of this 'ideal scenario' at the top of it to remind the reader how simple building designers want the question and the answers to be.

From Table 1, it is possible to see that, regardless of the question being asked, users need to undertake several steps to guarantee proper model set up prior to running any simulations. In Sefaira and ArchiCAD part of these steps happen in a BIM environment but they still require user input in terms of many building attributes not present or not possible to be retrieved from BIM databases.

It is also evident that output information meaningful to building design decision making is only partially provided, through performance summary overviews. Displaying results on top of architectural representations (e.g. floor plans, sections, elevation, etc.) always require post-processing BPS numerical results and going to third party tools.

None of the software provide automated scripts to answer specific building design questions. Even though one of them seems to be moving in this direction (Open Studio – via PAST tool). In this scenario none of the software provide automated elimination parametric tests to aid in understanding specific performance results based on model perturbations, a more accurate way of assessing building sensitivity to a set of parameters of interest as opposed to simply plotting heat balance breakdowns (as in Sefaira 'Element performance graphs'). In scenarios with questions involving optimization problems, this would imply building designers having to manipulate complicated third party tools themselves.

On the other hand, from Table 1 it is also possible to see that these different tools already provide some capabilities to reach the 'ideal scenario':

- Sefaira enables real-time results to be retrieved, which could make performance queries less disruptive throughout the design process (no need to wait for simulations to be run delaying answers)
- ArchiCAD automation in setting up model boundary conditions and in retrieving attributes from BIM database (material properties construction assemblages, etc.) saves time and hassle of building designers having to manually input this type of information.
- All tools provide access to libraries and templates with information on construction, building usage, HVASC, etc. facilitating retrieval of complementary BPS input data essential to run simulations.
- BIM input interfaces from ArchiCAD and Sefaira are in tune with what building designers want: not having to go to third parties tools to undertake performance queries
- Open Studio and Sefaira output interfaces enable users to compare side-by-side simulation results for different design alternatives. This is an essential output interface feature for design decision making as most design experiments involve comparing design alternatives.

Software developers should capitalise on these capabilities and start building up infra-structures to accommodate a proper question and answer system in which scripts facilitate simulation set ups and runs.

Much is still to be done about BPS post-processing and outputs. Time should be invested in constructing proper systems, potentially database management systems, easily customizable by different types of BPS users so that results are meaningful to their decision making processes.

Besides that, time should be invested in handling the particular caveat of semi-automated systems which require minimal user input: modelling quality assurance. This would require special attention in future studies and future BPS development. However, one can predict this issue could/should be handled mainly at BIM level, transferring BPS modelling quality assurance to BIM modelling quality assurance. This would require each practice to adopt clear BIM model construction rationales, including comprehensive attribute documentation and model information detailing, to facilitate scripting automated quality assurance checks.

'Provisional persona' end goal	Understanding a specific performance result			
'Provisional persona' design question	What is causing the performance of this building (to overheat)?			
'Provisional persona' mental model of an 'ideal' software	Within a BIM environment, the building designer ***asks the question*** 'what is causing the performance of this building?' directly to the software using natural language. ***Results*** are displayed on top of plans, facades or sections showing directly where a specific performance result is happening within the building (e.g. the overheating rooms) and what building elements are causing this performance result			
Persona trying to achieve end goals using current software				
	Design Builder	**Open Studio (SketchUp)**	**ArchiCAD**	**Sefaira (REVIT)**
Step 1	Create a new project in Design Builder to specify building location. Add new building and specify building type, which automatically recalls a set of default values for part of the complementary information necessary to run simulations, e.g. activities, usage, constructions, internal gains, etc.	Create a new model in Open Studio by loading a template, which automatically recalls a set of default values for most complementary information necessary to run simulations, e.g. activities, usage, constructions, internal gains, etc.	Prepare the BIM model for transformation into a thermal model by hiding unnecessary data and defining an ArchiCAD view dedicated to energy modeling.	Load 'Generate Sefaira' to check and correct which building elements are going to be used in the energy analysis. Make sure: internal walls are set as internal walls (i.e. no heat transfer)[i], shading devices (including overhangs, louvres, neighbouring buildings, etc.) are tagged as 'Shading for Sefaira' and that envelope elements have their exterior surface facing the outside.
Step 2	Create building geometry by importing a 2D drawing from a third party software (BIM, CAD, etc.). Draw and extrude building blocks and thermal zones with their associated boundary conditions. Edit geometry by adding/removing walls, windows, etc.	Create building geometry in SketchUp using Open Studio plug-in (e.g. floor plans + extrusion tool 'Create spaces from 2D diagrams') directly setting up thermal zones and boundary conditions. Edit geometry by adding/removing walls, windows, etc.	Assign ArchiCAD zones to every conditioned space and group them in thermal blocks to define HVAC types, thermostats settings, etc.	Either upload building model to the web or carry out 'real time analysis'. Sefaira can be operated using a 'real time analysis' local application or uploaded to the cloud. In both cases the geometry of the Revit model is used but the material thermal properties are set through the Sefaira interface and not taken from the Revit model
Step 3	Provide complementary information necessary to run simulations to each zone (manually or from a database with default suggestions) through specific tabs within the edit mode, i.e. activity, construction, openings, lighting, HVAC, etc.	Assign space types to the different thermal zones within a template – detailing information about activity, usage, thermostat settings, etc. by using Open Studio tool 'set attributes to selected spaces'. Information can come from local database or from building component library on the web.	Run the automatic model geometry and material property analysis function to automatically define boundary conditions, child parent relationships and recall surface materials and their attributes from the BIM database.	Set up the building location and building type. Preliminary results for default values are already shown for 'real time analysis'.
Step 4	Provide simulation settings	Load Open Studio Application to manage simulation (load weather data, design days, etc.) and edit model details (schedules, constructions, internal gains, HVAC systems, etc.)	Edit complementary information necessary to run simulations via Design > Energy Evaluation menu, i.e. environment settings. Climate data, operation profiles, HVAC systems, etc.	Changes to complementary default values necessary to run simulations can be undertaken directly in 'real time' Sefaira interface or in the cloud based version. Users can also setup or change envelope information (U-value, SHGC, constructions, etc.), internal conditions (occupants, density, lighting, ventilation, etc.), HVAC systems and zoning.
Step 5	Run simulation on the baseline building to debug the model	Run simulation on the baseline building to debug the model	Run simulation on the baseline building to debug the model	Run simulations / update results.
Step 6	Copy the baseline model several times saving each new version of it with one parameter of interest eliminated.	Call Open Studio Parametric tool (PAT) and create a new project: Load the baseline model and create one group of measures[ii] for each parameter to be eliminated. Recall elimination parametric measures from a library (either one's own or Building Components Library - BCL)[iii], assigning one per group.	Copy the baseline model several times saving each new version of it with one parameter of interest eliminated.	Clone your baseline building several times eliminating from each cloned version one different parameter at a time OR 'Create a new strategy' for each parameter of interest to be eliminated.

Step 7	Run all the elimination parametric simulations.	Create one design alternative for each elimination parametric measure and run all parametric simulations at once either in a local computer or in the cloud.	Run all the elimination parametric simulations.	Sefaira will be providing results real-time. No need to run any simulation. However, when in the cloud base mode the user should be saving each different model with the changes.
Step 8	Read results in tables and graphs directly in Design Builder OR Export results to a third party tool (e.g. Excell) to filter and summarise relevant information as well as to plot results from all eliminated variables alongside each other in graphs or tables.	Result summaries are displayed for each alternative side-by-side in the PAT tool (design alternatives can be loaded to SketchUp to display the actual model) OR Can be exported to a third party tool (e.g. Excell) to filter and summarise relevant information as well as to plot results from all eliminated variables alongside each other in graphs or tables.	Customize energy evaluation report (summary tables and graphs) OR Export results to a third party tool (e.g. Excell) to filter and summarise relevant information as well as to plot results from all eliminated variables alongside each other in graphs or tables.	Summary graphs (performance dashboard) are provided for all alternatives side-by-side. User would need to visually identify from these which parameters are contributing more to performance results. Results can also be exported to a third party tool (e.g. Excell) to filter and summarise relevant information as well as to plot results from all eliminated variables alongside each other in graphs or tables.
Step 9	Open plans, section and elevation in a third party image processing tool (e.g. Photoshop) and display result summaries on top of them (if results are to be visualized on top of design representations) making clear to the design team and/or client where problems are and what design features are causing them.	Open plans, section and elevation in a third party image processing tool (e.g. Photoshop) and display result summaries on top of them (if results are to be visualized on top of design representations) making clear to the design team and/or client where problems are and what design features are causing them.	Open plans, section and elevation in a third party image processing tool (e.g. Photoshop) and display result summaries on top of them (if results are to be visualized on top of design representations) making clear to the design team and/or client where problems are and what design features are causing them.	Open plans, section and elevation in a third party image processing tool (e.g. Photoshop) and display result summaries on top of them (if results are to be visualized on top of design representations) making clear to the design team and/or client where problems are and what design features are causing them.

Table 1 – Answering the provisional persona design question with four mainstream user-friendly BPS tools

CONCLUSION

This paper aimed to provoke the BPS community to think about what would be an 'ideal' BPS user interface for building designers. It attempted to do so by using the concept of 'provisional personas' and scenarios from HCI in BPS further development, which to the best of the authors knowledge, have not been used by this community before.

An example of 'provisional persona' is provided in an 'ideal' interaction scenario to illustrate a potential way for BPS to be embedded in one of the many ways building designers communicate and interact with their work. This 'ideal' scenario is contrasted with a step-by-step list of instructions for its aims to be achieved using four mainstream user friendly BPS tools.

Results indicate each of these four mainstream BPS tools already have the following parts of the infra-structure for the 'ideal' scenario to be implemented when:

- They are connected to BIM (i.e. are within a digital design environment)
- They provide real-time performance feedback
- They provide easy access to libraries and templates of attributes and building usage information
- They enable users to compare results for different design alternatives

However, more work is required from software developers for BPS tools to better respond to building designer's needs as the following is still missing:

- An infra-structure which enables performance questions to be asked in natural language
- An automated system which run scripts to answer building designers' questions about performance
- A set of post-processed outputs meaningful to design decision-making provided in a simple and interactive output interface connected to a BIM environment
- Semi-automated modelling quality assurance mechanisms embedded as much as possible within BIM environments

It is important to mention that most of these aforementioned points could not have been extracted from a non-user-centred approach as these are totally related to understanding how building designers think and how they wish to use BPS throughout the design process.

As the concept of personas summarises patterns of user behaviour and the concept of scenarios describe practice cases of problem-solving in context, they go beyond simple problem analysis. They also provide base cases for user responsive solutions to be developed since they illustrate mental models of an 'ideal' user interface. Happening predominantly at an abstract level, mainly through narratives rather than graphics, this 'ideal' interface is still open for creative solutions to emerge, providing essential information for software developers to explore visual representations of actual interfaces.

It is in the concepts of 'personas' and scenarios that one goes from the fields of science, or social sciences of understanding the user, to the field of design, in which problem definition is meaningless if not co-evolving with solutions. 'Personas' and scenarios bridge the gap between the definition of design requirements and the exploration of design responses, providing a suitable technique that can be explored with different types of BPS users besides building designers.

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Notes:

[i] Sefaira will assume each floor is a thermal zone, simplifying the energy model. If the user wants each room to be a zone, the REVIT model needs to contain Revit rooms so that each room will be interpreted as a zone by Sefaira

[ii] "a measure is a set of programmatic instructions (such as an Excel macro) that makes changes to an energy model to reflect its application" (http://nrel.github.io/OpenStudio-user-documentation/getting_started/about_measures/)

[iii] In this case, we are assuming elimination parametric measures will be in the building components library ready to be retrieved by the user. An intermediate step, in which the user would need to set up each variable to be eliminated would need to be included in the table, if elimination parametric measures would need to be set up.