Convergence and interoperability of BIM with passive design principles

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Standard Design Processes

Digital Plan of Works

Understanding where and how energy and environmental parameters are considered within the architectural design process is a complex mix of organisational working culture, the availability and understanding of suitable software tools, the skills of the professionals within the design team members and the significance or weighting given to sustainability within the initial project brief. However, "(o)ne of the main goals … is to move consideration of the issues related to energy performance and sustainability to the earlier stages of building design process when the opportunity to significantly improve the energy performance of a building design is still open" [Dawood 2013 p64].

As passive design principles are about following a fabric-first approach to a whole building solution, critical assessment at the early concept design stages are critical to success [Whang 2014] as this is the stage where decisions are made regarding basic orientation and the heat-loss parameters arising out of the building geometry.

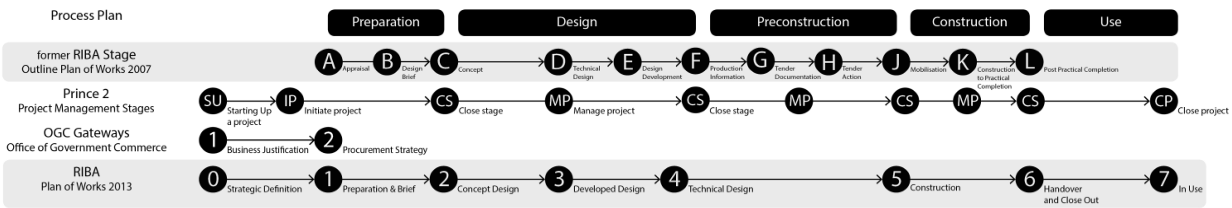

Figure 1: Comparison of standardised "plan of works" for the architecture and construction industry, highlighting stages for multiple input requirements and key decision-making controls.

Yet, often energy and environmental parameters are not considered within initial workflows. Thus, to realise the benefits of embedding sustainability and energy considerations earlier in the design process, we have to understand where these activities currently sit within the standardised design process; particularly the current RIBA plan of works and associated digital Building Information Modelling (BIM) overlays; how this relates to other professional skills and competencies and the need for professional integration, and the actual operational use of a standard plan of works itself. This paper and presentation tests this integration by describing workflows and decision-making stages for contrasting UK based domestic new build and retrofitting projects following passive design principles.

PHPP as an early stage design tool

The Passive House Planning Package (PHPP) is a parametric modelling spreadsheet for building energy performance, designed initially for the certification of buildings that meet *passivhaus* and *EnerPHit* refurbishment standards. PHPP is a trusted calculation tool that is comprehensive in the scope of factors and variables included to make it one of the most accurate and thus “scientifically superior” [Müller 2013 p589] tools available. Its’ practical value is reinforced from a series of comparative studies which have undertaken triangulation in design stage energy assessments [Moran 2014] and where it has proved to be relatively accurate and more cost effective in practice than other standard building energy modelling tools and methodologies.

Historically PHPP was created as an assessment tool, albeit in practice, it has become a flexible and evolving calculation tool that incorporates practice-based research into newer versions. Changes are developed, in part, by a community of users who are self-critical and subject the calculation process to peer-review to ensure that the gap between design standards and performance in practice is reduced. Examples of closing this ‘performance gap’ using PHPP as an early stage design tool can be seen in a range of case studies ranging from southern [Rodriguez 2014] to central Europe [Neururer 2010]. Increasingly practitioners are drawing on knowledge from case study material where the comparison with different energy modelling tools [Kachadorian 2006] have highlighted the specific benefits of PHPP as a concept design-stage resource. Thus, there are a growing number of applications of PHPP as a design stage decision-support tool for new build, hybrid and refurbishment development projects. It is perhaps one of the few instances in architecture where non-geometric data is given significance in these early design stages.

In a context where much of the available industry-standard technical software relates to detailed evaluation of building energy performance [Attia 2012] rather than early design stages assessment, PHPP is almost uniquely used as a design tool [Lewis 2014], to test strategic options for refurbishment. “In the traditional architectural workflow, performance assessment is mostly done subsequent to the architects’ design. It is done by the expert, in most cases the engineer. A lot of expert software exists … (a)vailable simulation tools are therefore aimed at the expert and make explicit expert knowledge necessary to input the data needed, run the simulations and interpret the results” [Schlueter 2009 p153]. Yet, early stage design in practice is about assessing different options and making trade-offs between different performance and cost parameters. It is a combination of industry assumptions and historical practices that the barriers to mainstream uptake in low energy design remain centered around this basic trade-off between technical performance and costs. This is the case even when some early examples of the cost effectiveness of following sustainable construction principles [Kibert 2008] challenge certain assumptions that green building is always relatively more expensive than standard construction standards.

Early design stage BIM processes

The processes of integrating passive design principles in a digital workflow is practically as much about having a multidisciplinary, cooperative and motivated team [Cotterell 2012]. Indeed, academic thinking about the adoption of BIM shows it needs to be much more that simple software acquisition and usage within a company [Succar 2015], but changing working procedures at different scale of influence around policy, process and technology.

There has been an implicit assumption that there is a role for BIM in this early design stage that will benefit technical energy performance, yet most energy tools suitable are not integrated with BIM or BIM enabled processes. This lack of process integration is due to limitations around the quality of the input data as well as the computational methods and software [Libor 2014], specifically the lack of any "consensus standard on (energy) simulation calibration" [Coakley 2014 p135] as practical decisions around the choice of energy assessment methodology relate to the level of detail and availability of input data parameters. Where BIM is a combination of geometric data generally found within a 3D model and a connected document management system (DMS), PHPP data has largely been limited to the latter, as one of the few instances in architecture and design modelling with a bias towards non-geometric data. This changed with the introduction of *designPH* as an add-on tool for *SketchUp* and the BIM enabling in the recent versions of *SketchUp*.

So while PHPP isn't necessarily non-expert software, the introduction of *designPH* supports the earlier application of elements of the PHPP calculation process. It is concerned with data accuracy (outline building geometry, energy parameters and running costs) to close the performance gap between modelled and actual building performance.

The aspiration of integrating PHPP as an early design stage tool into a wider BIM Execution Plan (BEP), is to include all the necessary data within a single BIM model; or access the data via the model. This can only be achieved by data interoperability between project / design stages and between different software applications that relate to each of these design stages [Miettinen 2014]. To date, interoperability has been explored using the addition of an energy domain to the IFC schema based on the input requirements for PHPP [Cemesova 2013], in effect to make PHPP more compatible with 3D modelling packages.

New Build Design Processes

In exploring the interoperability of digital data, the initial use case explored is the design development for a proposed new-build terrace property in Middlesbrough. Basic building geometry and orientation towards the street was set by a local design code and regulating plan which specified minimum and maximum heights for the massing of the project.

Concept design and initial Level of Detail / Definition (LOD)

This range of massing was the initial basis for a concept sketch for the street façade and the building cross section, including air-tightness and staircase / thermal stack strategies. This massing was translated / drawn directly into *SketchUp* at a low LOD100, but with the inclusion of internal walls, heated floor areas and solid / translucent ratios in the external skin. Variations of façade treatment and massing were explored in *designPH* to produce an optimised LOD100 model suitable for importing into object-orientated modelling packages for the detailed / technical design stages with confidence on the actual energy performance.

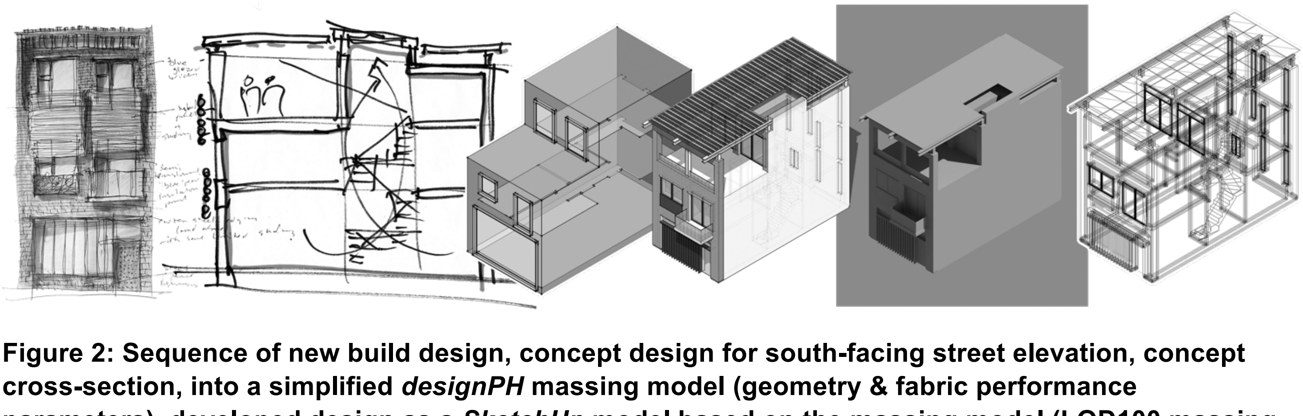

Figure 2: Sequence of new build design, concept design for south-facing street elevation, concept cross-section, into a simplified *designPH* massing model (geometry & fabric performance parameters), developed design as a *SketchUp* model based on the massing model (LOD100 massing geometry), imported into *Revit* and *Vectorworks* (geometry, materials & object parameters).

Retrofitting Design Processes

The second use case explored is the design development for a low-energy retrofit terrace property in Leicester. In this instance, the basic building geometry was fixed and the corresponding technical challenge was to accurately record this geometry in a cost-effect process, prior to testing options for varying the energy performance parameters for the building fabric, external walls, windows and doors.

Reality capture and interoperability with BIM authoring software

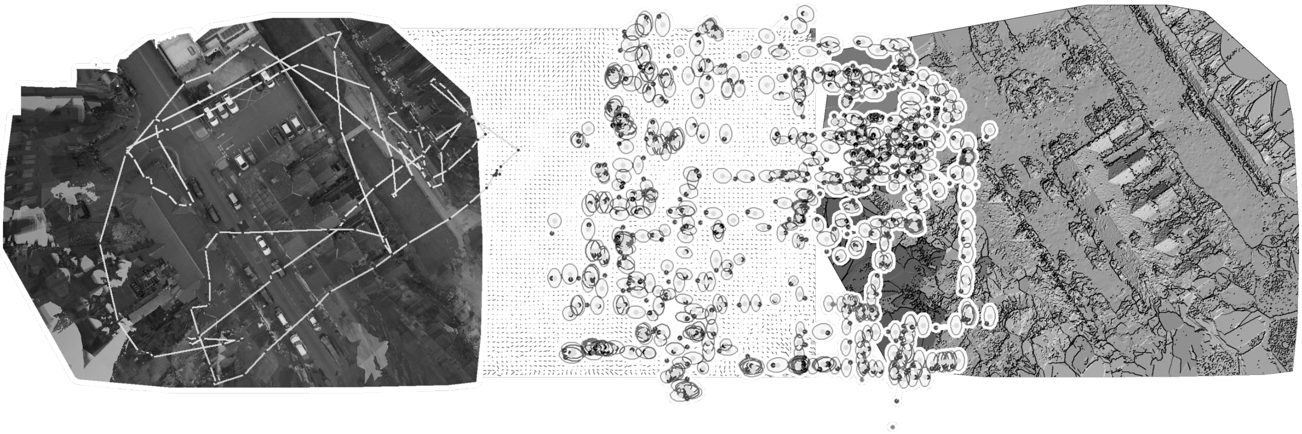

Figure 3: Workflow for reality capture for the retrofit property. Aerial drone collected GPS image capture were processed using Pix4D to create a photogrammetry model in a standard point cloud format. Collection of >200 images, quality checked, calibrated and optimised to create an orthomosaic aerial. Initial image positions (flight path) showing corrected camera positons (based on degree of overlapping images), tie-in points used to generate a sparse digital surface model (DSM).

A drone equipped with a GPS and high resolution camera was used to survey the property exterior. A suitable workflow was developed to support reality capture, with quality control regarding the geometry in the form of a dense point cloud that formed the basis for massing modelling LOD100 for use in *designPH* / *SketchUp* (sequencing and reviewing the modelling stages) that could be transferred as a hybrid point cloud and object model into Autodesk Revit for detailed / technical modelling stages.

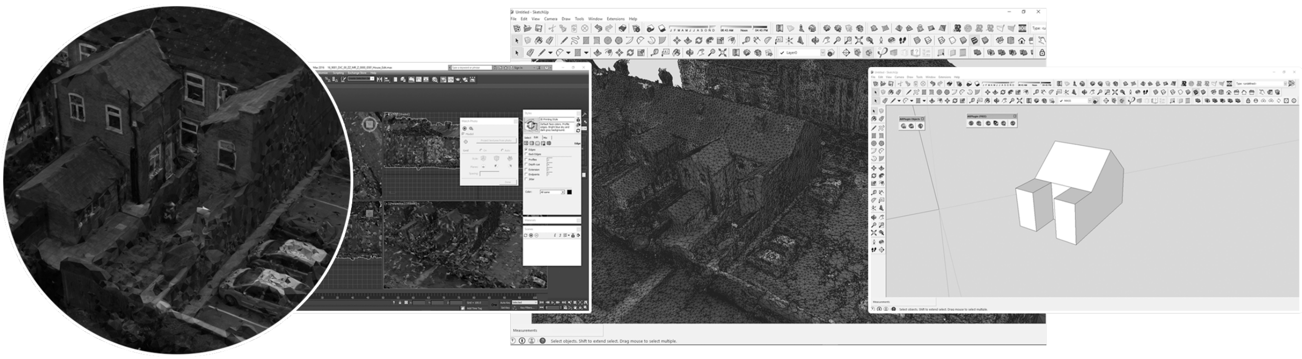

Figure 4: BIM workflow for retrofit property utilising photogrammetry point cloud. Import into *3D Max*, indexed as an Autodesk recap file format to provide a suitable format for inserting into Autodesk software, including *Revit*. Converted into CAD and imported into *SketchUp* as the basis for an accurate traced geometry massing model.

This workflow supported the staged development of a single 3D model moving between different software applications, with increasing LOD that set energy performance parameters for the building fabric objects from the outset of the concept design process.

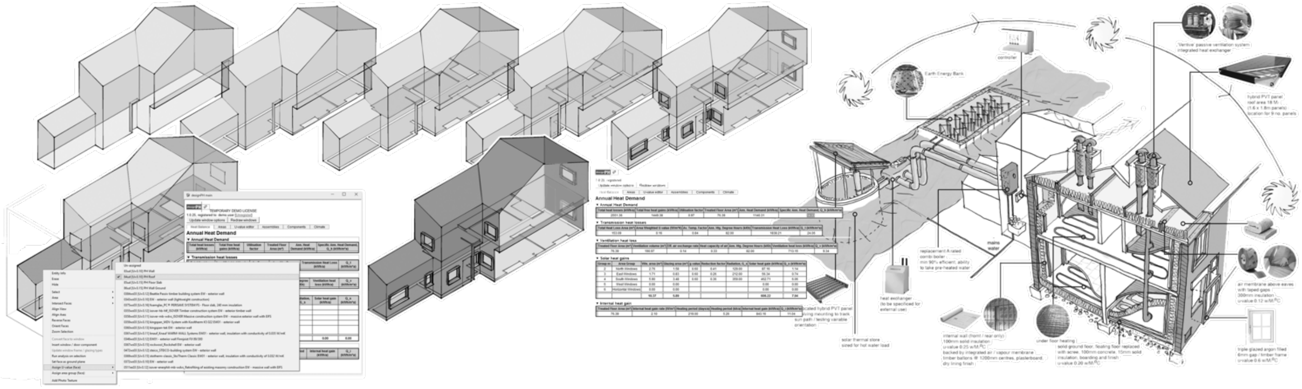

Figure 5: Sequence of modelling external walls, ground floors (gross floor area m^2), internal floors (total heated floor area m^2), window & door apertures (orientation & surface area m^2), model glazing, assign specific U-values to surfaces (*passiv haus* U=0.10 for external walls), generation of initial results (specific annual heating demand 30.28kWh/m^{2}a), and detailed retrofitting design strategy.

Summary of process integration

One of the peculiarities of many low energy designers, is the low-cost entry level, in contrast to the high expected costs for a practice to become BIM compliant. Thus, the provision of cost-effect digital tools, in this case using *SketchUp* add-ons, is a good fit to the actual requirements of passive design professionals.

input format	software	output format
.png a)	Pix4D b)	.fbx / .las c)
.fbx	Autodesk 3ds Max	.dae
.dae / .dwg d)	SketchUp / designPH	.skp / .xls e)
.las	Autodesk Recap	.rcp
.rcp / .dwg	Autodesk Revit	.rvt / .dwg / .pdf f)

Footnotes: a) geo-referenced images; b) photogrammetry; c) digital surface model(s); d) basis for traced LOD100 building geometry; e) partial PHPP geometry data; f) output project contract drawings.

Table 1: Summary of file / format interoperability within identified workflow.

Identifying workstreams that integrate the use of *designPH* and PHPP into the early design stages will ensure it becomes a mechanism for better integration between mathematical / parametric modelling of the energy performance and the building geometry [Paoletti 2011]; and thus remain attractive to a certain proportion of the architecture and design profession. These workstreams have the potential to support the expectations of professional interdisciplinary and organisational collaboration, particularly where both the geometry and parametric data can move between different BIM enabled software packages.

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