J. Zuo, L. Daniel, V. Soebarto (eds.), *Fifty years later: Revisiting the role of architectural science in design and practice: 50th International Conference of the Architectural Science Association 2016,* pp. 407–416. ©2016, The Architectural Science Association and The University of Adelaide.

The feasibility of implementing 'building performance sketching' within the building design process through the use of the distributed model method

Elzine Braasch[1] and Michael Donn[2]
[1] AECOM Ltd, Wellington, New Zealand
elzine.braasch@aecom.com
[2] Victoria University of Wellington, Wellington, New Zealand
michael.donn@vuw.ac.nz

Abstract: Performance Sketching is the act of assessing the performance of an architectural sketch through the use of detailed building performance simulation (BPS) tools in the early stages of design. BPS tools offer tremendous potential for informing design to improve the passive performance of a building, but are inhibited by limitations and barriers to their use in the early stages of the design process – where the most influential design decisions are made. This paper presents an exploration of the views and perceptions from the New Zealand building industry on the feasibility of performance sketching using the plug-in, Honeybee for Rhinoceros/Grasshopper, as an example of a distributed modelling method (DMM). The study concluded that DMM cannot currently address all wants and wishes of users established in literature, but has potential. Future research efforts are required to focus upon: creating industry specific templates for building types; developing these templates to be adaptable for the different modelling operators of the proposed workflow demonstrated to the participants within this study; and developing quality assurance standards for modelling and guidelines for model validation. Finally, the study concluded with future work required beyond tool development: improving education of architects; and introducing legislation.

Keywords: building performance sketching; design.

1. Introduction

Imagine the following scenario: an architect is approached by a client to design a commercial office building. The client asks for a 'sustainable' building, with high energy efficiency and excellent indoor environmental quality. How can the architect as a designer ensure that the building will perform as intended?

Recommendations from literature suggested that the first step should be to ensure the 'architectural sketch', or design concept, will lead to good building performance (Granadeiro, Duarte, Correia, & Leal, 2013; Jacobs & Henderson, 2002). The use of detailed building performance simulation (BPS) tools is contended to be the most reliable means of informing design decisions (Granadeiro et al., 2013; Jacobs & Henderson, 2002). Building performance simulation (BPS) enables the comparison of a broad range of design variants to understand the usability of a design, and the interactions between design parameters and the occupant comfort. However, in our scenario, the use of BPS tools to ensure the design will perform as intended has a number of challenges which discourage its use.

Over the past three decades, tool development focused on the architect has not been successful in encouraging the use of building performance simulation (BPS) in the design process. BPS modelling software is simply too technical, complicated and cannot be considered 'architect-friendly' due to the differences in language, modelling processes and visualisation of results (Attia, Beltrán, De Herde, & Hensen, 2009). Architects and designers have difficulty in using even the most basic BPS tools. Hence, BPS does not lend itself well to the casual user, but rather requires the input of an expert who can ensure reliable and robust performance predictions.

Thus, the proposed answer for the architect in our scenario is to look for an approach to 'sketching' the performance of their design concepts. This is suggested to be with the aid of the expert engineer in a partnership, using detailed BPS tools to provide high levels of accuracy, in a quick and easy manner.

1.1. Defining Building Performance Sketching

We propose this approach to be early design stage performance modelling called 'building performance sketching'. The 'Building Performance Sketch' is described by Donn et al (2012) as a building performance analogy for the architectural sketch. The architectural sketch roughly outlines key design features which distinguish the potential end product, but does not solidify any design ideas. Thus, the architect is able to choose between possible paths of development. The key principle of the performance sketch is thus mirrored in that by roughly modelling the basic design concept with minimal, but most influential, levels of detail, the likely performance of the concept can be simulated and evaluated in a quick and easy manner using detailed BPS tools.

Thus, accuracy becomes a high priority in performance sketching. Unlike the architectural sketch, the performance sketch cannot leave precise details of elements such as windows or shading for later stages. In the absence of confirmed design parameters, unknown parameters in a performance sketch are defaulted to a range of low, typical or high scenarios using real-world building data. Building performance sketching uses this data in sensitivity analysis to analyse the cloud of design potential that a concept could be developed into. This approach does not require the burden of creating a detailed representation of the building, but rather looks to develop ways of modelling the richness of the human experience of interaction with buildings through the use of detailed accurate performance simulation tools in conjunction with building 'sketches'.

For building performance sketching as an approach to early design stage performance assessment to be plausible, the same barriers against building performance simulation integration in the design process must be overcome. In literature, several studies exist which outline these barriers faced within developed countries and their building industries. The studies outlined in literature used user feedback from surveys to determine the barriers present in industry, and established user requirements as recommendations to tool developers. Negendahl (2015) proposed the theory that the answer to the problems faced in industry, and a means to address all recommendations, is by considering the integrated design process (IDP) approach by the application of the distributed model method (DMM).

2. Research Design

Despite the many theoretical advantages of DMM within the design process to integrate BPS, there were no studies which could prove its feasibility. Furthermore, it seemed inadvisable to create yet another tool which did not meet the wants and wishes of the current building industry professions, on the theory that this method could encourage building performance sketching in design. Thus, before blindly launching into tool development, the study aimed to first understand how and why DMM could or could not make building performance sketching feasible within the design process to guide future tool development. This would test the hypothesis that DMM could meet the wants and wishes of building professionals for tool development.

To achieve this aim, the study established the need to approach the 'players' of the scenario (the architect and the engineer) of a building industry which: a) designs buildings similar to the majority of the building industries in the world; b) does not currently implement building performance sketching in practice; and c) is growing into a building industry with a focus on 'sustainable', high performance building design. As an unproven concept, no building industry in the world currently implements building performance sketching as common practice. New Zealand's building design and construction industry is largely trained in the same manner as in other countries. Therefore, the study focused upon the developed building industry of its location, New Zealand, to provide indicative results of the building industry.

The study had a unique problem in that DMM was not a commonly established method of design. There was no case example to question the professions for feedback on the use of DMM as a means to make building performance sketching feasible within the design process, thereby gaining feedback was a near-impossible research task.

The study took the approach of demonstrating an example of building performance sketching using DMM by creating a conceptual template workflow for the commercial office building type within an example tool, Honeybee/Ladybug for Grasshopper/Rhino (Sadeghipour Roudsari & Pak, 2013).

2.1. The Building Performance Sketch Workshop

The participants were invited to 'play' within the program, Honeybee, in order to get a sense of the practical use of such a workflow within parametric design and the speed of its interoperability features directly before the focus group session. A computer room facility was made available for use through the Victoria University of Wellington's Architecture Department. The workshop was conducted over a period of three hours for each participant group, in which the participants were provided with a brief presentation on the context of building performance sketching, the processes of DMM and its unique features which differ from the methods they were familiar with. Participants were allowed to 'play' within the selected program for this study, Honeybee/Ladybug as plug-ins for Grasshopper/Rhino, within a structured tutorial exercise. The workshop was finalised with a demonstration of a workflow created within Honeybee which illustrates the application of building performance sketching on an example building form.

2.2. The Building Performance Sketch Workflow

Due to the scope of the study, a conceptual workflow was created in Honeybee to provide a means to test theories from the recommendations made by literature on the participants of this study, and provide a basis for recommendations to be made for future development. The aim of the workflow was to address the recommendations from (Donn, Selkowitz, & Bordass, 2012) in using detailed simulation engines and real-world data, along with enabling sensitivity analysis at the early stages of design to ensure reliable and useful results for the users.

Figure 1 illustrates the workflow's Honeybee components visible in the Grasshopper interface and demonstrates the significance of the features made available through the interoperability of the DMM.

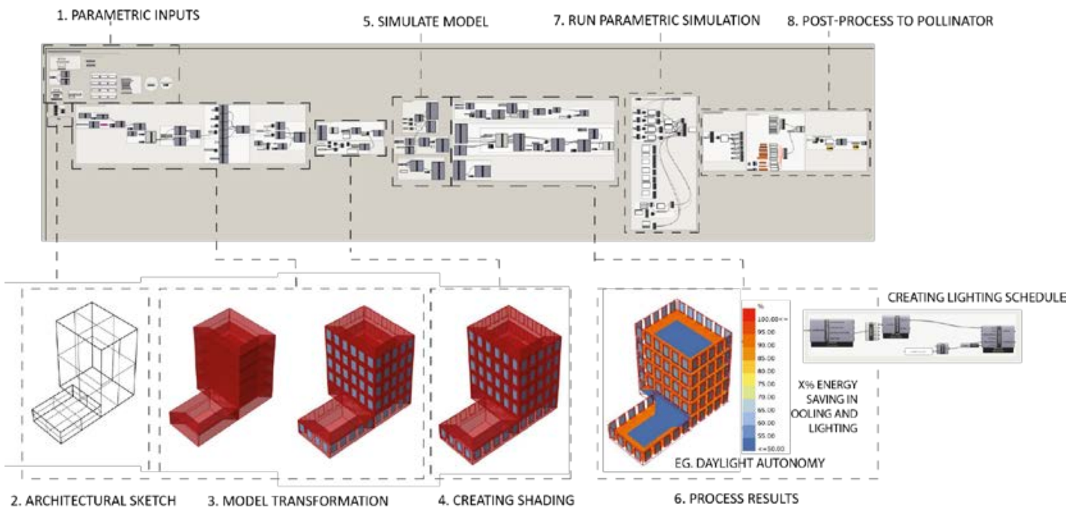

Figure 1: Overview of workflow and its components

We acknowledge that this workflow has not been created to be robust or for immediate use within the industry, but rather a concept to provide feedback and explore options for future development. The workflow has been set out with two main themes: full transparency of how the model is created, and the defaults of certain components; and minimising necessary inputs. Everything which requires user input is grouped at the start of the workflow in the 'Parametric Inputs' area as a means to simplify the required input for the architects. Where the users wishes to edit any particular part in creating the models, they are able to do so, given they follow the correct processes to link the change into the workflow. This therefore requires expertise from the engineer. Therefore, all features were created at the most conceptual level to demonstrate their use, however particular attention was given to the creation of:

- The ability to add any geometry to the beginning of the workflow and have the geometry be converted into Honeybee Zones to run simulations - This saves valuable time during the early stages of design, as the design team do not need to rebuild the design model.
- The ability to parametrically run simulations for sensitivity analysis
- The ability to edit all parameters and have full control over the creation and processing of the models
- A user library specific to New Zealand from real-world data provided by BEES (Amitrano et al., 2014) - The construction data specific to New Zealand commercial office buildings was taken

and converted from (Cory, Gates, & Donn, 2011) into a Honeybee user library of constructions and materials.

- The ability to run both a thermal and daylight simulation with the same model - In the workflow, using Honeybee to connect DAYSIM and EnergyPlus together within the same interface, the same model is used for both. Therefore, any change for daylight analysis would be automatically made for thermal/energy analysis.

With these processes of the workflow outlined and described to the participants of the study, the participants are provided with a foundation to provide feedback. This workflow in particular focused upon demonstrating to the participants how the DMM can address the recommendations for future tool development in literature and how the method can provide rapid comparison of early design concepts "with flexibility, ease and speed" (Donn et al., 2012).

2.3. Data Collection: Focus Group Interviews

A group interview method was chosen to obtain feedback from the New Zealand building industry in regards to their views on the feasibility of building performance sketching using the distributed model method (DMM). Three recorded focus groups were conducted after their respective workshops to provide the participants of each group the opportunity to answer structured, open-ended questions as feedback which formed the main means of data collection for this study.

This study was particularly interested in the feedback provided by the professions within the building industry who directly work within the design process of the early stage of design. The study thereby had homogeneity in the first two focus groups, with the intention that the information from each group could be compared against another group of a different profession. The final group consisted of a mixture of both to explore the emergence of data and to test whether or not the same issues would be raised by the respective parties given the presence of the other which may argue the answers.

The determination of the 'appropriate' number of focus group participants did not have an aim of being statistically 'representative' of a given sample. Rather, the research method relied upon 'qualitative sampling' in order to compose a structured rather than random sample. In focus group design, this is often due to the need to mitigate the disadvantages of the focus group method such as having domineering or quiet participants. The study followed the recommendations from Morgan (1995), where it was stated that fewer participants would provide more opportunity to both tell and compare their stories in detail. In respect to this, each focus group within this study aimed for four to five participants in each group, resulting in five participants in each.

Hence, the focus groups were split into three categories: five Architects (Wellington); five Engineers (Wellington and Auckland); and a mix group of two architects and three engineers (Auckland).

4. Results

The data from the focus groups were coded into categories established for tool development in (Attia et al, 2012) and was analysed via Directed Content Analysis (DCA). The analysis used a six-category coding scheme to deductively code transcripts from the focus groups. This section presents a brief summary of the results of the study from the three focus groups.

The architects discussed four main reasons why they do not implement performance sketching: the time and cost provided by the client/stakeholder; the perception of time in relation to understanding the program interface; their prioritisation on architectural aesthetics and method of design; and their lack of expertise as a user. They discussed the only ways in which they perceive these to be overcome would be if: the interface would be made adaptable and educational; they could see the value in performance sketching in informing design decisions; if they would be provided with training; and if the client could see the value in the process in order to allow for more time and money.

However, they noted that architects cannot be fully trained to the point where they would replace the expertise of the engineer. Therefore, the groups suggested the need for a partnership with the engineer in order to facilitate the creation of easier, but accurate, interfaces. Hence, the barriers of the engineer need to be overcome along with those for the architect. The engineers believed that their barriers are: time of engagement within the project; effective communication between team members; the use of programs which do not make their assumptions and calculations transparent; the inability to continue models through into different phases of the design process; and the assessment of design parameters for their accuracy. The engineers indicated within this study that all but the barrier of engagement can be overcome by the use of the example, Honeybee, using the DMM.

The barrier of engagement was rooted in the 'Old School' market attitude of 'We just don't do it that way'. Engineers and architects alike suggested that in order to overcome the current market attitude, building performance sketching should become mandatory and the new generation of architects should be trained to design using performance sketching within their process. Thus, the designer would include comfort in their list of priorities, and the client would be required to include performance sketching within the early stages of design, thereby allocating cost and time to the process.

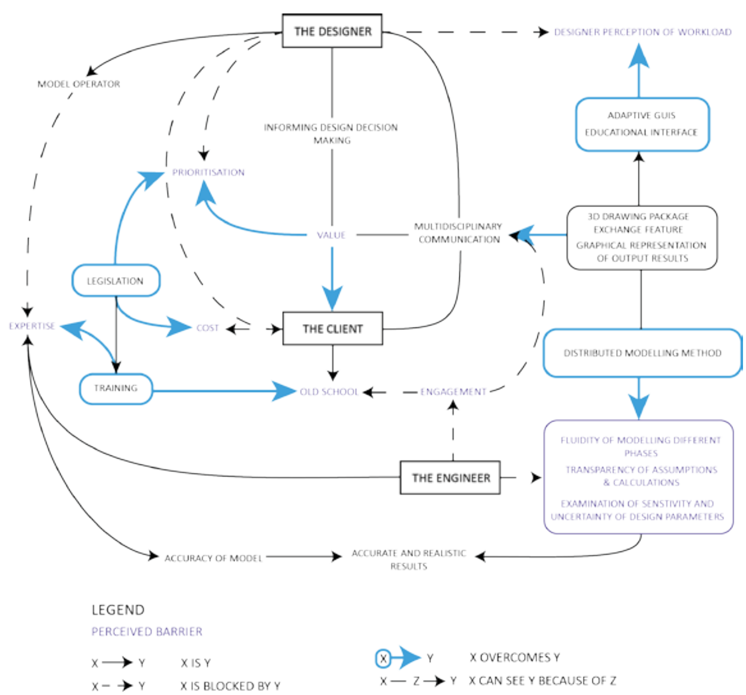

Figure 2: Mapping Concepts and their relationships

Figure 2 illustrates the relationships indicated by the participants between various concepts/categories brought up in their discussions. This mapping exercise illustrates the means in which recommendations made by the participants overcome the barriers they have established which prevent the implementation of the building performance sketch.

In creating the category connections through mapping, the categories which described the participant's established barriers were firstly identified in relation to their descriptions by the participants and which concepts represented the recommendations made by the participants to 'overcome' the barriers. This means of summarising the results through mapping an operational model diagram highlights four areas for future development and discussion, and are highlighted in blue borders: Legislation; Education through training and available resources; improvements of the interface; and features specific to quality assurance using DMM.

5. Discussion and Conclusion

The distributed model method (DMM) was hypothesised within literature as the best means to overcome the challenges within the integrated design process (IDP) approach, to enable effective design team collaboration and to provide the capabilities to address quality assurance barriers. The data of this study from the focus groups is sufficient to conclude that the distributed modelling method (DMM) cannot overcome all barriers preventing the implementation of building performance sketching. This study has shown that architects and engineers within New Zealand's building industry consider some external influences on the design process to be barriers which the DMM cannot overcome on its own. These include barriers such as the client and current 'set in their ways' attitude of the market. However, the architects and engineers of this study believe the DMM has high potential to address all the wants and wishes for future tool development made by current literature, including their own.

The architects concentrated on how the workflow, and the use of the DMM, could be feasible in the industry's Building Information Management (BIM) processes. The engineers focused their discussions and feedback upon the matter of quality assurance. They expressed their concerns in having the inexperienced simulator as the designer creating simulation models. The mixed group commented upon both, BIM integration and quality assurance, but focused their attentions on the feasibility of implementing a new tool such as the example tool Rhino within their design studio. Their comments surrounded the idea of competitive fees and 'backing the wrong horse' – viewing a new emerging tool as a gamble to invest in:

> "We'd have to back one horse but if it's not Honeybee and Grasshopper, it's something else".

> "It will improve the level of analysis that we can provide early on. I think internally, our biggest barrier might be lining up all this software, to be honest. Actually getting some of that 3D business, and making sure it interfaces well with Revit" – Engineering participant.

These considerations are not clear in literature, and raise a need for further exploration into business decisions surrounding the adoption of new tools within the design studio. These comments suggest that the implementation of new tools should focus upon not only making the use of the tool easier and efficient in a design team context, but must also consider interoperability to current tools used in industry. This would increase the likelihood of adoption within the design studio. It would be seen as a means to improve current operations rather than demanding a radical change in processes which would take time and training to implement successfully. Their lasting comment was that future development should focus upon furthering the processes in the DMM to implement building performance sketching for the future.

> "I think it opens up a whole new round of possibilities that to me didn't exist five years ago. I've been a consultant for a bit more than 10 years. When I first started, programs like IES were relatively new and they offered a level of computing power that wasn't there before. I feel like it's stayed about the same, most of the time that I've been working. But the ability to run numerous iterations and parametric simulations like that, is a new thing I think that wasn't available and I can't see it going away" – Engineering Participant.

The DMM was seen by the participants as a means to aid in overcoming the barriers against the implementation of building performance sketching by increasing design team communication, reducing time taken during the design process for simulation, and enabling means for quality assurance and effective team collaboration. Before building performance sketching can become a reality within the future, this study concludes with three main features which must be addressed by future development and research. These features were:

Standard modelling guidelines and templates specific to New Zealand: The participants liked the workflow created within this study, and requested the conceptual workflow to be developed into a standard workflow with templates specific in modelling building types for the New Zealand building industry which contain New Zealand specific building data. Participants also requested the creation of modelling guidelines for their use in DMM for design. These templates should include benchmarks for their respective building type and uncertainty reporting to inform the user of the validity and reliability of their results in the building context.

The development of adaptable graphical user interfaces for different users of these templates to meet their level of modelling expertise and priorities: Architects wished for the number of inputs to be simpler, as the current example is "too overwhelming"; engineers wished for the templates to provide full control and transparency of assumptions, along with the ability to simplify the interface for the architect to ensure the interface is not "too point and press". Thus a template workflow should be created which allows the engineer to quality assure the workflow for the specific building, 'cover the hood' and hand over a template which the architect can trust to provide reliable performance predictions, enabling them to focus upon what they are trained to do.

The development of the user interface of the workflow structure to be educational for a non-simulation expert to understand the processes of building performance simulation – The interface given to the architect from the engineer mentioned above should be visually appealing in order to communicate the value of building performance simulation and encourage continual use. Furthermore, it would help the architect in remembering the process if they had been disconnected in its use for a long period of time due to the scope of a project.

Other recommendations from the participants of this study go beyond tool development, focusing on means to address the external barriers on the design process such as: the level of expertise of the architect as designer; and the traditional 'set in their ways' attitude of the current market.

5.1. Education

A continuous underlining theme of this study has been lack of understanding, knowledge and value awareness by the industry and designers. The participants believed that an approach to overcoming the issues of expertise in modelling for quality assurance, and the Old School attitude of the market was to educate the 'old' and 'new' architects of the building industry. Thus, the study concludes the need for:

Tertiary education of architects to integrate building performance sketching in their design processes: The problem faced in this recommendation is that architects are currently already taught some form of building performance simulation in their education. However, it was clear from the participant recommendations that architect graduates should be taught the value of BPS to design. This would encourage the educational and the professional design studio to include building performance sketching in their routine assessment and dialogue in designing.

The creation and sharing of publicly available resources for upskilling professionals within the field: The barrier of expertise and knowledge of performance simulation prevents a willing architect from building performance sketching within their design studio. Thus, tutorial workshops, and online documentation should become more readily available to the industry to encourage designers to continue their professional development within the industry and implement better ways to inform their design decisions to designing high performance buildings.

5.2. Legislation and Standards

The participants in this study believe that the greatest driver to change is legislation. In referring to the category map diagram of Figure 2, the participants believed that legislation could demand the education of architects and more engineers. Furthermore, engineers believed that the priorities of the architects, and the time allocated to them by the client and/or project manager, would be changed if it were made mandatory to implement building performance sketching within the design process. Thus we conclude with the following recommendations if legislation were to be used as a driver as suggested by the participants:

Legislation made through expertise: Where it is made mandatory to performance sketch a building design, the quality assurance process of building performance sketching should be followed carefully and by an expert within the field.

5.3. Future Work

All participants believed that future work should focus upon developing the Distributed Model Method (DMM). The limitations of the scope of this study can be addressed by future academic studies which focus on the use of the DMM. Features which were unable to be tested due to the scope of this study are:

The comparison between Honeybee/Grasshopper/Rhino vs. Dynamo/Revit – At the time of this study, Dynamo/Revit was not at a state which could provide reliable coupling between the design tool and BPS tools without requiring some difficulty in translating model geometry. The comparison study may however provide grounds for a new research project investigating the interoperability between the DMM and central model method used in BIM. The participants of the study did ask regarding the interoperability between Rhino and Revit, *"Taking just the building out of Revit, what's that sort of step putting that into this, is that very hard?",* to which an example plug-in (Grevit, 2016) was briefly described however this interoperability was not the subject of the research therefore was not demonstrated.

Validation testing of the translation of languages between programs in the DMM – e.g. the translation of geometry from Rhino to Grasshopper to Honeybee to the building performance simulation engine is coded and may contain a bug within the code. This issue was briefly raised by the engineers of the study in relation to the open source quality of the example Honeybee for the DMM. Due to the DMM process using VPL as a middleware program to translate from one program to the next, this program must be validated.

Focus groups exploring the views of the client to such a process of design – We note that it would be beneficial to hear the perspective of the 'other side' – the client – to understand their wants and wishes for visual communication and expectations of the use of such a process to design.

Acknowledgements

This paper presents the data from a Master's of Building Science thesis entitled, 'The feasibility of 'Building Performance Sketching' within the Building Design Process'. I would like to thank all the participants who took part in this study. I would also like to thank the sponsors of this study for all their help and support. For more detail, the reader is encouraged to read the thesis found at Victoria University of Wellington, New Zealand.

References

Amitrano, L., Isaacs, N., Saville-Smith, K., Donn, M., Camilleri, M., Pollard, A., … Cory, S. (2014) *Building Energy End-Use Study (BEES) Part 1: Final Report* (Study Report SR 297/1 (2014) No. SR 297/1). Judgeford, New Zealand: BRANZ.

Attia, S., Beltrán, L., De Herde, A. and Hensen, J. (2009) "Architect Friendly": a comparison of ten different building performance simulation tools. Retrieved from http://orbi.ulg.ac.be/handle/2268/167578

Cory, S., Gates, A. and Donn, M. (2011) The creation of generic energy simulation models which represent typical commercial buildings and their calibration against real energy data. In *Proceedings of 12th Conference of International Building Performance Simulation Association*. Sydney, Australia.

Donn, M., Selkowitz, S. and Bordass, B. (2012) The building performance sketch. *Building Research & Information*, 40(2), 186–208.

Granadeiro, V., Duarte, J. P., Correia, J. R. and Leal, V. M. S. (2013) Building envelope shape design in early stages of the design process: Integrating architectural design systems and energy simulation. *Automation in Construction*, 32, 196–209.

Grevit. (2016) Grevit. Retrieved April 8, 2016, from http://moethu.github.io/Grevit/

Jacobs, P., & Henderson, H. (2002) *State-of-the-Art Review Whole Building, Building Envelope, and Hvac Component and System Simulation and Design Tools*. Architectural Energy Corporation, Boulder, CO (US); CDH Energy Corp., Cazenovia, NY (US). Retrieved from http://www.osti.gov/scitech/biblio/795581

Negendahl, K. (2015) Building performance simulation in the early design stage: An introduction to integrated dynamic models. *Automation in Construction*, *54*, 39–53. http://doi.org/10.1016/j.autcon.2015.03.002

Sadeghipour Roudsari, M. and Pak, M. (2013) Ladybug: a parametric environmental plugin for grasshopper to help designers create an environmentally-conscious design. In *Proceedings of the 13th International IBPSA Conference*. Lyon, France.