Precourt Energy Efficiency Center

Funded Project Final Survey Report

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Project Title: Design Guidance, Assessing Process Challenge, Strategy and Exploration

1. Project Description:

Summary

The Architecture, Engineering and Construction (AEC) Industry today is falling short of its potential to generate high performance buildings. Precedent-based and even point-based design strategies are proving inadequate. Evolving and emerging advanced strategies create the need for methods to measure the guidance they enable toward energy efficiency for specific design challenges. We define design guidance as the relative impact of strategy on exploration for a given design challenge. As strategies are implemented or proposed, the need arises to measure and compare the guidance provided by competing strategies on different challenges to support their selection and improvement towards achieving high performance designs. Design theory lacks precise definition and metrics for design processes and the guidance achieved. This research addresses the questions:

How can we measure the Guidance of a design process? More specifically, how can we assess the challenges addressed, strategies implemented, and explorations executed?

We use building energy-efficiency as the domain of the study. The larger opportunity is to provide greater guidance across objectives. This research illuminates the multidimensional relationships between challenge, strategy and exploration. It provides evidence that guidance can be assessed. The power of this research is to demonstrate that DEAM is an effective method to measure and compare the guidance provided by various strategies for energy efficient design. The generality is that DEAM works across various design challenges and strategies, and is not domain specific. Initial findings support the development and selection of advanced strategies since they are shown to provide better guidance economically. The value of information generated by strategies, however, varies across challenges. This finding makes different strategies more or less effective relative to the challenge addressed. This research motivates further work to develop greater understanding of the relationships and relative value of individual strategies to specific challenges.

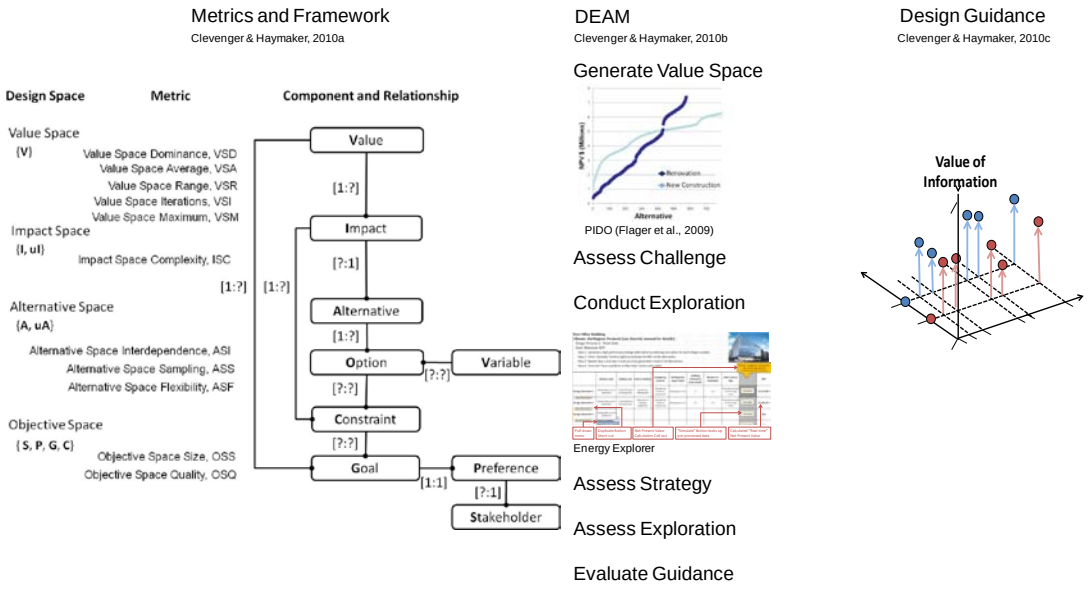

Figure 1: Diagram outlining the contributions of recent research. We developed a framework, metrics and software interface, Energy Explorer, to support our Design Exploration Assessment Method (DEAM). We tested DEAM and provided evidence of its power and generality by enabling comparisons of the levels of guidance and value of information afforded by twelve design processes- six strategies applied to two energy efficiency challenges.

Research Activities:

Without the ability to measure a process, it is not possible to identify improvement. The research we performed developed a method to measure and compare existing and emerging performance-based design processes. For this research we performed the following tasks:

- Through preliminary survey, we assessed whether the strategy of precedent-based design or "point-based" performance verification typically provides sufficient guidance to meet recent energy performance objectives in high performance building design.
- Using case studies, we identified potential short-comings in professional high performance building design processes.
- Through literature review, we synthesized a framework and set of metrics to evaluate and compare design process.
- We developed an Excel-based software tool, the Energy Explorer. With this tool, users are able to quickly and easily generate design alternatives, and analyze and record their energy and first cost performance. This tool was used to support and document our synthetic experiment using building practitioners applying charrette test research methods.
- We developed the Design Exploration Assessment Methodology (DEAM) to support the comparison of Guidance across design processes.
- We performed laboratory testing using professional designers to evaluate explorations afforded by six strategies with respect to two challenges (energy efficient design in renovation and new construction of a mid-rise office building).
- We added process cost to my metrics and assessed the value of information generated by various strategies relative to challenge.

Major Findings:

We present major findings in three papers:

Metrics to Assess Design Guidance (Clevenger & Haymaker, 2010a). We lay the foundation for our research by precisely establishing definitions and metrics for performance-based design processes. These metrics provide a method for characterizing the challenge, strategy and exploration embodied. The contribution is the synthesis from literature of a framework of definitions and metrics to enable systematic and quantitative evaluation of the guidance afforded in energy efficient building design by a given design process.

Design Exploration Assessment Methodology: Testing the Guidance of Design Processes (Clevenger et al., 2010b). In this paper, we develop and implement a Design Exploration Assessment Methodology (DEAM). We present the results of a laboratory experiment where we study the Explorations performed by professionals who implement six strategies, across two challenges. We rank the strategies tested according to their ability to guide exploration toward the objective of energy efficiency as follows: random guessing, tacit knowledge, combined point and trend analysis, point analysis, and trend analysis alone. The results are surprising: more data does not always help the designer achieve higher performing designs. We discuss possible explanations, and conclude with a discussion on the strengths and weaknesses of DEAM.

Calculating the Value of Strategy to Challenge (Clevenger & Haymaker, 2010c). In this paper, we perform further computer experimentation to show that building design challenges vary non-trivially across climate type. We introduce a new metric for the process cost of a strategy. We use empirical data to calculate and compare the value of information generated by individual strategies across challenges. This work illustrates that that the optimal selection of strategy to promote higher building performance varies relative to challenge and motivates further development of advanced strategies.

2. How have the results from this project contributed to the solution of energy efficiency challenges? How is it likely to contribute to solutions in the future?

As the complexity of building design challenges continues to increase, design teams will look to use more advanced design strategies to define objectives, generate alternatives, analyze performance, and make decisions. This research, which enables the systematic comparison and improvement of processes within the domain of building energy performance, will continue to grow in importance as the challenges facing designers continue to expand.

3. **What undergraduate or graduate students, as well as Post-Doctoral fellows, were involved this project. How were they involved? *Please list their name, classification and a short description of their involvement.***

Benjamin Welle, Stanford PhD Student, is a primary researcher and developer of Process Integration Design Optimization software (PIDO) applied to building design (Flager et al., 2009). We collaborated with Benjamin to use PIDO to automate input generation and analysis of EnergyPlus and to perform a full analysis of two simple building models, representing new construction and renovation project challenges.

Andrew Ehrich, Stanford Undergraduate Student, ’09 provided research support for our synthetic experiments. Her provided assistance with the statistical analysis of the results, and served as third author on *Design Exploration Assessment Methodology: Testing the Guidance of Design Processes (Clevenger et al., 2010b)*.

4. Will you be continuing work on this project? How and with whom? Please include any comments.

Caroline Clevenger and John Haymaker plan to continue to collaborate on related work in the future. In addition, Caroline will continue to develop related work as an Assistant Professor at Colorado State University.

5. **Are you seeking or have you received additional funding as a result of this project, or for continued work on this project?** ***Please list the amount you are seeking/have received, source of the additional funding and a short description.***

This work served as one of the primary drivers for a NSF preliminary grant proposal: Haymaker, J., Stanford University (PI), Clevenger, C., Colorado State University (Co-PI), Fischer, M., Stanford University (Co-PI) EFRI-SEED Preliminary Proposal: Process Communication, Automation, and Measurement Platform (NSF 1009357) National Science Foundation ($2,000,000), 9/10-8/14. The preliminary proposal was not accepted.

6. **Has this project generated any other projects?** ***Please describe*****.**

OVIZ has become a principle point of departure for CIFE project "Managing Energy and Water Consumption of Institutional Buildings" (Toledo and Fischer)

DEAM is being adapted and used to validate advanced strategies being developed in Haymaker's lab including the Process integration Platform (Senescu and Haymaker).

RBOM (Reference-based Optimization Method – Welle & Haymaker) has been used to generate data for this work, and DEAM will serve as a validation method fro RBOM.

7. **What patents, if any, have you received or applied for?**

None.

8. **Please list all academic and non-academic (Op-Eds, news magazines, etc) publications and conference presentations as well as articles in progress that came about as a result of this project. May we post these on the PEEC website?** ***If so, please list the URL or provide a pdf version***.

Clevenger, C (2010) Dissertation Introduction: The Need to Measure the Guidance Afforded by Design Strategies. http://cife.stanford.edu/online.publications/TR190.pdf

Clevenger, C., Haymaker, J., (2010a). Metrics to Assess Design Guidance, submitted to Design Studies. http://cife.stanford.edu/online.publications/TR191.pdf

Clevenger, C., Haymaker, J., Ehrich, A. (2010b). Design Exploration Assessment Methodology: Testing the Guidance of Design Processes, submitted to Journal of Engineering Design. http://cife.stanford.edu/online.publications/TR192.pdf

Clevenger, C., Haymaker, J., (2010c). Calculating the Value of Strategy to Challenge, submitted to Building and Environment Journal. http://cife.stanford.edu/online.publications/TR193.pdf

*Clevenger, C., Haymaker, J., (2009). Framework and Metrics for Assessing the Guidance of Design Processes, (**Reviewer's Favorite**) The 17th International Conference on Engineering Design, Stanford, California.* *http://mycahs.colostate.edu/caroline.clevenger/documents/ICED09-449-SUBMITTED.pdf*

Clevenger, C., Haymaker, J., and Swamy, S. (2008). The Importance Process: Enabling Creativity in Performance-based Design through Systematic, Model-based search of Multidisciplinary Impacts, World Sustainable Building (SB) Conference Proceedings, Melbourne, Australia, 2008. *http://www.stanford.edu/~haymaker/Research/Papers/Importance-Process-Clevenger-Haymaker-SB514-Sept2008.pdf*

Akbas, R., Clevenger, C., Haymaker, J., (2007) Temporal Visualization of Building Occupancy Phase*, American Society of Civil Engineers Workshop- Computing in Civil Engineering, Pittsburgh, Pennsylvania.* http://mycahs.colostate.edu/caroline.clevenger/documents/TemporalVisualization_2007.pdf

Clevenger, C., Haymaker, J. (2006) The Impact of the Occupant on Building Energy Simulations*, Joint International Conference on Computing and Decision Making in Civil and Building Engineering, Montreal, Canada.* http://mycahs.colostate.edu/caroline.clevenger/documents/OccupantImpact_2006.pdf

9. Provide a URL address for any websites that provide more information for interested parties on your research project, including photos and videos. We will add this information to your project summary on the PEEC website.

http://mycahs.colostate.edu/caroline.clevenger

10. Have you developed any specific products, (such as databases, physical collections, educational aids, software, etc), as a result of this project? *If so, please list along with a short description.*

As part of this research, we developed an Excel-based software tool, the Energy Explorer. This tool enables users to quickly and easily generate design alternatives, and analyze, compare and record their energy and first cost performance. Hidden libraries and look-up tables support the interactive interface, containing results from pre-simulated full analyses. The tool is useful as a research and educational platform.

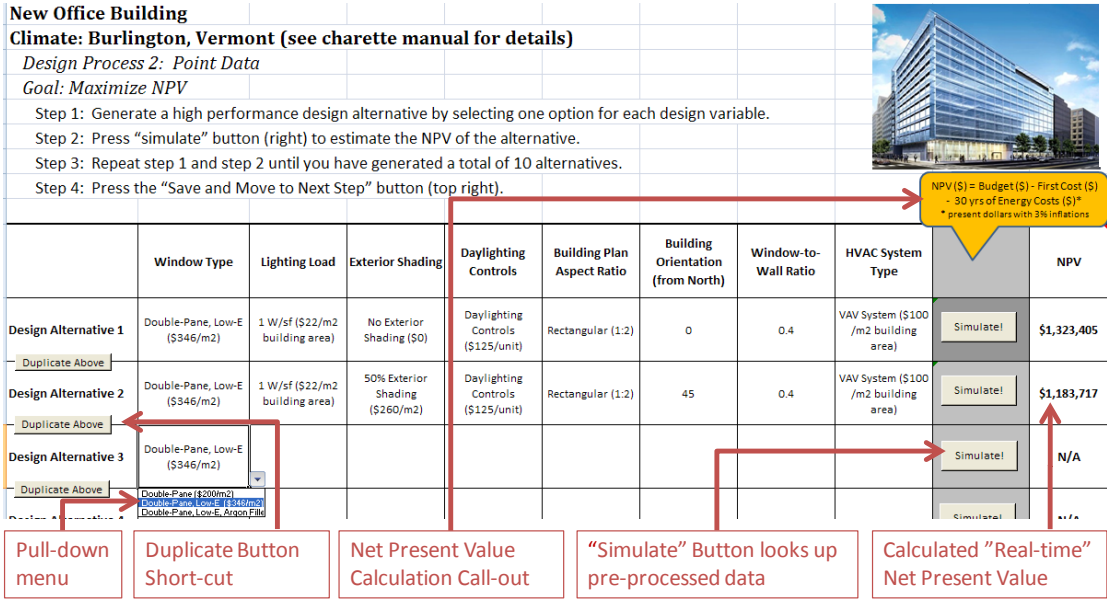

Figure 2: Custom interface for Energy Explorer, an interactive software tool developed by Caroline Clevenger, John Haymaker and Andrew Ehrich, 2009.

During earlier research, we developed a software tool entitled OViz to visualize multi-dimensional building occupancy and performance. By running OViz models synchronously, users can quickly compare simulated and actual building occupancy. Figure 3 shows in reality, the building is not at full occupancy (fewer occupants on right), in reality an occupant may enter and not turn the lights on (no yellow fixtures on right), in reality plug loads may remain high while occupancy low (purple computers on right).

Figure 3: Images from of OViz software, developed by Ragip Akbas, Caroline Clevenger, and John Haymaker, 2007.

11. Were any undergraduate or graduate courses generated as a result of this project? *If so, please list the course title and a short description.*

N/A

12. Have you provided any information regarding your research to any public or private institutions (e.g., legislative briefing, government panel, congressional testimony, corporate presentation) or any public or private institution asked you for information regarding your research? *If so, please list the organization, date and a short description.*

Professionals from General Services Administration (GSA), (6/8/2009 in Washington, DC), and Architectural Energy Corporation (AEC) (6/30/09 and 7/28/09 in Boulder, Colorado) participated in our charrette test experiment. During the charrette test they were introduced to our research and used the Energy Explorer tool. In follow-up emails there were presented a brief overview of preliminary research results.

Brief follow-up discussions with AEC included the possibility of licensing the Energy Explorer tool for use in support of charrette activities being performed as part of California utilities' EnergyDesignResources program. Southern California Edison (Diane McLean) participated in these discussions (8/5/09). The researchers decided not to grant a licensing agreement at this time.

13. Have you partnered or worked with businesses, governmental agencies, NGOs, or other public or private organizations in connection with your project? If so, what role have they played? Please list the institutional name, type of institution and a short description of the partnership.

Since 8/15/09 Caroline Clevenger has worked as an Assistant Professor at Colorado State University, Department of Construction Management.

14. What public education activities have you undertaken in conjunction with this project?

None.