Process Integration and Design Optimization in Support of Energy Efficient, High Performance Building Design

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The majority of buildings designed today suffer from thermal comfort, lighting, and energy performance issues. These deficiencies often result because architects and engineers lack the time, money, processes, and tools to consider a wide enough variety of design options that address all these criteria. Better solutions exist; the design team simply is not able to find them. Design teams trying to optimize energy, thermal comfort, daylighting, cost, and other forms of building performance require far more systematic, iterative, and collaborative design processes and tools. My research proposes to develop and test a collaborative methodology and tool, for both process and building analysis, that reduces the time required for project teams to complete meaningful design iterations. The methodology will help them define sustainable design goals, generate many options rapidly, and evaluate tradeoffs in the areas of energy, thermal comfort, daylighting, and cost. This methodology will build upon several points of departure:

Information Delivery Manuals (IDMs): IDM is an integral component of the International Alliance for Interoperability's (IAI) buildingSMART initiative and Industry Foundation Classes (IFC) development effort for the advancement of building information modeling (BIM) functionality. IDMs indentify "best practice" design processes and the information flows necessary to execute effective model-based design analyses. However, current IDM structure is limited, and more comprehensive process maps are needed that allow for the inclusion of a project's participants, goals, preferences, schedule, budget, and building delivery process, providing design guidance and management for the required communication and data exchange processes and iteration loops.

MACDADI (Multi-Attribute Collective Design Assistance for Design Initiatives), also developed at CIFE, enables design teams to structure a formal integrated design process by building models that define and weigh goals, propose options, analyze each option, and visualize multidisciplinary tradeoffs.

Narratives are a visual process modeling language developed at CIFE to help design teams communicate and manage project-specific design processes and information.

Process Integration and Design Optimization (PIDO) is an emerging line of optimization software products developed in aerospace design that aims to give users the ability to integrate processes that utilize multiple digital design and analysis tools. These products allow software tools to be "wrapped", and their simulations automated and optimized based on a set of user-defined design variables and constraints. Very little work has been done to date to test the effectiveness of these frameworks in the AEC domain, and whether or not the PIDO framework can effectively capture, analyze, and optimize the necessary design parameters of building analysis tools for energy, daylighting, and thermal comfort.

Importance analysis is methodology that isolates and provides the ranked correlation of input variables to explicit multi-criteria performance metrics. Weighted Importance incorporates project goals and preferences into the rankings.

My research proposes to develop and integrate these points of departure in seven fundamental steps. In step one we will develop "general" IDM process maps for energy, daylighting, thermal comfort, and cost for early concept design. In step two, we will develop a database of supplemental process information and a set of integration rules and algorithms that will be used in the subsequent steps to fill some of the knowledge/process gaps in the generalized IDM processes. In step three we will integrate the MACDADI methodology to help teams model organizations, goals, and preferences, transparently and systematically. In step four, we will build an open source web-based process tool that allows project teams to create a "customized" process map using a Narrative graphical user interface. This interface will create a customized IDM by processing input from MACDADI, a database of "general" IDMs, and the supplemental process information database, and integrating those IDMs (e.g. combining separate IDMs for energy, daylighting, and cost into one comprehensive IDM) using the integration rules. The project team will be able to modify, maintain, and generate new visual, interactive, and collaborative design processes as needed. In step five we will evaluate the potential of PIDO to enable multidisciplinary analysis and optimization using Digital Project by Gehry Technologies for geometric design, EnergyPlus for energy simulation, Radiance for daylighting simulation, and a FLUENT, a computational fluid dynamics (CFD) software, for thermal comfort simulation. Step six will

extract information from the PIDO optimization and MACDADI to provide the Weighted Importance. The final step closes the design loop by integrating this Weighted Importance data back into the customized design process.

This proposed research will provide design teams the tools and processes they need during early concept design to dramatically increase the number of design options considered. Its goals and innovation reflect that which the Precourt Institute aims to support.