An Integrative Process for Advanced Energy Retrofit Projects

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ABSTRACT

Advanced Energy Retrofit (AER) projects can significantly reduce energy consumption of existing buildings, and studies have indicated that they can be more economic than constructing new building. Retrofit projects vary in complexity based on the building characteristics, building area, client requirements, project budget, payback period and energy savings targets. The lack of a transparent and streamlined integrative process makes it difficult for the participants to implement AER projects. To implement comprehensive AER projects (also known as Deep Retrofits) in an efficient manner, it is important to understand the process along with the information exchanged during the planning, design, construction and operation phases. This paper describes the development of an AER integrative delivery process model with a focus on the planning and design phases. The integrative process has been developed through a detailed literature review, and studying the project documents and procedures used to deliver an ongoing comprehensive AER project. It was validated by review in multiple industry workshops, and through interview with industry and academic experts, including all the primary team members of a comprehensive AER case study. The process is undergoing additional validation through AER integrative workshops and a detailed case study analysis. The final integrative process includes activities focused upon specific building systems along with integrated processes and information exchanges, which support the integrated workflow among team members. The identified important information exchanges outline a series of exchanges that support application interoperability for AER projects.

INTRODUCTION

Limited resources, cost of the building materials and site, and land availability have made it a necessity to reuse the existing building along with making them more energy efficient. Though there is a demand for energy retrofit projects, they are not picking up the required pace because of knowledge gaps. Energy retrofit projects involve more uncertainty and even the most experienced projects teams may find it difficult and feel lost at first when considering elements such as energy audits, conservation measures, financing, and measurement and verification (Sanders et al. 2012). The planning and design phases of a project play a major role in the outcome of an AER project and it is important to understand the process for successful and effective implementation. Having a well-defined process can increase the probability for success by guiding a team through a structured, transparent and repeatable process. The integrated design approach can help in meeting the energy goals of a project by downsizing system components, minimizing redundancies, improving performance, and reducing energy consumption (Deru et al. 2005).

This research focused on the development of an efficient and structured planning and design process for performing comprehensive (deep) AER projects. It contributes to filling the knowledge gaps identified during the literature study. It also identifies the level of system integration and team integration that occurs in retrofit projects that are focusing on reducing the energy consumption in existing buildings. With the help of literature on building systems and case studies, the process was developed and validated. The resulting process models aid project teams in the implementation of repeatable, consistent retrofit processes, along with the identification of important higher-level information exchanges that take place between the project participants. The information required and produced by the activities in the process can help in understanding the information requirements and in the development of information delivery manuals (IDMs). This work will not only help address interoperability issues, but also help the project team in understanding the data required to successfully implement the process. The process models can be used as a guideline to help illustrate the activities involved during the planning and design phases, and the information and activity dependencies on other disciplines.

AER PROJECTS AND THE NEED FOR INTEGRATIVE PROCESS

The main aim of an energy retrofit project is to reduce a building's energy use by replacing or modifying the systems, equipment or parts of a building. There are three different scales of energy retrofits defined by Pacific Northwest National Laboratory in their Advanced Energy Retrofit guide (Pacific Northwest National Laboratory and PECI 2011). The three types include existing building commissioning (EBCx), standard retrofits, and deep retrofits. Among the three, deep retrofits typically have longer payback periods and higher upfront investment. Deep retrofits aim to achieve much larger energy savings than the other conventional types of retrofits, and they use a whole-building analysis. A deep retrofit project calls for an integrated design process, which requires the evaluation of opportunities across multiple building systems. Standard retrofits require the implementation of measures in stages where only one or a few systems are addressed at a time (Pacific Northwest National Laboratory and PECI 2011). While working on AER projects, both building system integration and project team integration have been identified as important.

Project team integration. Integrative design is a process that requires all the major team members to work together from the start of the project. It is different from the traditional design process, which is typically executed in a linear fashion. As defined by Löhnert et al. (2003), "Integrated Design is a procedure considering and optimizing the building as an entire system including its technical equipment and surroundings and for the whole lifespan." The ANSI (American National Standards Institute) Consensus National Standard Guide defines the integrative process as a process that engages all project team members in an intentional process of discovering mutually beneficial interrelationships and synergies between systems and components. Higher levels of building performance, human performance, and environmental benefits are achieved by unifying technical and living systems. The integrative process structure, which involves the flow of people, information, and analysis, can be managed by gathering information and data relevant to the project from all disciplines, by analyzing the information and by gathering together in workshops to compare notes and identify opportunities for synergy (American National Standards Institute (ANSI) 2012).

Building system integration. According to Bachman (2003), all buildings have to achieve some basic level of integration to some degree before they can be built and occupied. Integration among the hardware components of building systems can be approached by having the physical, visual and performance goals in mind. These components should share space, their arrangement has to be aesthetically resolved, and they have to work together without disrupting the performance of each other. In the book Natural Capitalism, Hawken et.al (1999) state that, “You can actually make a system less efficient while making each of its parts more efficient, simply by not properly linking up those components. If they’re not designed to work with one another, they’ll tend to work against one another.”

The systems in retrofit projects should be designed in concert, rather than as a sum of individual parts (Pacific Northwest National Laboratory and PECI 2011). Simultaneous evaluation of opportunities across multiple building systems is required to achieve a successful comprehensive (deep) retrofit project. An integrated design process can help in achieving this goal more efficiently. The integrated process can focus on the impact of retrofitting multiple systems of varying complexities at the same time. An integrated design approach can facilitate the optimization of equipment sizes when multiple building systems and assemblies are replaced simultaneously (Pacific Northwest National Laboratory and PECI 2011). Project actors can understand each other’s work and the effect of one’s work on the other, thereby identifying the available opportunities for increased energy savings.

INTEGRATIVE PROCESS MODEL AND INFORMATION FLOW IN BUILDING PROJECTS

The integrated design process of an AER project demands a need for a visual representation of the design process as it involves a lot details and is sometimes complex. The flow of information and the workflows that support collaboration can be visualized using process mapping (Rother and Shook 2003). A process model can help by providing a big picture of the project workflow and help in solving the complexity of the design process. These maps can help the project team members to better understand other stakeholder’s role and responsibilities. Process maps show the relationship of actors, processes, and information exchanges in swimlanes (Davis and Karlshoj 2011). Business Process Modeling Notation (BPMN) developed by Object Management Group (OMG) can be used for process model development. A key element of BPMN is the choice of shapes and icons used for the graphical elements

(*Business Process Model and Notation (BPMN)* 2011). The integrative process model developed in this research was based on BPMN.

Process Models can also help us identify the important information exchanges that occur within the process, which will then allow us to clearly define the content required in each exchange to enable more detailed analysis. It is important to understand how flows of information or material become networked and how decision making about the systems can affect outcomes (Bachman 2003). This includes information transferred from one discipline to another or from one application to another. There are a number of different participants from different disciplines in the Construction Industry. Each participant should know which and when different kinds of information have to be communicated. This issue becomes even bigger when digital tools are applied as most tools have a low threshold of tolerance when it comes to the ability to interpret digital data.

DEVELOPMENT METHODOLOGY

The integrative building planning and design process models were developed partially with the help of literature and have a strong influence from case studies of one completed and one on-going comprehensive retrofit projects. There are not many existing process models that show the flow of activities for an AER project. Therefore, much of the data used to develop the process models was collected using different sources of literature on each building system or component. This data was later bolstered by reviewing retrofit project documents, and studying the background and context. Minutes of project meetings, contract documents and other project related documents were reviewed to get additional information, which is not obtained, through literature. A focus group meeting with design experts was conducted to obtain the data needed to create the initial design process model. The research team (including authors of this paper) who developed the design phase process model printed out multiple process maps and discussed the detailed process with experts from Construction, Mechanical, Structural and Lighting specializations. The important activities, their flow and their requirement of integrating with other disciplines were discussed and the feedback helped in updating the process model.

VALIDATION METHODOLOGY

This research work was validated using case studies, focus group meetings and interviews. The planning and the design phase process models were validated simultaneously. The factors considered for the selection of case studies are the building type, building size, scale of the AER project, number of building systems being retrofitted and the target energy reduction percentage. Commercial and educational buildings where a substantial amount of renovation occurred were chosen as case studies for validation purposes. The extent of team integration and system integration were also studied during the process.

Focus group meetings were an integral part of the case studies. They involved group discussions where participants collectively focused on the topic selected by the authors. The participants in the focus group meetings included project team members, domain experts and a well-recognized integrative design expert. The authors presented the topic to the group in the form of a printed process models along with questions. The process model was presented to the participants well in advance the focus group meeting so that they had sufficient time to review the activities in the model. During the focus group meetings, several questions tailored by the authors were posed and the information obtained was recorded. This activity helped in getting an overall understanding of how the process within an AER project worked.

A series of interviews were then conducted with all the major team members of the projects. The interviewees were selected based on their role in the organization, their domain expertise and their experience working on retrofit projects. As part of the interview, a questionnaire was developed to get higher-level information about the project. These questionnaires were distributed and a small survey was conducted among the project team to get an overall understanding of the project. The questionnaire was highly structured and the researcher introduced the subject matter of study to the respondents before performing the survey. Later, each team member belonging to different disciplines was interviewed in person by walking through the process in detail. After the focus group meeting and the interviews were completed, the process model was updated.

DESCRIPTION OF THE FINAL OUTCOME

The final outcome of the research is the planning and design phase process model. The model is not prescriptive, but can be used as a guideline by the project team while performing a comprehensive AER project. A simple representation of the process model is shown in Figure 1. A full scale detailed integrative AER project process model can be accessed online at www.engr.psu.edu/ae/cic/projects/IBLCPM.aspx?p=31.

Planning phase process. The planning phase process is a simple one page (11” x 17”) reference document. The planning phase process details the important factors to be considered when starting to plan an AER project. The model guides an owner and the project team through the available options and steps that can be followed to make the planning process more transparent. The swimlanes of the process model include: owner, occupant/tenant, possible disruption to the building with occupancy, building evaluation, project developer, and government incentives and financing. Each swimlane shows the activities to be performed and the flow of the process. Eighty-seven different activities are identified in the planning phase of an AER project.

Design phase process. The goal of the design phase process is to guide the project team through a structured design process that will support the decisions within the process; and help them understand the important activities involved along with the higher-level information they need, to perform an AER project. The information about the different phases of design was referred from the Integrated Project Delivery Guide (2007). The four phases of design include conceptualization, criteria design, detailed design and implementation documentation. Conceptualization phase has 227 activities, criteria design phase has 139 activities, detailed design phase has 127 activities and implementation documentation has 21 activities. On the whole, the design process has 514 activities. All the activities in the map are documented by defining each activity in detail.

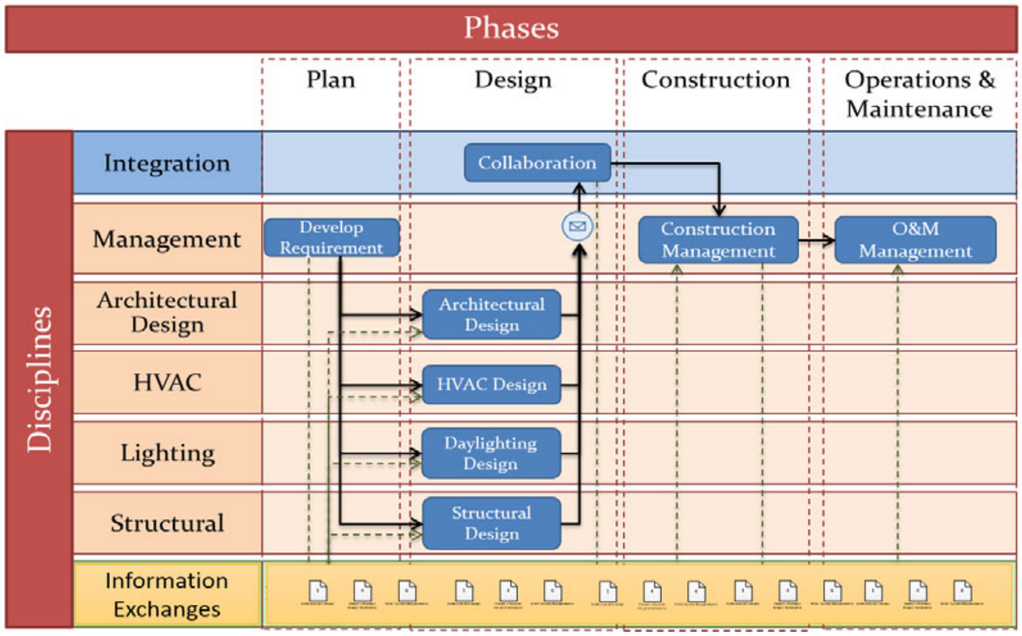

Figure 1. Integrated building life cycle process model (higher level).

According to the BPMN (*Business Process Model and Notation (BPMN)* 2011) terminology the horizontal rows are called swimlanes. The process model has the important building systems and elements along with an integration swimlane and an information exchanges swimlane (see Figure 2). The other disciplines that are important for a successful design, such as architectural design, project budget and schedule management, were also considered while developing the process model. They are termed as Space Design and Management. All these building elements and disciplines are shown in swimlanes in the process model. The activities in the integration swim lane are the ones that involve two or more team members working together to complete an integrated task. It also shows the level of building system integration that needs to occur. The building systems/elements which are in the process model were referred from the Omni Class Table 21 for Elements. Figure 3 shows a sample of lighting and building automation swimlanes. The numbers marked on the top and bottom of the lighting swimlane activities are the information consumed and produced by that particular activity. These numbers can be referred at the bottom of the map where information exchanges are shown. This will help a member of one discipline to understand how the information that an activity produces is used by a member of another discipline. The current process model has information exchanges identified for HVAC, lighting and structural disciplines. These information exchanges along with the process of each discipline can be used to develop individual Information Delivery Manuals (IDMs). The information exchanges can be viewed here: [www.engr.psu.edu/ae/cic/projects/IBLCPM.aspx?p=31.](www.engr.psu.edu/ae/cic/projects/IBLCPM.aspx?p=31)

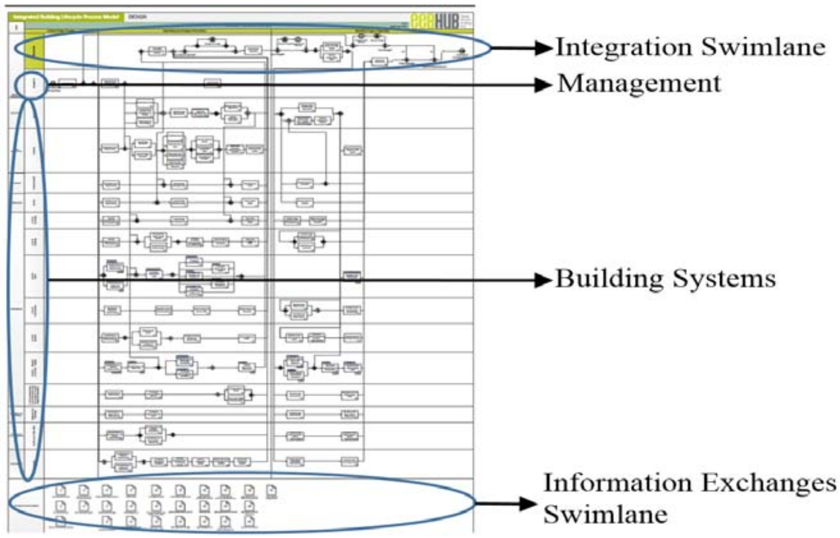

Figure 2. Process Model showing the organization of different elements.

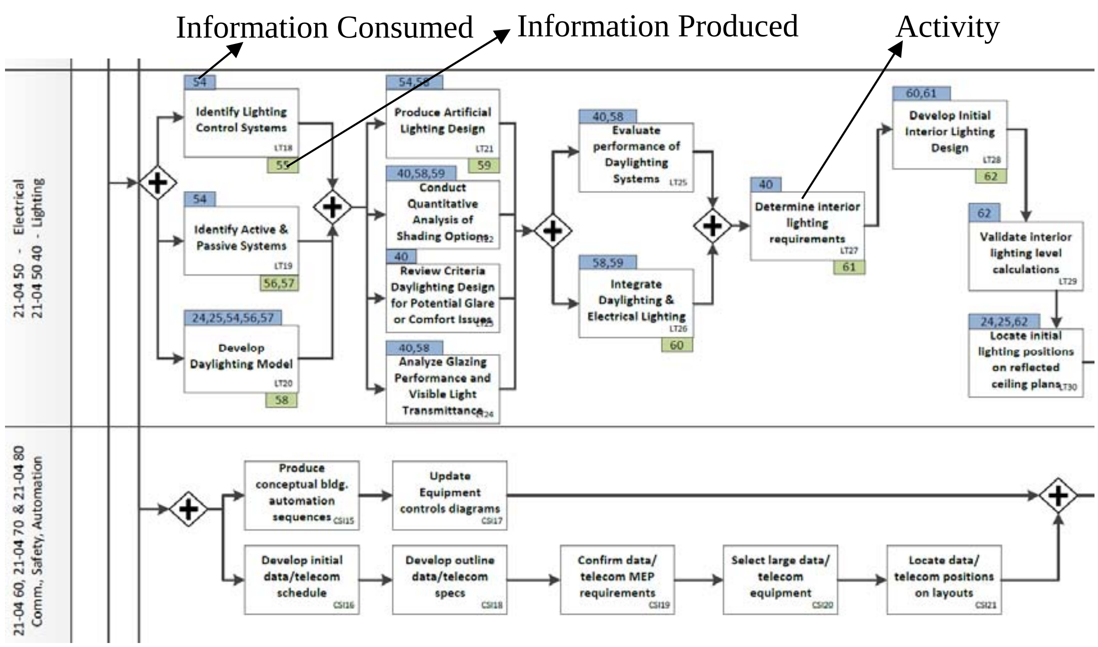

Figure 3, Lighting and communications, safety, building automation swimlanes with activities

CONCLUSION AND FUTURE WORK

This paper describes the development of an integrative process for the planning and design phases of AER projects that are complex in nature. The process model documents a structure for delivering an AER project. Though there are many resources available for both owners and project teams regarding AER projects in general, there is no resource which provides the process and information exchanges to produce a successful comprehensive AER project. The research contributes by identifying the locations within a process where there is a need to exchange information. Future work can leverage the clear documentation of these exchange points, and then develop information standards for the exchanges. The present work just focuses on the planning and design phases of an AER building project. The research team is working on developing the integrative process models for all the phases (Planning, Design, Construction and Operation) of the building lifecycle along with capturing the important information exchanges.

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