ANALYSIS OF THE DESIGN PROCESS OF GREEN CHILDREN'S HOSPITALS: Focus on Process Modeling and Lessons Learned

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ABSTRACT

Healthcare facilities are among the most complicated facilities to plan, design, construct and operate. A new breed of hospitals is considering the impact of the built environment on healthcare worker productivity and patient recovery in their design, construction, and operation. A crucial subset of healthcare facilities are children's hospitals where the consequences of poor building system design and performance have the potential to seriously impact young lives with compromised health. Green facilities are not always pursued: they are perceived as difficult to build and costing more than equivalent conventional hospitals. This study explored the design process of the Children's Hospital of Pittsburgh of the University of Pittsburgh Medical Center (UPMC) and Penn State's Hershey Medical Center Children's Hospital to understand the critical steps and processes for green children's hospital design. Producing a series of process maps that identify the key characteristics in the complex design requirements of a green children's hospital, this paper reveals the importance of design process to design quality. More broadly, this research will help future project teams meet the complex design requirements of green children's hospitals.

KEYWORDS

sustainability, healthcare design and construction, process

BACKGROUND

Healthcare facilities are among the most critical and complex types of buildings to plan, design, construct, and operate. Children's hospitals can be considered even more significant given that they are used to care for young lives with compromised health at early stages of development. The consequences of facility design, construction and operation can be considerable in the care of these patients and in the quality of care provided by healthcare workers (Hodgson 2000).

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Integrated design is often used to meet sustainable design objectives and offers an important focus for research whose goal is to understand the synergies between project delivery, building performance, and occupant performance. The design process of healthcare facilities, however, involves complex trade-offs and iterative activities such that design attributes that have been shown to enhance building performance are often not fully considered. Healthcare literature continues to report about important research connecting the health and well-being of healthcare facility occupants to the performance of the built environment. For instance, the Fable Hospital and Pebble Projects are currently examining the effect of healthcare design decisions on the health and productivity of staff and patients (Berry L.L. et al. 2004; Center for Health Design 2006). This "evidence-based design" approach is used to formulate a business case for spending additional money up-front for better design of healthcare facilities that result in significant lifecycle savings due to healthier and better operating facilities. Unfortunately, sustainable design technologies are often cut from healthcare projects based on perceived additional first costs despite lifecycle cost savings. This, in large part, is due to limited knowledge of the design process for healthcare facilities. Research in this discipline identifies the key activities and events that impact first costs and achieves design process efficiencies for delivery of better facilities (as in more functional and/or healthier hospitals).

Survey results from four regional healthcare conferences held by the Design-Build Institute of America reinforce the need for research focused on the design and delivery process of green healthcare facilities (Phelps 2006). The results shown in Figure 1 were obtained from a survey of healthcare designers, engineers, owners, and administrators attending these conferences; the findings demonstrate that lower operating costs and improved clinical outcomes are the two main reasons for pursuing green healthcare facilities. These are expected results; however, the survey also showed that perceived higher costs of design and construction, current delivery and contracting practices, and facility complexity, are the biggest barriers to greening healthcare facilities (Figure 2). Successful green healthcare projects can provide substantial and much-needed insights on these practices.

With over 120,000 healthcare buildings in the U.S. and the healthcare industry employing over 6.2 million workers, totaling 6% of the workforce, a huge opportunity exists to impact how the built environment affects occupant health and well-being. Given that the healthcare industry is embarking on $100 billion of projected construction activity over the next ten years, now is the time to investigate and model how green strategies are best woven into the healthcare facility during design, construction and operation. The potential return in terms of occupant health and wellbeing and the bottom-line is tremendous (Carr 2003; CMPBS 2005; USGBC 2002).

Children's Hospital of Pittsburgh (CHP) of UPMC (University of Pittsburgh Medical Center) completed the design of one of the nation's first green children's hospitals. In addition, Penn State's Hershey Medical Center is currently designing its own pediatric facility. The lessons learned by CHP and other current green projects can provide significant insights for the design of other children's hospitals regarding the most critical aspects for the successful greening of hospitals.

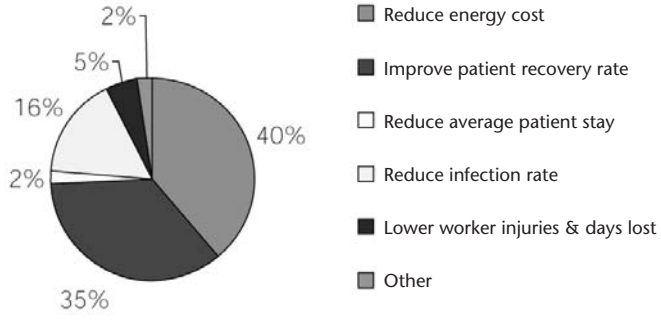


FIGURE 1. Primary Role of Green Healthcare Facilities.

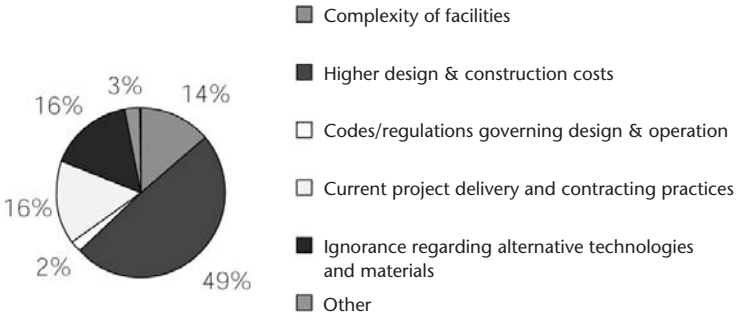


FIGURE 2. Barriers to Green Healthcare Facilities.

Additionally, the outcomes of this research are compared against the results of Lapinski et al. (2006) that describes important elements in successful green building design. The elements are the following:

- Early evaluation and adoption of environmental considerations: Sustainable objectives are evaluated and adopted during project programming;
- Business case imperatives: Early evaluation and adoption of sustainable objectives allows project budgets to be aligned with environmental project goals;
- Sustainable compatibility: Sustainable building features are aligned to site conditions and parameters during project programming;
- Early selection of team members with sustainable experience: Teaming is a critical part of sustainable building delivery; and,
- Alignment of team member goals and project goals: In addition to selecting the project team early, clearly define success for the project.

OBJECTIVE

The objective of this research was to study the design process of green children's hospitals in order to understand the important elements. Events and processes that make up the design process were identified, documented on a process map, and evaluated for their effectiveness in achieving project goals.

RESEARCH METHODOLOGY

Two case studies of green children's hospitals were investigated to identify and map the key characteristics of the design process. The emphasis was on a factual accounting of the design process with an interest in identifying any particular steps taken to meet sustainability objectives. For each project, data was separately collected through focus group sessions with key project participants including the architects, engineers, and owners. These sessions were transcribed and translated into a visual process map to highlight the key events and activities that occurred during design. The analysis involved comparison between the process maps from each project for similarities, differences, and events critical to the success of the project design.

CASE STUDY BACKGROUND

Children's Hospital of Pittsburgh of UPMC

The new CHP is located in Pittsburgh's primarily residential neighborhood of Lawrenceville (see Figure 3). The location represents a significant departure from the cohesive yet complex UPMC hospital community in Oakland. UPMC is a major health system in western Pennsylvania and a nationally recognized academic medical center (UPMC 2007).

The new CHP represents a part of a major development consisting of a clinical services building (the hospital), academic research center, plaza building, faculty pavilion, administrative office building, and three parking garages. Importantly, the CHP hospital project is primarily new construction with a portion of an existing building retained, on a congested, brownfield site. The entire project is not just new construction; six buildings were retained with about the same amount of renovated space as new. The cost of the entire development is approximately $625 million; the hospital will be completed in 2009. CHP is a nine-story building consisting of inpatient and outpatient areas, 296 licensed beds, including

FIGURE 3. The Neighborhood Surrounding the New CHP and its Relationship to the Clinical, Research, and Office Buildings. (Children's Hospital of Pittsburgh of UPMC 2007b)

the critical care unit, pediatric intensive care unit, cardiac intensive care unit, and neonatal intensive care unit. The hospital also has a surgical suite with thirteen operating rooms (ORs), of which six contain minimally invasive equipment.

The design of the hospital was guided by the following principles (Children's Hospital of Pittsburgh of UPMC 2007a). The process used to identify the principles and then translate them into design attributes was accomplished using a novel approach which will be discussed later in this paper.

- Family-centered care: Private rooms with sleeping space for parents and a desk with internet access, a chapel, library, business center, sibling center, laundry facilities, and playrooms;
- Healing garden and adjacent atrium: For personal downtime, able to feature movies and group activities;
- Quiet and calm environment: To reduce stress and promote healing. Specific details and materials were created in order to minimize noise. Staff and consult rooms were strategically spaced to minimize sound and promote privacy. Personal communications are used, instead of overhead paging;
- Patient safety and quality: Reflected in private patient rooms that lower infection rates and increase privacy. Surgical services are all located on one floor and specialty services are located close to the associated laboratories; and,
- Integrated Digital Technology: Site-wide secure wireless data network; uninterrupted power services; cell phone friendly campus; patient tracking and child abduction system; centralized electronic records; automated medication control and dispensing systems; online access for diagnostic images; visitor-friendly environment.

Green Attributes: The new CHP is pursuing "certified" certification under the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system. Some of the building's features include:

- Reduced heat island effect and light pollution;
- Water efficient landscaping and recycling of water;
- Key building materials have high recycled content, are purchased locally or regionally, and emit low to no volatile organic compounds;
- The air filtration system ensures high-quality indoor air, and despite the hospital's large floor plate, the design maximizes daylight and views;
- The healing garden is a prominent feature, for which CHP is attempting to achieve an innovation credit (see Figure 4); and,
- CHP is developing educational programs and materials to teach staff how to inhabit and work in the building to maximize the benefits of their green environment.

FIGURE 4. Healing Garden, CHP. (Rendering by Astorino)

Penn State Hershey Children's Hospital

The Penn State Children's Hospital is located in Hershey, Pennsylvania. It currently occupies a floor of the Hershey Medical Center that serves central Pennsylvania and includes the Penn State College of Medicine. The proposed new seven-story Children's Hospital and adjacent Cancer Institute (which is currently under construction) will also include a new main public entrance and "front door" to the entire hospital. The conceptual design of the hospital was developed through business case studies, interviews with various user groups, and visits to other children's hospitals, and presentations from children's hospital design consultants.

The Children's Hospital will be approximately 323,500 s.f. with spaces for hemotology/oncology, medical and surgery beds, neonatal intensive care units, teaching space, pediatric intensive care units and spaces for amenities, offices, and cardiovascular clinical space. After initial programming, scope was added including operating rooms, pharmacy, mechanical space, and labor and delivery space. Additional refining of the scope was needed to reconcile the estimated cost of the project at $360 million with the target cost of $270 million. In the end the facility includes 105 pediatric beds (54 medical/surgery and 51 pediatric intensive care and intermediate care units) and 49 neonatal intensive care unit beds.

As the Children's Hospital is tying in to the existing Hershey Medical Center facilities, the project is subject to Infection Control Risk Assessment (ICRA) requirements that dictate how areas of the center are to be monitored and kept contaminant-free during the course of construction. These requirements are particularly stringent.

Green Attributes: One of the goals of the project is to achieve LEED certification which was driven by a Penn State mandate that all new buildings achieve this basic level of certification. This directive stems from the University's initiative to reduce building energy use and life cycle operational costs. Since this was a goal from the beginning, all parties involved were aware of this requirement. In addition to energy efficiency, the University is also concerned with improving the indoor environmental quality for the critical role that it plays in clinical outcomes, so many of the LEED credits pursued in this facility are concerned with a healthy indoor experience.

While CHP and Penn State are both creating green children's hospitals, the decision to green the facilities are diverse. As will be discussed in the following sections, CHP's decision to pursue a green facility was championed by key individuals; conversely, Penn State's Children's Hospital green decision was made in part from a mandate. Since the projects are at different stages, the Penn State project may yet encounter challenges similar to those at CHP that may impact greening scenarios and budget reconciliations.

DATA COLLECTION

Process Mapping

Process mapping is a hierarchical method that visually illustrates how a product, process, or transaction occurs. Process mapping is a commonly used tool within companies to support efforts such as Six Sigma, total quality management, and balanced score cards. The primary purpose of process mapping is to visually describe and understand a process, along with identifying potential barriers or opportunities. The process mapping protocol is adopted from previous research on the sustainable building delivery process (Lapinski 2006). A modeling approach was used to map the project delivery process, i.e., master planning, programming, design, procurement, and construction. These maps provide an annotated graphical representation of various levels of detail. For example, a building project's Level 1 may describe the high-level stages of a project (master planning, programming, design, etc.). Level 2 delves deeper into each of the phases, such as "design," which can be further disaggregated into schematic design, design development, and construction documents. The maps can be used to identify value adding versus non-value adding steps. A value added step in a building design process map is one that contributes to the end goal of final drawings or a final construction project. A non-value added process, such as repeated budget reconciliation, does not explicitly contribute to the final set of drawings or construction project. Microsoft Visio was used to create the process maps herein. While not illustrated herein, the detailed vertical axis (or swim lanes) was broken down by major stakeholder; e.g., owner, architect, subcontractor, etc.

Once created and validated by case study project personnel, the process maps were analyzed. This analysis served four functions. The first was to clearly understand the sequence of events that made up the delivery process and the interaction between project team members. The second was to understand when key decisions related to greening or LEED certification occurred throughout the process. The third was to identify activities or sequences of activities that either facilitated or reduced the effectiveness of implementing LEED. Finally, the fourth was to allow the researchers to compare the process maps of different children's hospital projects. The two projects are at different stages of development as reflected in the process maps. For CHP, the process map depicts the order of occurrence (beginning with master planning and programming and ending with construction documents) while highlighting major issues, including greening and site changes. For Penn State's Children's Hospital, the process map focuses on programming and green issues.

Process Map—Children's Hospital of Pittsburgh of UPMC

Master Planning and Programming. CHP's design process map is shown in Figure 5. In 1997, the design process started with hiring the architectural engineer to initially assist CHP with site selection with respect to master planning, budgeting, and programming. The architectural engineer conducted a study and found that $187 M was required for renovation; and this estimate only met 70% of CHP's expectations. An estimate for a new hospital project meeting 100% of CHP's goals was $250M to $275M in an effort to reach all of the hospital's expectations. CHP decided to pursue moving from its existing site to a new location. Four sites were closely investigated, all being located within the same community as the existing CHP. It is important to note that during initial site selection phase, CHP was an independent healthcare system and not a part of UPMC. Merger discussions with UPMC did not start until around 1999.

Schematic Design—Montefiore Site. From 2000 to 2001, UPMC offered CHP an existing hospital, known as the Montefiore site as a proposed location for the new CHP. CHP accepted the offer, and the architectural and engineering firm began the design for the new CHP at the Montefiore site, which was adjacent to CHP's existing Oakland site. A construction manager was hired to assist in programming and budgeting, and demolition began. As merger discussions continued, both CHP and UPMC had concerns regarding the impacts of construction on traffic and hospital operations disruption in Oakland. The official merger occurred in the third quarter of 2001, which was additional motivation for seeking an alternative site.

Site Change—Programming. During this transitional period while Astorino was working on the design for the Montefiore site, St. Francis Health Care System closed in 2002, and UPMC purchased the site. UPMC then directed the architectural and engineering firm to start a new master plan for CHP on the former St. Francis site, known as the Lawrenceville campus. The architectural and engineering firm along with an outside consulting firm applied an elicitation process known as the Zaltman Metaphor Elicitation Technique (ZMET) to guide and solidify programming efforts; however, this did not occur concurrently as ZMET was used after several months of design.

ZMET. ZMET was used in conjunction with traditional programming techniques because while the design team's experience, client programmatic needs assessments, interviews, and pre-design surveys provide insight in determining essential physical attributes, they are not fully capable of capturing users' emotional, intellectual, or experiential expectations and needs. ZMET is grounded in multidisciplinary sciences, including clinical psychology, anthropology, linguistics, cognitive neuroscience, and sociology; and it uses different means to capture information with an emphasis on visual images, metaphors, and emotions that are usually missed by traditional focus groups or surveys. ZMET is based on the premise that 95% of thought occurs in the unconscious mind. It is the first patented marketing research technique in the United States. Although ZMET has been in use for over a decade and was used for market research for financial services, cars, political candidates, and the arts, the CHP project

was the first architectural design project in which ZMET was applied (Christensen 2002; Zaltman 1995; Zaltman 1997).

Astorino and consulting firms conducted a total of 29 interviews with patients, parents, and hospital medical and administrative staff. About one week prior to interviews, participants were asked to collect some images that they think best described their current and ideal CHP experiences. During the interviews, with the help of a graphic designer, participants created a montage of these images. These metaphoric images and their interpretations conveyed a wealth of information about the respondents' underlying needs. As a part of results, the *ideal* hospital was reported to be a *transformative* experience providing "a sense of renewal." In addition to the main metaphor of "Transformation" there were three more deep metaphors, or "Key Domains":

- Control: Patients', families', and hospital staffs' need for control over their life and environment;
- Energy: The need for energy from all sources to give people hope they need to make it through their hospital journey; and,
- Connection: The need to connect with the "inside" and "outside" world.

Deep Design Filter (DDF) is a tool to translate these metaphors uncovered by ZMET into design solutions by mapping all issues or relevant dimensions (Astorino 2003). The design team later translated these relevant dimensions into a series of design objectives. The main façade design was changed from a façade that was designed to complement the context of the surrounding facility to a façade with vibrant colors, forms, and shapes that are more dynamic and appealing to the hospital users. For example, the ZMET and DDF processes showed that "energy" is as important for parents and hospital staff as it is for patients. Therefore, the design team decided to add more lounges, a fitness center, and the Healing Garden to help all hospital users recharge themselves.

Green Issues. During the programming and early design phases of the new CHP in Lawrenceville, sustainable design concepts were introduced by the green champions, namely, the CEO of CHP, the Executive Director of the Green Building Alliance, a Pittsburgh not-for-profit organization, and a principal of the architectural and engineering firm. The green champions adopted the view that sustainable design is the responsible decision—socially, environmentally, and financially. CHP also recognized that greening the new facility could benefit the local economy due to the use of local materials. CHP, the designers, and the contractor evaluated the greening costs and decided to pursue LEED Certified for the Clinical Services Building (CSB), and LEED Silver for the new research building.

Schematic Design and Construction Documents. During 2003, design was underway for many of the buildings located on the Lawrenceville campus. The project team began a value engineering (VE) process to reconcile the program and budget. The hospital (CSB) was reduced from ten to nine stories due to budget constraints, introducing significant design changes. However, green features such as the healing garden were retained through the VE process because they had clearly been identified as supporting the goals of the project team. Due to considerable budget escalations and unresolved VE decisions, the entire design and construction stopped in mid-2004. Because the budget number was rising and costs were soft, UPMC decided to stop design and construction and move away from the original fast-track project delivery to design-bid-build (DBB). UPMC believed DBB would provide them with a solid cost; this decision led to the selection of a new general contractor to replace the previous construction manager. Because of the issues associated with cost, program, and budget, the distinction between schematic design and design development was fairly fluid and iterative; therefore, a distinction was not explicitly made in the process map. Construction documents continued to be developed, and construction is expected to be completed in 2009.

Process Map—Children's Hospital for the Hershey Medical Center

The notion of building a separate Children's Hospital for the Hershey Medical Center began over ten years ago. The process map of Hershey's Children's Hospital is shown in Figure 6. In 2002, Penn State updated their master plan for the Hershey Medical Center/Penn State College of Medicine Campus. Part of this master plan update included two high

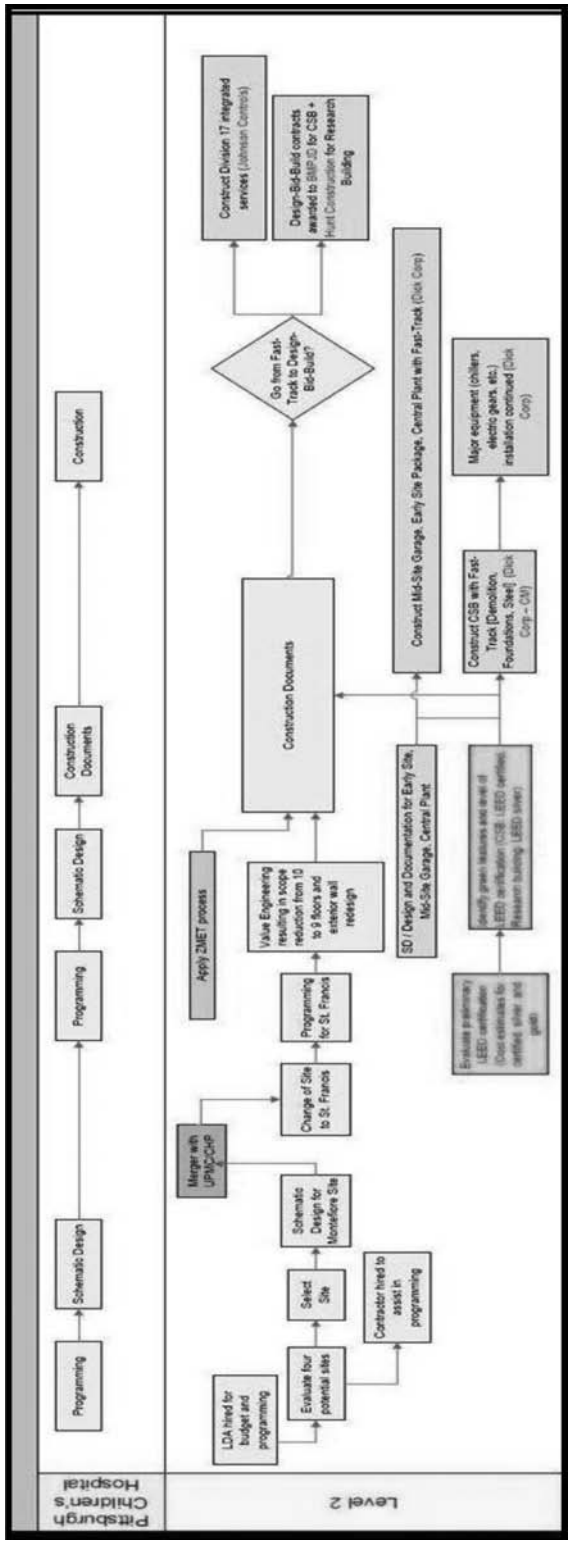
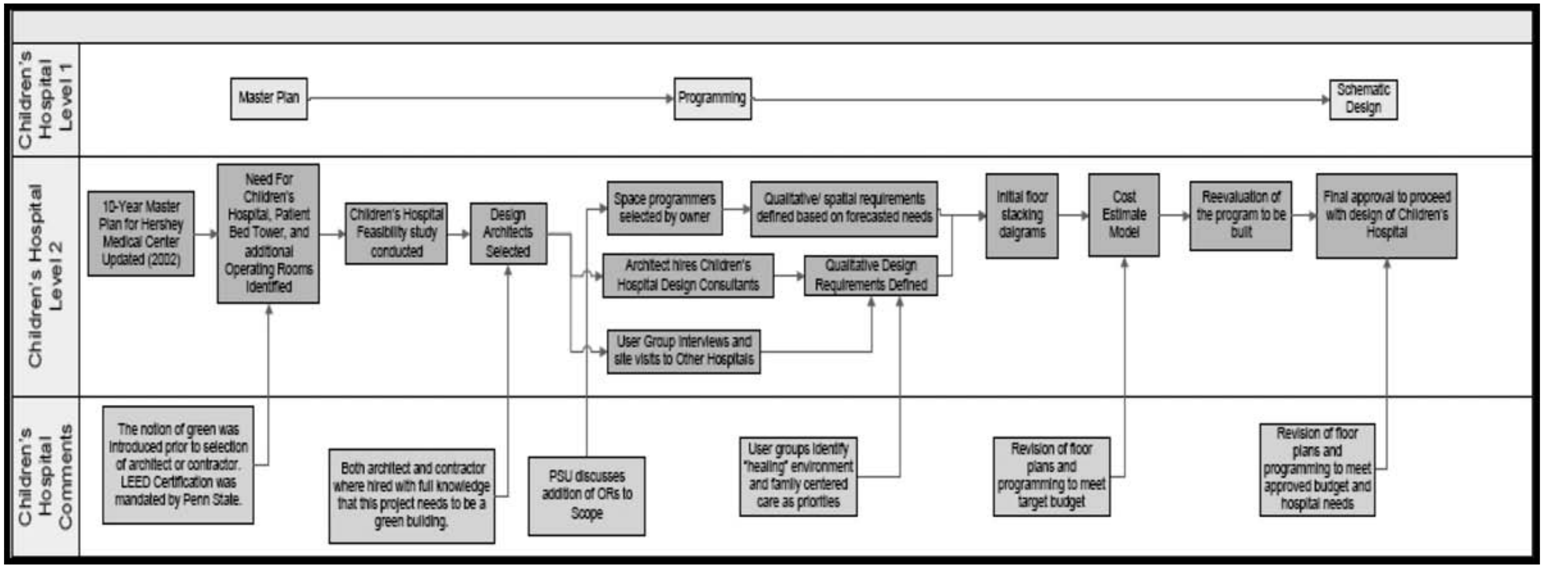


FIGURE 5. Children's Hospital of Pittsburgh of UPMC—Design Process Map.

FIGURE 6. Children's Hospital for the Hershey Medical Center—Design Process Map.



profile buildings that would serve as the new face and main entrance to the Hospital: a proposed Cancer Institute and Children's Hospital. During the Fall of 2005 and Spring of 2006, user groups from different departments of the existing Children's Hospital were assembled to begin the process of defining the qualitative and quantitative requirements for the proposed new hospital. Planning architects were contracted to help with this process. In addition, Penn State hired a well-known healthcare architect to take on the design. The architect in turn hired a children's hospital design consultant to present to the user groups other children's hospital designs from around the U.S. The user groups also took site visits to see other recently constructed children's hospitals such as Vanderbilt and Morgan Stanley Children's Hospital.

Programming

The user groups meetings, site visits, and consultants developed the basis for determining how much space various departments would need in the future. These department areas were vetted against other needs of the hospital and used by the healthcare architects to plan the footprint and space layouts for each floor of the proposed new children's hospital. In addition, the qualitative requirements stressed patient- and family-centered care, healthy environments designed to ensure the highest levels of quality and safety, and design for flexibility, adaptability, and efficient provision of care. Since the healthcare architect is currently working with the contractor employed together on the Cancer Institute, the contractor also provided assistance in creating a cost model and initial estimate for the proposed children's hospital which was used to help refine the scope.

Green Issues. As noted earlier, the project is to achieve LEED certification, a goal that has largely been driven by a Penn State mandate that all new buildings achieve this basic level of certification. In terms of team selection process, the same firms working on the early design of the Children's Hospital have also been working on the Cancer Institute which is currently under construction. In terms of the dynamics of the project team, the owner has driven many of the sustainability-related innovations in that project. These include an advanced infection control risk assessment program, early involvement of a commissioning agent, and consideration for how to pursue Green Guide for Healthcare Operations credits.

The process maps were developed to accurately reflect the current stage of project progress for each project. For CHP, the project is near completion, but the Penn State project is at a considerably earlier stage. Hence, the scope of the conclusions from the process maps is constrained by the current status of each project.

DATA ANALYSIS

Through a comparative analysis the researchers can identify similarities and differences in the design processes. These similarities and differences can be studied to determine if they are site specific (Pittsburgh vs. Hershey), design specific, project delivery method specific (fast track, design-bid-build, etc.), or even specific to the greening efforts (including certification level sought e.g., Platinum, Gold, Silver, or Certified). Without the process maps, this type of detailed comparative analysis would be very difficult to perform.

Analysis and Synthesis of Greening Achievements

Since CHP is in construction and Hershey is in the design development phase, it was not possible to perform a complete side-by-side comparison using the process maps for each case. Instead, the two case studies are compared to findings from Lapinski et al.'s study (2006). A summary of the comparisons is shown in Table 1.

Early evaluation and adoption of environmental considerations. While both case studies had early green involvement, the mechanisms and people were different. For CHP, the owner, a local green building advocacy group, and the lead engineer championed the green pursuit. The green efforts were not introduced during the design for the initial site but were introduced early during the design for the final site. For Penn State, three factors influenced early greening efforts: the campus-wide mandate, performance criteria for the project team during the proposal stage, and a project champion (the owner's representative).

TABLE 1. Green Comparisons—Two Case Studies with Lapinski et al. (2006).

Green Strategy (Lapinski 2006)	Children's Hospital of Pittsburgh of UPMC	Penn State Children's Hospital
1. Early evaluation and adoption of environmental considerations	• Owner was the green champion • Green introduced at initial design process for final site selection.	• Owner mandated LEED from the beginning. • Project team hired with expectation of meeting minimum LEED certification. • Owner's representative championed LEED and GGHC.
2. Business case imperatives—aligning sustainability with the business case	• Green was a part of the hospitals' overall vision.	• Case made for infection control, but not for green in general. • Penn State LEED mandate based assumption that LEED aligns with business case to reduce life-cycle costs.
3. Sustainable compatibility—selection of green features that naturally align with the other project goals	• Green features aligned with project goals, e.g. healing garden (family centered care and patient quality), and systems integration (technological sophistication)	• Focused on indoor environmental quality that corresponds with healthcare building codes • Targeted energy reduction in alignment with reducing energy usage and associated costs.
4. Early selection of team members with sustainable experience.	• Architectural firm experienced in green projects, but some individuals had limited experience. • Owner not experienced with LEED.	• Project team experienced with LEED. • Individuals had limited experience.
5. Alignment of team member goals with project goals.	• LEED was *one* project team goal, among others. • LEED did not guide the design, but was treated as another goal. • Conversely, ZMET and DDF were approaches that did guide the design that were innovative and successful.	• LEED is being treated as extra and not really aligned with project goals

Aligning sustainability with the business case. Administrators at CHP believe that greening is a part of their commitment to a patient's well-being, and greening is not a decision but a part of their vision. Therefore, greening aligns with not only the business case, but also the hospital's overall philosophy on patient care. Penn State has made an institutional commitment to decrease the lifecycle energy and maintenance costs of their facilities. As a result, the University has mandated that all new construction meet LEED "Certified" level. For the Children's Hospital, they have expanded this commitment and will also be pursuing opportunities to be a pilot project for the new LEED for Health Care Standards.

Sustainable compatibility—selection of green features that naturally align with the other project goals. CHP aligned green features with the projects goals; for example, the healing garden and atrium are green design features that also align with the project goals of family-centered care. Three of the major innovations that the PSCH project team is pursuing involve development of extensive and proactive ICRA (Infection Control Risk Assessment) and commissioning plans. In addition, the project team has closely integrated the design, construction, and occupancy so that a holistic approach to sustainability can be pursued based on the guidelines set out by the Operations section of the Green Guide for Healthcare.

Early selection of team members with sustainable experience. While CHP selected an architectural firm with green experience, the basis of selection was not solely on the firm's green experience, but other factors as well, such as the firm's local and hospital design experience. Astorino had green design experience, but not green *hospital* design experience. All project team members were selected with full knowledge of the need for this project to achieve LEED certification. Members of the project team have already collaborated on the design and construction of the adjacent Cancer Institute which is also pursuing LEED Certification and therefore have not only general past experience with green healthcare facilities, but also have experience as a team.

Alignment of team member goals with project goals. LEED, in the CHP case study, was one of several project team goals. However, LEED, unlike ZMET, did not guide the design. ZMET and the DDF was an approach that did guide the design that was innovative and successful. Because members of the PSCH project team have worked together on past projects, they have had the opportunity to reconcile their differing individual goals and focus more on the common project goals. They also have the opportunity to build on the knowledge that was developed and the lessons that were learned from past projects.

Lessons Learned. In addition to the information gleaned from the comparative analysis, a set of lessons learned and best practices were developed to further document the design processes and assist others during the design of their own green children's hospital. All projects are ultimately unique, but documenting lessons learned provides an important record of experiences, which is especially important for green children's hospitals. While most of the highlighted areas are directly related to sustainability aspects, some points are related to the general design process, independent of environmentally preferable practices.

Data System Integration. Hospitals have extremely complex data systems. Integrating the systems can save not only initial costs, but also future costs due to maintenance and upgrades. For CHP, the data systems are fully integrated, and this goal was achieved by awarding the entire data system (Division 17) to a contracting firm who was responsible for both design and installation. This decision turned 50 separate data systems into three main backbones allowing the owner better control and operation. During the process mapping charrette, Astorino, the architectural and engineering firm indicated that having one source responsible for all the components was a key element towards a successful product, especially a hospital project. The project team is pursuing a LEED Design Excellence point for the data systems integration.

External Factors and Design Efficiency. As one can see from the process map for CHP, external factors impacted the efficiency of the design process. External factors include site selection decisions, mergers and acquisitions, strategic market analyses, and greening decisions. In the case of CHP, the initial site selected changed, resulting in redesign and reprogramming. The merger between CHP and UPMC affected the site location, and ultimately the decision to change project delivery methods from fast-tracking to design-bid-build. Changing the project delivery method affects the manner in which the designer's documents are presented, formatted, and level of detail.

ZMET and the Deep Design Filter (DDF). Including ZMET in the design process enhanced the design, built consensus, maintained design integrity, and facilitated fundraising. During the process mapping meeting, the designers indicated that ZMET and DDF helped to inform both the owner and the designer of the true meaning behind the design. ZMET and DDF were used in addition to traditional programming efforts. The transitional site selection period allowed the designers to step back and reflect on the design. Astorino conducted national site visits of children's hospitals to understand the current state of design and obtain ideas. Many of the children's hospitals that Astorino visited had "applied" designs with literal child-like murals. Astornio and CHP believed that the facility should appeal to children without displaying an obvious theme. Using ZMET allowed Astorino to create an intrinsic (and metaphor-driven) design that appealed

to all of the hospital's constituents without creating an extrinsic applied design. ZMET helped Astorino to build consensus around the hospital design, both with decision makers and internal staff. The Astorino architects were able to focus on principal areas of concern elicited through ZMET, which limited redesign and guessing the client's preferences. While using ZMET led to a redesign of the main façade, the overall design was also enhanced. Additionally, during budget reconciliation, Astorino was able to inform their client about the ramifications if certain changes were made; for example, if you eliminate "X", then the "Energy" theme is affected. CHP designed the inpatient floors so that patient rooms are analogous to homes, corridors represent streets, nurse stations represent small establishments, and the atrium stands for the city hall and town square. The Transformation theme is illustrated through the main entrance corridor via an abstract transformational butterfly. The ZMET process led to brighter colors and distinct shapes especially reflected on the building facade. ZMET and green aspects of the design were running in parallel and were not necessarily connected. If there was a connection, ZMET would have influenced the green design.

Greening—Experience and Influence. CHP essentially went through two design processes. During the first design, greening was not introduced, but during the second design greening was introduced in the schematic design phase. LEED was relatively new, and the designer was not sure if a hospital could get certified. Additionally, the designer tried to figure out if the entire "campus" could attain certification. The owner decided to pursue LEED certification for the hospital, and the decision process took about one year. A state grant of $5M allowed the research building to pursue LEED silver, which was introduced early in the design process. The decision to pursue LEED for the hospital did necessitate a significant amount of rework, mainly due to identifying the appropriate points and energy modeling. As a hospital, codes and guidelines that influenced lighting, HVAC, and windows in patient rooms, drove the design, instead of LEED driving the design. The designer stated that the greening process was not unusual, and just one aspect of good design practice. It was important for the designer to make sure the building worked, rather than chasing points. The largest effort from the designer regarding the LEED process was for calculating points and changing specifications.

CONCLUSION

Developing, refining, and implementing a successful green design and construction process for hospital facilities could improve the health and welfare of patients, increase the effectiveness of doctors, nurses, and other hospital staff, and reduce the life cycle costs of these facilities. Analysis of the design process of two similar and recent hospital projects has identified several key areas that project teams should focus on to facilitate the implementation of green design in hospitals from both a practical and a theoretical perspective. Having clear project team leadership and experience on green design early in the process yielded good results for these projects. They are both on a path towards their goal of LEED certification. In many cases, achieving LEED certification was aligned with good hospital design practice, the owner's aspirations, and other project goals, such as providing an indoor environment conducive to patient recovery. Having a tool such as ZMET helped the CHP design team identify, develop, and clearly substantiate programmatic and aesthetic attributes of the design. Although ZMET was not used explicitly for green design, theoretically, the same or a similar approach could be used to elicit relevant stakeholder expectations and requirements specifically in this area. Finally, in these projects, the LEED green building rating system has provided substantial assistance to the project team in identifying green design features and performance goals. LEED has not provided a clear approach to integrating the LEED process with the design and construction process, and therefore, in both cases, LEED has remained somewhat independent of and secondary to the hospital's design development and execution.

Although naturally much of the analysis focused on the sustainability aspects of successful green children's hospitals, the research team concluded that there were other significant aspects that were related to general design processes. The aspects included the importance of data system integration to support the complex data systems requirements in a hospital; the various external factors such as site selection and

project delivery methods; the use of elicitation techniques ZMET and DDF to solicit design input from project stakeholders; and the use of LEED to influence the design.

As an initial step, research on these two case studies has yielded preliminary findings that may contribute to developing guidelines for effectively executing the green hospital facility delivery process. Additional research into the design of green hospitals is required to develop a broader and more robust set of best practices that can be reliably used to inform and guide the green hospital facility design and construction process. This area is prime for further analysis and development.

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