

Green Healthcare Facilities: Improving the Building Delivery Process of Children's Hospitals

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Abstract:

Healthcare is one of the most significant built environment markets today with over 120,000 buildings in the United States. Moreover, in the next 15 years, an estimated \$300 billion will be spent on hospital construction across the United States; therefore, there is a great opportunity for research and improvements to be made in this area. Increasing research in the life sciences is showing the built environment impacts healthcare, particularly the health, safety and well-being of patients and staff. Children's hospitals are the most specialized centers for care, providing care for children with complex and rare conditions and they are therefore amongst the most complex types of facilities to design, construct and operate. This paper outlines the findings from three children's hospitals with different levels of sustainability in regards to the project delivery process, greening strategies and lean principles. This paper will provide an understanding of the building delivery process in green children's hospitals, starting from programming, through design, construction, operations and maintenance pointing out key factors that are most important in the delivery of a green children's hospital. Using the Dell Children's Hospital of Austin, the Children's Hospital of Pittsburgh and the Hershey Medical Center Children's Hospital, this paper will show how coupling lean and green principles can make healthcare facilities not only efficient, but healthful places for treatment.

Keywords:

Children's hospitals; delivery processes; healthcare design and construction; sustainability

1. Introduction

The continued growth of the healthcare industry provides an important opportunity to dramatically impact how the built environment affects human health and well-being. In the U.S., healthcare is a \$1.4 trillion industry, accounting for 13.2 % of the entire U.S. gross domestic product (GDP), with projected growth to \$2.8 trillion, or 17 % of GDP by 2010 (Frampton 2003), being the world's largest. Healthcare is one of the most significant built environment markets today with over 120,000 buildings in the United States. Moreover, in the next 15 years, an estimated \$300 billion will be spent on hospital construction across the United States (Ulrich 2004).

The built environment has a great impact on healthcare, particularly on the health, safety and well-being of patients and staff (Ulrich 2004). Paramount, of course, is that healthcare facilities are places for treating and healing humans. Unfortunately, however, healthcare

facilities are also responsible for inducing health problems: Hospital-acquired infections are one of the leading causes of death in the U.S., killing more people than AIDS, cancer or automobile accidents (Institute of Medicine 2001). A promising area of research and action to combat the stressors that affect patient and worker health and well-being has been the use of “green” or “environmental” strategies. Green healthcare also offers benefit of reducing operating costs, energy consumption and water use. Productivity in green buildings is increased due to better occupant health and decreased absenteeism. When workers are less stressed, less congested, they are more likely to be more productive. Research has found that 16-37 million cases of colds and flu could be avoided by improving indoor environmental quality, resulting in \$60 \$14 billion annual savings in the US, and the sick building syndrome could be reduced by 20-50 % resulting in \$10-\$30 billion savings in the US (Fisk 2002). Children’s hospitals are the most specialized centers for care, providing care for children with complex and rare conditions. Therefore, they are amongst the most complex types of facilities to design and construct amongst complex facilities.

2. Objective

There are significant benefits in incorporating sustainable and lean principles in the construction industry, but at the moment there are major challenges to incorporating these strategies in the healthcare building industry, more so than the commercial and residential building industry. Children’s hospitals are a type of healthcare facilities where the consequences of poor building design, construction and operations have the potential to affect the lives and health of the children and staff. In short, they are the most complex facilities to procure, design and construct. To this end, this paper seeks to provide an understanding of the building delivery process and the most important factors in green children’s hospitals, starting from programming, through design, construction, operations and maintenance. An emphasis is placed on how the delivery process, the stakeholders present in each project and also the project environment affect the final product. Understanding the delivery process is the first and most important step in facilitating the construction of more green facilities, and in reducing the challenges that come with it at the moment.

3. Background

Unlike regular hospitals, in children’s hospitals planners and designers are challenged to accommodate adults and also children of all ages. Children’s hospitals are one of the most challenging types of buildings to design and construct. Hospitals must be calming environments for the children and their families in order to aid the healing process.

Children are a unique end-user, especially in an environment such as healthcare, which supports their healing. Designers and constructors have to create children’s hospitals that are playful and provide a supportive environment for the children, while performing technically and functionally. Given the extra complexities and needs in children’s hospitals, a research focus on the design and construction of children’s hospitals is likely to have a major impact on the delivery of all healthcare facilities. The patient-friendly successes in children’s hospitals will influence all other healthcare facilities, and therefore set the standard for the next generation of hospitals and buildings in general. This paper focuses on the construction of green, LEED certified children’s hospitals, with a focus on three case studies. The Leadership in Energy and Environmental Design (LEED) Green Building Rating System,

developed by the U.S. Green Building Council, provides a suite of standards for environmentally sustainable construction.

4. Research Methodology

To investigate this problem, this research will use detailed case study research to investigate the differences that exist in the building delivery processes for each of a LEED Platinum, the Dell Children’s Hospital of Austin and two LEED certified, Children’s Hospital of Pittsburgh and Hershey Children’s Hospital. The case studies provide a wide range of data, and the comparison between two moderate and a highly green project will be beneficial for the design and construction industry.

4.1 Case Studies

4.1.1 The Dell Children’s Hospital of Austin

The Dell Children’s Medical Center of Central Texas is located on 32 acres of the old Robert Mueller Municipal Airport. It is four-stories, containing approximately 480,000 square feet. The hospital also has a Healing Garden, totaling 3 acres, that is located on the south side. The previous Children’s Hospital of Austin located downtown Austin could not be extended; therefore the new facility took into consideration the planning for future generations, creating an environment that can grow through time (Dell 2007). The project was fast-track, being on an aggressive 27 month schedule, and it opened in June 2007. The hospital is on track for being LEED Platinum, which will be the first LEED Platinum hospital in the nation. The children’s hospital uses sustainable building practices as seen in Table 1 (Dell 2007):

Table 1: Sustainable Building Practices at Dell

Sustainable site planning	The site is part of the City of Austin’s Smart Growth Initiative
Water Conservation	The facility contains a rainwater collection system and is xeriscaped for water efficiency
Energy Efficiency & Energy Plant on site	Heat recovery systems and high efficiency equipment Seton is building a District Energy Plant on site which provides power and chilled water and steam to the hospital and the surrounding areas.
Conservation of Materials and Resources	Use of Recycled Materials and low VOC Minimize construction waste
Indoor Environmental Quality	Optimize natural daylight, eliminate airborne pollutants

The hospital is located in a brownfield development, adding to the list of LEED points. The runway of the Muller airport was demolished and recycled. 35,000 tons of asphalt were used as a base for the parking lots. Moreover, 41,000 cubic yards of high volume fly-ash concrete were used for the foundation and walls which added to the project’s LEED points. About 75% of all waste is being recycled. The roof of the facility is TPO single-membrane with standing-seam metal in a few areas. The roof reflects sunlight instead of absorbing radiant energy. Other LEED points achieved in the sustainable site section include credit for urban redevelopment and a rain and ground-water collection system for irrigation. Additional features include carbon dioxide monitoring and sealing the ends of the ductwork during

construction. Water-efficiency points were earned by using low-flow toilets and fixtures and native plants in the landscaping. The construction cost for the facility is estimated to be around \$110,000,000, while the 35,500 combined cooling-heating power plant is estimated to have a construction cost of approximately \$18,000,000.

The decision to go green and pursue LEED Platinum has been aligned with the corporate mission from the start of the project. Austin's Green Initiative is another reason for going green. The owner also looked in depth at the life-cycle cost analysis and it was discovered that the facility would have a 5.9 year payback. Lastly, one of the factors for pursuing green was to "improve the quality of life for all".

4.1.2 Children's Hospital of Pittsburgh

The New Children's Hospital of Pittsburgh is located in Pittsburgh's Lawrenceville neighborhood on 10 acres -1.5 million square feet of usable space. The actual hospital is 900,000 square feet with 262 beds. The cost of the hospital is approximated at \$555million. The hospital is under construction on the urban campus of the former hospital, which will benefit the new hospital by using some of the assets of the previous hospital.(Pittsburgh 2007)

The hospital has been designed with input from physicians, nurses and families in order to inspire transformation to all who pass the doors. The hospital has been designed with the children in mind from the very beginning and it is committed to family centered care. The hospital is on track to be LEED certified. The hospital is grounded on five principles: patient safety and quality, family centered care, technological sophistication, environmental sustainability and quiet building:

4.1.3 Penn State Hershey Children's Hospital

Penn State Children's Hospital is part of the Penn State Medical Center, the only medical school and university hospital in Pennsylvania located outside the urban areas of Philadelphia and Pittsburgh. The present Penn State Children's Hospital is the only children's hospital in central Pennsylvania and has the region's only LEVEL III, state -of the art neonatal intensive care unit (NICU). The hospital is well-known for the following specialties: neonatal care, pediatric oncology, pediatric cardiology, pediatric surgery and pediatric trauma.

The new Children's Hospital will be approximately 323,500 square-feet. The hospital will have a total cost well in excess of approximately \$270 million dollars and is seeking to raise \$65 million in philanthropy.(Hershey 2007). The proposed new seven-story Children's Hospital and adjacent Cancer Institute (which is currently under construction) will make up the new face and main entrance to the entire hospital. The conceptual design of the hospital was developed through business case studies, interviews with various user groups, visits to other children's. All new construction Penn State facilities are mandated to be LEED certified and this will be one of the.

4.2 Data Collected

A comparative case study approach is used to compare certain features of the hospitals such as the LEED level achieved and the reasoning behind going after the specific points, incorporation of a "charette" system, sequence and timeline of each step in the delivery process, owner and other stakeholders involvement, costs associated with each step in the

delivery process and percentage of total cost, life-cycle cost analysis if available, an evaluation of the green design feature for each hospital, integration of technical systems, satisfaction of users with green features.

Data is collected through the following methods: 1) A series of meetings, phone and email **interviews** with the stakeholders in each project. Most of the data will be collected using this method. 2) **Project materials**: design documents, meeting minutes, bidding documents obtained from the stakeholders. These materials will be primarily used to obtain an overview of the case studies and to follow their development.

After an extensive literature review and recommendations from industry representatives and academic researchers, the issues identified in Table 1 are selected to be most important in the delivery of a successful green, LEED certified building. The stakeholders for each project, owner’s representative, architecture firm and construction manager, were interviewed based on the issues below in Table 2:

Table 2: Data Collection Tool

Key green factors	Specific attributes	Data to be collected
<i>Early adoption of green</i>	This enables a more clear understanding of project scope requirements and project needs	When was the notion of green first introduced? At what point in the delivery
	Saves project rework due to accurate project bids and costs	Who proposed the notion of green? (owner, architect, design-builder)
	Saves time for incorporating sustainable objectives later in the project	Was the team trained on these sustainable objectives?
	A sustainability filter can be applied to all decisions	Were green objectives discussed in relation to overall project goals and objectives?
<i>Business case for green initiatives</i>	Project budget aligned with environmental project goals	Was there a business case for going green performed
	Life-cycle cost analysis data to justify operational savings	Is life-cycle analysis data available?
	Payback period for sustainable objectives	What is the payback period for the sustainable aspects and LEED certification?
<i>Owner commitment</i>	Increased commitment from the owner side leads to better project planning and to better cost and schedule performance	Was the owner the green driver of the project? Did the owner introduce the concept of green? Was the owner in charge of educating the rest of the team members?
<i>Architect and CM commitment to green and a consistent approach</i>	Better delivery in regards to green aspects if teams are committed to sustainability.	Are these teams committed to sustainability as one of their core values regardless of owner commitment?
<i>Early team selection/ team experience</i>	bringing the teams together early engages critical process integration and allows system and environmental knowledge to evolve as design begins	Individual experience of team members with healthcare facilities? With green buildings? Previous team experience as a unit? Did the project have a sustainability consultant in the beginning?
<i>LEED certification</i>	Level of certification and break-out of points	Why did you go after the specific points? Which specific points required the most effort?
<i>Energy Modeling</i>	Energy modeling helps optimize the building design and allows the design team to prioritize investments in the strategies that will have the greatest effect on the building's energy use	Who was in charge of energy modeling? What were the costs associated with it? Effort and rework? At what stage in the design were energy simulations used?

4.3 Process Maps

One type of analysis in this research is **process mapping** analysis. After the first wave of data collection was completed, the data was synthesized and process models were created for each case study. The critical processes and events for each children’s hospital are modeled and compared. Process modeling is the critical step in analyzing and understanding the delivery process. A lot of green projects have rework, changes and overproduction as a result of not using the best delivery processes. The Lean and Green process modeling protocol will be used to model each step in the delivery process and convey it in a simple and effective way. Comparisons between the four case studies will be more effective by making everything more transparent through the process models. By using this protocol, wasteful and unnecessary processes can be identified. The timing and sequence of the different activities will be identified in each process model and also which stakeholders were involved in what phases of the projects. To prepare the maps the following protocol will be used (Klotz 2007):

- Level 1: a big picture map to understand the overall delivery process and organization. Interviews with an employee, typically a high-level executive, will be completed in two stages. First stage is to record the main events and processes and a follow-up interview is used to clarify that the draft map represents the interviewee understanding.
- Level 2: focus on each individual process, for example programming stage or design, and interview members in each project who understand best the applicable process.

Microsoft Visio has been used to create the maps. An example from the Hershey Process Map is presented below in Figure 2.

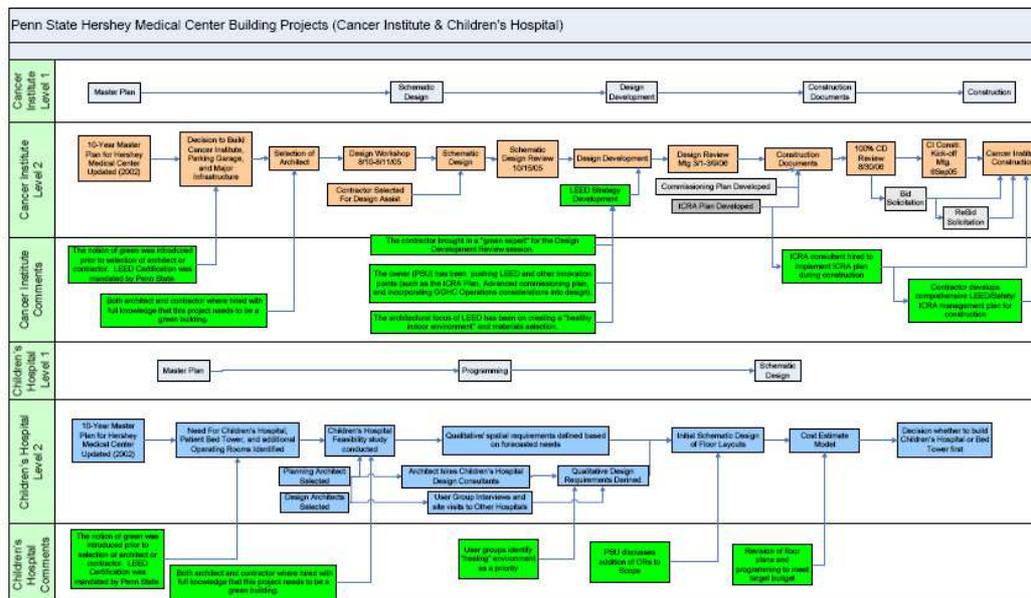


Fig. 2. The Hershey Process Map

The delivery processes for green buildings are different than those for conventional buildings. For example, green projects tend to use a stronger interdisciplinary and integrated approach, complex modeling and analysis, untraditional materials and systems that require

more planning in the early stages of the project delivery process. Green buildings are often perceived as having a higher first cost due to the complexity of materials, systems and building envelopes, although their life-cycle cost is lower (Klotz 2007)

Process modeling is the crucial step in understanding green building delivery processes. A lot of green building processes have a lot of wasteful rework, delays, changes and overproduction due to inappropriate delivery processes. Process waste can undermine sustainable outcomes and limit the business case for sustainability (Lapinki 2005). The process maps for the three children’s hospitals show that they all had a conventional delivery process starting with a master plan followed by programming, schematic design, design development, construction documentation, construction and occupancy and maintenance. The Dell Children’s Hospital of Austin has been a design-bid-build project from the start, while the Children’s Hospital of Pittsburgh had a fast-track construction management at risk delivery system but now is also design-bid-build. The Hershey Children’s Hospital is in the schematic design phase right now, although the master plan was developed in 2002. The delays due to financing in the case of the Hershey project and site selection for the Children’s Hospital of Pittsburgh are examples of situations where specific phases in the delivery process could take longer than expected. The Dell Children’s Hospital followed their strategic plan they set in the beginning and opened in July 2007, while the other hospitals are set to open in 2009 and 2010 specifically. This shows that the commitment for a LEED Platinum project to be completed on time and a commitment to green features is higher in a Platinum project than a LEED certified project.

4.4. Data Analysis

Data analysis consists of categorizing the data collected, examining, tabulating, and recombining the quantitative and qualitative data. The different parts of the delivery process and issues, such as owner commitment, LEED points achieved, will be analyzed and compared between the case studies, and they are considered individual embedded units of analysis. A criterion for analyzing the findings is to look at the patterns, a technique called **pattern-matching analysis**.

The data is analyzed by using different arrays, making a matrix of categories and placing evidence within each category, examining the frequency of certain aspects and events, charettes as an example. The issues in the data collection tool are summarized and analyzed below in Table 3 with discussions for each project.

Table 3: Analysis of Results

<ul style="list-style-type: none"> • <i>Early adoption of green</i>
<p>The notion of green was introduced very early in the programming phases at the Dell Children’s Hospital and similarly at Hershey it is a campus-wide mandate for the Penn State campus. At the Children’s Hospital of Pittsburgh the adoption of green happened in the design phases of the project. An early adoption of green enabled a more clear understanding of the project goals and needs at Dell, and it saved project rework due to accurate project bids. Although LEED certification at the Hershey Children’s Hospital has been mandated from the beginning it has not been a priority for the team yet.</p>
<ul style="list-style-type: none"> • <i>Business case for green initiatives</i>
<p>A business case for infection control was made at the Hershey Children’s Hospital, but not for green in general. The Penn State LEED mandate based assumption that LEED aligns with business case to reduce life-cycle costs. At the Children Hospital of Pittsburgh, sustainability was part of the hospital’s overall vision. The Dell Children’s Hospital of Austin focused on a business case for each initiative from the very beginning of programming. The owner has been the proponent of green on all the projects.</p>
<ul style="list-style-type: none"> • <i>Owner Commitment</i>

<p>For the Dell Children’s Hospital of Austin the owner’s commitment was the most important aspect in the delivery of the LEED Platinum building. The owner never wanted to sacrifice LEED Platinum. They never said it was too difficult or back down from it. Similarly to this, the owner was committed to green as part of the overall vision but not to that extent. In the case of the Hershey Medical Center, the LEED certification is a Penn State mandate.</p>
<ul style="list-style-type: none"> • <i>Architect and contractors commitment to green</i>
<p>Most of the teams are starting their involvement in LEED certified projects and are relatively new to the delivery of green building. The architect for the Dell Children’s Hospital is greening their specifications and promote themselves as green experts. They hope to achieve LEED certification in every project without the owner asking for it.</p>
<ul style="list-style-type: none"> • <i>Early team selection/ team experience</i>
<p>At the Children’s Hospital of Pittsburgh the architectural firm was experienced in green projects, but some individuals had limited experience. At the Hershey Children’s Hospital the project teams had previous experience with LEED, but similarly individuals had limited experience. The owners were not experienced with LEED. At the Dell Children’s Hospital none of the teams had previous experience with LEED, but they were strongly committed to pursuing the LEED Platinum certification and their commitment played an important role in the success of the project. The Dell Children’s Hospital had an experienced sustainability consultant throughout the project.</p>
<ul style="list-style-type: none"> • <i>LEED certification</i>
<p>LEED Certification in the Children’s Hospital of Pittsburgh case study was one of the several project team goals. However, LEED did not guide the design. Penn State has made an institutional commitment to decrease the lifecycle energy and maintenance cost of the facility. As a result, the University has mandated that all new construction meet LEED Certified levels of sustainability. At Dell, the LEED Platinum has guided the design from the beginning and along with patient care has been the top priority for the hospital. All the case studies have focused heavily on the indoor air quality aspect of LEED, due to the nature of the facilities.</p>
<ul style="list-style-type: none"> • <i>Energy Modeling</i>
<p>Both the Children’s Hospital of Pittsburgh and the Hershey Children’s Hospital had the energy modeling performed by the architecture teams, but the Energy and Atmosphere section was not their main focus. In contrast, the Dell Children’s Hospital spent an extensive amount of time and effort on the energy modeling; the energy modeling was performed by an engineering firm. The energy modeling is probably the most important aspect in the achievement of LEED Platinum. Austin energy played an important role in the design and construction of a combined heat and power plant on site which provides all the energy for the hospitals and a few of the surrounding facilities.</p>

5. Conclusions

Increasing the implementation of successful green design and construction processes for healthcare facilities can improve the health of the patients, in this case study the children, increase the productivity of doctors and nurses, and reduce the life cycle cost of the facilities. The analysis of the design and construction process in the three children’s hospitals examined identified several key areas and issues that project teams should focus on to facilitate the implementation of green design in hospitals from both a practical and theoretical perspective. Having a committed leadership that believes from the start in the value of sustainability, adopting green issues from the very beginning, using extensive energy modeling for increased efficiency, transparency, an integrated approach to the project and most importantly an owner that is very committed to green will yield successful results in these projects. Team experience on previous LEED projects also plays a very important role, but as shown in the Dell LEED Platinum project the commitment could be in some cases more important than the experience. Energy modeling and the use of a combined heat and power plant has played a very important role in reducing energy use and achieving LEED Platinum. In the case studies examined, achieving the 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. Finally, the LEED green building rating system has provided substantial assistance to the project team in identifying green design features and performance goals. For the Children’s Hospital of Pittsburgh and the Hershey Children’s Hospital LEED was not fully integrated with the design and construction process, and therefore LEED has remained independent and somewhat

secondary to hospital's design development and construction process. In contrast to that, LEED has been integrated through out the design and construction process and it has been a goal and a priority from the start. Completing a LEED Platinum healthcare facility successfully requires a well integrated design and construction approach, buy-in from every team, owner commitment from the very beginning and a sustainability consultant who can guide the teams through the process and provide expertise on the documentation process.

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