LEAN AND GREEN HEALTHCARE FACILITIES:
IMPROVING THE DELIVERY PROCESS IN CHILDREN’S HOSPITALS

A Thesis in
Architectural Engineering
by
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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. The built environment has a great impact on healthcare, particularly on the health, safety and well-being of patients and staff. Green healthcare offers benefits of improved clinical outcomes, reducing operating costs, energy consumption and water use.

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 research study outlines the findings from four children’s hospitals with different levels of sustainability in regards to the project delivery process, greening strategies, lean principles and key factors that are most important in the delivery process. The key factors investigated are: transparency in relation to green outcomes, owner commitment, early team selection, team experience, early adoption of green, commissioning process, energy modeling and the role of the construction management team in the delivery of a green building. The findings provide a detailed description and analysis of the delivery process for each case study. The results show that certain delivery process attributes vary with the level of sustainability, with the top three attributes being: owner commitment, expertise on sustainable delivery and early timing of sustainable objectives being introduced. Owner commitment has played a very important role, and this outcome leads to intriguing and potentially significant future research on the delivery of green buildings.
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Chapter 1: Introduction

1.1 Background

1.1.1 Greening of Healthcare Facilities

The sheer size and 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. Paramount, of course, is that healthcare facilities are places for repairing 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). These hospital-acquired infections are mostly due to environmental factors. The design and construction of a hospital environment can have detrimental effects on patients and staff. For example, research has shown poor ventilation and indoor air quality are major causes of nosocomial infections. Improper lighting is correlated with patient depression and medication errors. Excessive noise upsets patients and causes increased stress and lack of sleep.
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 in place of manmade solutions. These include natural remedies in place of chemical options, and benign approaches rather than aggressive or dangerous methods where possible. In the built environment, green healthcare uses facilities, materials and practices designed to advance the health of the building occupants, protect the environment, and also be cost-effective by reducing operation and maintenance costs.

The focus on greening the healthcare built environment is rightly placed on evidence-based design. Evidence-based design comes from the recognition that the physical environment can have a measurable effect on the well-being of people, especially in healthcare. The focus on evidence-based design has been crucial to separating fact from fiction in the pursuit of green healthcare facilities. Only scientifically-tested environmental strategies can be claimed as “evidenced-based design.”

Green healthcare also offers benefit of reducing operating costs, energy consumption and water use. These are important given that healthcare facilities use complex equipment to run without cross-contamination and transfer of harmful bacteria that use large amounts of energy as a consequence (Phelps 2005). Hospitals have very high energy uses and energy bills due to the fact that some of their facilities are run 24 hours a day. In addition, the healthcare industry is also one of the most significant consumers of resources and producer of waste, and, therefore, has a large ecological footprint (Frampton 2003). For these reasons, it is also important that healthcare facilities are
constructed, and operated appropriately in order to demonstrate that they are a source of health for our communities.

As the healthcare industry extends its use of green approaches, many benefits are emerging: 1) environmental benefits by polluting less and using less non-renewable resources, 2) health benefits by reducing stress and infection rates, improving comfort and productivity 3) economic benefits by reducing life-cycle costs of the facilities (Ulrich 2004). Most important of these, however, are the benefits that lead to clinical outcomes. When healthcare facilities lead to superior patient and worker health and well-being, then a more effective healthcare system is enabled and healthcare cost-efficiencies can be realized.

There are many opportunities to enhance the benefits of green healthcare, but the strategies to doing so are still very incomplete. In particular, the incorporation of the best green strategies into healthcare facility design, construction and operation remain very challenging.

1.1.2 Children’s Hospitals

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 amongst complex facilities. Moreover, children’s hospitals serve as research centers and promote health protection by addressing issues such as child abuse, child obesity and injury prevention.

There are approximately 250 children’s hospitals in the United States, representing 5% of the total number of hospitals in the US. These hospitals treat more than 3 million
children annually, with a volume of impatient care that has been increasing by more than 10 percent in the past five years. The children receiving care from these hospitals range in age and economic backgrounds (NACHRI 2007).

Most children’s hospitals are not-for-profit corporations. Furthermore, children’s hospitals provide care to all children, regardless of their ability to pay, therefore philanthropy pays an important role in financing. Children’s hospitals receive grants and donations from the government, private organizations and individuals (NACHRI 2007).

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.
1.1.3 Lean and Green Project Delivery in Healthcare

The biggest challenge to furthering green strategies in healthcare facilities is navigating the delivery process of a healthcare project. Healthcare facilities are considered to be one of the most complex project types. It is estimated that a complicated building such as a hospital could involve over two million “yes/no” design decisions (Marberry 1996). Healthcare facilities involve more clients, outside agency reviews, functional issues, codes, rapidly changing technology and other design influences than almost any other building type (Marberry 1996). The **building delivery process** in most healthcare facilities is separated into a number steps. Crucially, these steps are often conducted sequentially and independent of each other, and sometimes over many years.

- Strategic planning
- Scope of specific project
- Selection and organization of the team
- Programming
- Schematic design
- Design Development
- Construction documentation
- Selection of the construction and installation teams and purchasing
- Construction and installation
- Occupancy and maintenance

Green buildings often need to employ additional steps and use sustainable tactics in the delivery process. These include: using a sustainability champion from each stakeholder group to educate the entire project team, describing sustainability goals and
emphasize the roles in getting LEED certified, holding a design charrette with all project
stakeholders, engaging a commissioning agent from the schematic design phase,
enforcing environmental issues during construction also and educating patients and staff
on the green building features and operational requirements. In many projects, teams have
found these requirements add complexity to the delivery process resulting in increased
costs.

In the building industry, many green buildings fail to fulfill their goals due to the
wasteful approaches that are used to design, construct and operate them. A focus on the
whole building delivery process looking at value added activities and waste, facilitates an
opportunity to enhance the building delivery process (Horman 2006). Lean principles,
derived mostly from the Toyota Production System, focus on the reduction of waste in
order to improve the customer value.

Lean project delivery has four main goals that could be applied to the design,
construction and operation of healthcare facilities:

I. Improve quality: improve the ability of the final product, in this case the
healthcare facility, to conform to the patients and staff’s needs.

II. Eliminate waste: the elimination of activities that take up time and
resources and do not add value to the final product

III. Reduce lead time: by reducing lead times a healthcare facility can respond
faster to changes in customer demand while improving its return on investment.

IV. Reduce total costs: the organization must balance its products, services and
operating costs in order to succeed. (MacInnes 2002)
A successful delivery process incorporating lean and green strategies is likely to have a strong commitment from the entire project team, establish goals related to lean principles and sustainability early in the process, have an integration of team ideas and a thorough execution throughout the entire project.

1.2 Problem Statement

Research has shown that there are significant benefits in incorporating sustainable and lean principles in the construction industry. 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 research seeks to provide a thorough understanding of the building delivery process in green children’s hospitals, starting from programming, through design, construction, operations and maintenance. An emphasis is placed on how the delivery process and the stakeholders present in each project 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. Process modeling is used as a crucial element in understanding this delivery process.
1.3 Research Method

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, a LEED certified, Children’s Hospital of Pittsburgh and Hershey Children’s Hospital and a conventional children’s hospital, the Children’s Hospital of Philadelphia. The case studies provide a wide range of data, and the comparison between a conventional project, two moderate and a highly green project will be beneficial for the design and construction industry. Process maps will be created in order to illustrate how the building delivery process evolved in each project, and to understand when key decisions related to greening occurred throughout the process.
Chapter 2: Literature Review

2.1 Introduction

The following literature review provides a summary, synthesis of the ‘state of the art’ of issues regarding greening of healthcare facilities and clinical outcomes, lean principles, process modeling. Background provided on the topics stated above is based on review of case studies and references, but it does not cover all the work in each field. The literature review will continue throughout the course of this research in order to keep up to date with the latest findings. The literature has been collected from case studies, journal articles and internet resources. This literature review is not only used to find what is known on the topics investigated, but also to develop insightful questions and explanations about the study.

2.2 Greening of Healthcare Facilities and Clinical Outcomes

2.2.1 Objectives and Tasks

The main objective of this literature review is to show benefits of incorporating green strategies in healthcare facilities, and the effect that green strategies can have on clinical outcomes. This literature review first assesses the critical issues, which are divided into two categories, green design strategies and clinical outcomes. Second, the literature review outlines the methodology used in assessing the studies. Third, a results section presents the studies and will summarizes the findings in tables. Furthermore, the results of the studies are evaluated and synthesized. Lastly, conclusions are provided.

2.2.2 Critical Issues
An important aspect of a hospital is to ensure that its built environment does not have a negative impact on clinical outcomes. Although hospitals have huge expenditures and technological resources available, hospital-care today does not follow the important principle of medicine “first do no harm” (Frampton 2003). Modern hospitals, with an emphasis on diagnosing and curing, have become noisy, muddled environments without considering the damaging effects these environments can have on the well-being of occupants, such as patients and staff. Certain systems and features of healthcare facilities contribute to unhealthy indoor environments in hospitals, and, therefore, it is necessary to investigate these critical issues.

This literature review investigates the following critical features of healthcare facilities and their impacts on occupants’ health:

1.  ventilation and indoor air quality
2.  noise and sound
3.  views in patient rooms and gardens
4.  lighting in the facilities

The four critical features were selected due to their potential to reduce building impacts on human health and the environment. The four features were selected based on their closer relationship to the construction industry than the other elements of evidence-based healthcare such as furniture, music in the facilities, and aromatherapy.

The results of the existing studies are divided into five categories related to clinical outcomes:

1.  nosocomial patient infection rates
2.  length of patient stay
3. reduced stress levels in patients and staff
4. staff health and productivity, and
5. additional health problems.

This review explains and synthesizes the results of case studies available in the literature according to the outlined categories.

The case studies were selected from different fields, including psychology, medicine, public health, and biology, architecture, and landscape architecture. This literature was designed to reveal the health benefits of appropriate interaction with the natural and built environment. A summary of the results has been created in a table using the following categories for each study: critical feature (greening strategy), research questions/study description, clinical outcomes, and major findings of the study. The studies were selected based on the research design, sample size, and also outcomes that investigate their importance to the health and safety of patients and staff.

2.2.3 Results

The design and construction of a hospital environment can have detrimental effects on patients and staff. For example, poor ventilation and indoor air quality are major causes of nosocomial infections. Improper lighting is correlated with patient depression and medication errors. Excessive noise upsets patients and causes increased stress and lack of sleep. The studies included in this literature review show positive results of green strategies and their effects on the five selected clinical outcomes.

Ventilation and Indoor Air Quality

Protecting indoor air quality is essential for healthcare facilities. Studies show that proper ventilation in healthcare facilities can reduce infection rates and improves patient
and worker health. Natural ventilation can increase energy efficiency of buildings, and also improve indoor environmental conditions, therefore making the building more ‘green’. The Environmental Protection Agency estimates indoor air pollution as one of the top five environmental risks to public health, causing eye irritation, nausea, cancer, damage to the liver and other systems. A study shows that tuberculosis (TB) infection among healthcare workers was associated with ventilation of patient rooms of less than two air exchanges per hour (Menzies 2000). Moreover, isolating SARS patients in wards with good ventilation reduced viral load (concentration of a virus in the blood) and might help reduce hospital staff outbreaks (Jiang 2003). Furthermore, another study performed in Norway found decreased nasal inflammation of 115 females working at 36 geriatric nursing departments in relation to presence of *Aspergillus fumigatus* (fungal spores) in ventilation supply and elevated room temperatures (Smedbold H 2002). Research has linked the type of air filter, direction of airflow, air changes per hour in room, humidity and ventilation system maintenance to air quality and infection rates. The Technical Research Centre of Finland, VTT, Lifa Air has developed high efficiency air filters to protect building occupants from airborne hazards. Efficient cleaning with the appropriate equipment makes a huge difference in ventilation hygiene. Figure 2-1 shows a supply air duct in a hospital before and after cleaning (Lutz 2003). Appropriate ventilation rates can increase staff productivity, comfort and also reduce absence at work. In comparison to the
studies presented above fresh air in healthcare facilities coming from an outside environment could also increase the risk of infections, if the outside air is ‘dirty’. The studies presented above demonstrate that proper indoor air quality can have a great impact on the health of the patients and staff by significantly reducing infection rates. The benefits of using green strategies could also lead to lower healthcare and insurance costs.

Views in the Patient Rooms and Gardens

The studies examined show that views of nature in the rooms and gardens have a positive effect on stress/anxiety, pain medication use, pain tolerance and lengths of stay for patients. A study performed on patients recovering from abdominal surgery demonstrates that patients with a view of nature required fewer strong pain medications than those with a view of a brick wall. (mean number of doses of strong analgesic per patient .96 vs. 2.48) and had a shorter length of stay than those with a view of a brick wall (mean day per patient, 7.96 vs. 8.70). The patients with the view of nature also had a $500 lower cost per case. (Ulrich 1984). Furthermore, another study reveals that patients using hospital gardens reported reduced stress levels and positive mood changes(Whitehouse 2001). Windows are shown to influence the healing process because “variations in the perceived environment affect brain processes that in turn alter outcome measures associated with positive patient experiences.”(Eberhard 2006). At St. Michael Hospital in Texarkana, a healing garden was incorporated and research demonstrates that
rehabilitation patients returned home within 2 to 3 weeks rather than 6 or more weeks it took before the garden was built (Raver 1995). Women recovering from surgical treatment for stage I or stage II breast cancer engaged in a restorative activity, such as sitting in a garden or tending plants, showed improved attentional performance (Cimprich 1992). Likewise, a 2-year study of patients with Alzheimer’s and other forms of dementia confirms a decreased rate of aggression and violent behavior in facilities with gardens (Mooney 1992). The Comfort Garden at San Francisco General Hospital brings joy, contentment and peace to visitors. Patients surveyed at the San Francisco General Hospital reported improved mood changes; they seemed calmer, more relaxed, less stressed, refreshed, and pleased. Incorporating the natural world into the settings of healthcare facilities is a way to improve the healthcare of the patients and make healthcare more ‘green’. The atrium garden at Branson Hospital in Kalamazoo Michigan helps patients feel more relaxed during the long winter months. Overall, the reviewed studies demonstrate that stress and pain medication use can be reduced by providing hospitals with gardens and views of nature in the patient rooms.

*Lighting*

Daylighting and brightly lit rooms have a positive impact on patients and staff. A study shows high light levels reduce errors on pharmacists dispensing prescriptions. One study investigated the impact of the amount of daylight on the length of hospitalization of patients with unipolar and bipolar disorder, and found that patients in the rooms facing east, exposed to sunlight in the morning had an average 3.67-day shorter hospital stay than the patients in the rooms facing west (Benedetti 2001). Moreover, another study suggests that bright light is effective in reducing depression among patients with seasonal
effective disorder or bipolar disorder (Beauchemin 1996). In addition, exposure to bright light improves sleep and circadian rest-activity rhythms. The illumination level was increased in different parts of a dementia unit and the study found that the stability of the rest-activity rhythm increased in patients with intact vision, but not in visually impaired patients (Van Someren 1997). Patients with cervical and spinal surgeries exposed to increased sunlight experienced less stress, less pain and therefore were able to take 22 percent less analgesic medication and 20 percent less pain medication costs (Walch 2000). The shorter period of daylighting during the winter months has been shown to cause seasonal affective disorder with symptoms of irritability, sadness and weakness (Zilber 1993). Exposure to an increased intensity of light improves conditions in patients by increasing the amount of melatonin produced in the brain. Differences between natural and artificial light include “uniformity, level of illuminance, diffusion of light variation of time, color, and amount of ultraviolet radiation” Daylight intensity levels are between 10,000 and 40,000 lux, while a brightly lit interior has an average between 300 and 500 lux. Daylighting creates a simulating and productive environment, while significantly reducing energy costs. (Terman 1995). Poorly designed or maintained indoor lighting can result in glare and flicker, which can cause vision problems, eye fatigue, headaches and loss of concentration on patients staff and visitors. Moreover, control over the temperature in rooms could greatly improve comfort of patients and staff, while also decreasing energy consumption. Lack of control of lighting fixtures could create a sense of loss of control and increased stress with hinders their healing. In general, the studies reveal that daylighting and brightly lit rooms decrease the amount of pain medication taken by patients, the length of hospital stay and the agitation levels.
**Noise/Sounds**

Similarly to nature views and gardens, decreased noise in the healthcare facilities has a positive correlation with stress levels and sleep quality of patients. Noise is one of the biggest complains of patients and it should be seriously taken into account. The World Health Organization guideline values for continuous background noise in hospital patient rooms are 35 dB, with nighttime peaks in wards not exceeding 40 dB. Many studies demonstrate that hospital noise levels are much higher; background noise levels are typically 45dB to 68dB, with peaks exceeding 85dB to 90dB (Schweitzer M 2004). Surfaces in healthcare facilities, such as floors, walls and ceilings, are hard and sound reflecting. Sound reflecting surfaces cause noise to reflect over large distances, going into patient rooms and adversely affecting patients and staff. In a typical hospital there are a lot of beepers, telephones, alarms, pagers. In order to minimize negative impacts standards should be more strictly enforced to establish appropriate levels. Several studies centered on infants found that high noise levels decrease oxygen saturation, elevate blood pressure, increase heart rate and reduce sleep (Johnson 2001). The problem of noise in increased in double-bed rooms. Noise made by the roommate, visitors of staff can become stressful for the patient because there is no control over it (Kaldenberg 1999). A study of surgery patients shows that natural sounds cause a relaxing effect on patients and therefore improves their sleep. A study published by the Journal of Otolaryngology (Abel, S.M, 1990) shows that patients exposed to high levels of noise assume that they are unimportant and those making the noise do not care about them. Solutions for better construction include the use of high performance sound absorbing ceiling tiles and providing single-bed rather than multi-bed rooms. Stress levels and sleep quality are
important aspects in the healing of patients and the length of stay of patients in the facilities and therefore noise levels should be decreased.

**Results Summary**

The reviewed results presented below in Table 1 show the importance of using appropriate ventilation and indoor air quality, providing nature views in patient rooms and appropriate lighting, and also the importance of reducing noise levels in healthcare facilities. Table 1 shows a summary of the results divided in the following categories:

1. Critical Feature
2. Study Description
3. Variable
4. Clinical Outcomes

<table>
<thead>
<tr>
<th>Critical Feature</th>
<th>Study Description</th>
<th>Variable</th>
<th>Clinical Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilation and indoor air quality</td>
<td>Tuberculosis infection correlated to ventilation of patient rooms</td>
<td>Air changes per hour</td>
<td>Infection rates can be reduced if ventilation rates are high</td>
</tr>
<tr>
<td>Ventilation and indoor air quality</td>
<td>SARS patients were isolated in wards with good ventilation</td>
<td>Ventilation</td>
<td>Reduced viral load (concentration of virus in the blood)</td>
</tr>
<tr>
<td>Ventilation and indoor air quality</td>
<td>Presence of Aspergillus fumigatus in the ventilation supply</td>
<td>Presence of fungal spores in ventilation supply</td>
<td>Reduced nasal inflammation due to decreased presence of Aspergillus fumigatus</td>
</tr>
<tr>
<td>View of nature</td>
<td>Abdominal surgery patients with a view of nature have a shorter length of stay and fewer medications than those with a view of a brick wall</td>
<td>Nature view vs. brick wall view</td>
<td>shorter length of stay (7.96 days vs. 8.70 days) and fewer pain medication (.96 doses vs. 2.48 doses)</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------</td>
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</tr>
<tr>
<td>Healing Garden</td>
<td>At St Michael's Hospital in Texarkana a healing garden helped rehabilitation patients return home faster</td>
<td>Healing garden vs. no healing garden</td>
<td>Patients had shorter lengths of stay - 2 to 3 weeks vs. 6 weeks</td>
</tr>
<tr>
<td>Garden</td>
<td>Women recovering from surgical treatment for cancer engaged in a restorative activity (sitting in a garden, tending plants) showed improved performance</td>
<td>Garden</td>
<td>Improved attentional performance</td>
</tr>
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<td>Daylighting</td>
<td>Unipolar and bipolar disorder patients had a shorter length of stay due to daylighting</td>
<td>Patients in rooms facing east vs. patients in west rooms</td>
<td>East patients had a 3.67 day shorter length of stay</td>
</tr>
<tr>
<td>Lighting</td>
<td>A study performed in a dementia unit on patients with intact vision and visually impaired patients</td>
<td>Illumination levels</td>
<td>Rest-activity rhythms increased in patients with intact vision</td>
</tr>
<tr>
<td>Sunlight</td>
<td>Patients with cervical and spinal surgeries were exposed to increased sunlight</td>
<td>Illumination levels</td>
<td>Patients with increased sunlight experienced less stress, less pain and took 22% less analgesic medication and had 20% lower costs</td>
</tr>
<tr>
<td>Noise</td>
<td>Studies on children show adverse affections to increased noise levels</td>
<td>Noise levels</td>
<td>High Noise levels decrease oxygen saturation, elevate blood pressure, increase heart rate and reduce sleep.</td>
</tr>
</tbody>
</table>

**2.2.4 Conclusions**

This literature review revealed the relationship between building performance and clinical outcomes such as staff and patient stress, infection rates, length of stay of patients, staff productivity and retention rates. Proper indoor air quality can have a great
impact on the staff and patient’s health, and it can significantly reduce infection rates. Stress and pain medication use can be reduced by providing hospitals with gardens and views of nature in the patient rooms. Decreased noise in the healthcare facilities has a positive correlation with stress levels, length of stay, and sleep quality of the patients. Moreover, daylighting and brightly lit rooms decrease the amount of pain medications taken by patients, the length of hospital stay, and the agitation levels. For all these reasons, it is important that healthcare facilities are designed, constructed and operated properly to assure dependable performance. This literature review study provides an opportunity for patients, healthcare practitioners, constructors, designers and researchers to reconnect the effects of natural and built environment to human well-being.

The delivery process of facilities has an effect on building performance, and the building performance has an effect respectively on clinical outcomes. These studies show the effects the building performance has on clinical outcomes but little is known about the relationship between the delivery process of a facility, building performance and clinical outcomes. This research is trying to reveal some of the unknowns.

2.3 Lean Healthcare and Project Delivery

Buildings have an important role, not only where construction takes place but also through their life cycle from planning, design, construction, operation and maintenance. Buildings should not be viewed only as a product, but also as a service to its occupants. Moreover, the environment must also be seen as a customer. An economical healthcare facility that aids the healing process can only be achieved by
incorporating lean and green strategies in the design, construction, operation and maintenance processes.

The main principles that characterize lean projects are:

- *Specifying value* as defined by the end customers (patients)
- Identifying the *value stream* and the specific actions for the process
- Making the value-creating steps *flow* towards the end product (patient care, staff satisfaction)
- Letting the customers *pull* the end product from the value stream
- *Pursuing perfection* in every aspect (Institute 2007)

Lean principles applied to healthcare will change the healthcare value stream, improve the working conditions for nurses and doctors, improve patient care and have benefits for the community as a whole.

Lean construction reduces the non-value generating activities, taking into consideration the customer’s needs. By viewing the environment as a customer lean construction principles become also green.

Lean construction requires an increase in the output and product value through a systematic approach of customer requirements. All the project stakeholders should be taken into account, the patients, staff, the surrounding community and the project’s environment. (Degani 2002)

Green concerns on site are related to lean concepts. For example, the unnecessary movement of materials on site wastes energy, and therefore pollutes if gasoline is used.
One way that the production management process can be greatly improved is through the incorporation of green strategies.

Construction and buildings are one of the main consumers of resources, materials and energy. Healthcare facilities use even more energy than regular buildings. Some of the major challenges to sustainability found in construction are greenhouse gases, scarcity of materials, use of toxic materials, insufficient reuse and recycling and contaminated sites. The elimination of material waste in the construction and operation of healthcare facilities meets sustainable/green objectives confirming the synergies between the two.

An interpretation of lean healthcare is:

*The elimination of waste in every area of operations with the aim of reducing inventory, cycle times and costs – so that delivering higher quality patient services can be provided in the most efficient, effective and responsive manner possible, while maintaining the economic viability of the organization. (Doss 2007)*

By supporting lean principles, the customer should come first in healthcare. Customers in healthcare are the patients and they drive the definition of value. The needs of the patients are most important in healthcare and without lean, the healthcare industry will continue to struggle with the pressure of meeting the needs of all patients at a low cost. There is skepticism in the industry on the appropriateness of the lean principles to the healthcare industry. Lean principles work in healthcare as shown by Lean Advisors Inc., a lean consulting, training and support firm in North America. Here are a few examples:

- 20% increase in patients throughput: MRI processing time
• Decreased waiting time: technicians in X-ray area were found to be waiting 30% of their time while now they could use the time more efficiently and service patients faster

• Reducing lead time for test results from 8 hours to between 2-3 hours by decreasing batches and eliminating waste activities

• Delivery personnel were spending most of their time walking to deliver specimens. A new schedule was able to significantly reduce this wasted time walking

• Rework elimination

• Using 5S, one lab freed up enough space to add three more needed stations without increasing existing floor space.

Sutter Health, the largest healthcare provider in northern California, has adopted the lean construction technique for the completion of their capital projects ($6 billion) in the next 5 years. This is the largest company to adopt the lean concept which will hopefully influence the way we design, construct and operate healthcare facilities. Sutter is also requesting that its general contractors and subcontractors adopt lean principles also.

To engage other participants to use lean principles Sutter Health promotes lean thinking through “Five Big Ideas”:

1. Collaborate, Really Collaborate

2. Manage as a network of commitments

3. Increase the relatedness of the project participants

4. Tightly couple learning with action

5. Optimize the project as a whole (Lichtig 2005)
These ideas were used in the project delivery of the Camino Medical Center in Palo Alto, California. The entire project was looked at as a whole and decisions were made accordingly. Site planning considerations were taken into account early on with the project being built virtually using a 4D model. The entire design team—including design-assist contractors—met at the beginning of design documentation to establish modeling protocols. This project uses lean production management with a progressive, collaborative system for providing the highest quality, while minimizing waste and using resources to increase overall production thus maximizing value for all the project stakeholders. Furthermore, the entire team has an opportunity to inform the design/construction process. The team developed an optimal schedule acknowledging information flow from owner to design and construction. Revit was used for structural modeling and therefore the modeling provided better coordination between teams and more efficient quality control. A more efficient crew resulting from the modeling by far offset the addition costs of the virtual model. 4D modeling gave the ability to do more prefab work earlier, at lower labor rates and additionally there was also less material waste. Moreover, the modeling also allowed for a more accurate good manufacturing practice (GMP) since there were fewer risks. Allowing contractors to provide input and plan months before construction starts created a better quality and more cost effective project for the client. In summary, a few aspects of the project delivery that show good production management include: builders brought in early to participate in design, target costing, optimizing the project not the pieces, tightly coupling learning with actions.

Lean construction is rarely discussed in the industry and the potential impacts of incorporating lean principles in construction are not very often addressed in specific
projects. This research study gives the opportunity of investigating the synergy between lean and green delivery processes in high-performance buildings, and the role of stakeholders in affecting the decisions.

2.4 Process mapping

Process mapping addresses all activities involved in defining exactly what an organization does, who is responsible, how a process should be completed and how the success of a business process can be determined. A process map is one of the most important visual displays of “who does what” and “when” activities are accomplished. A process map helps identify the greatest opportunity for improvement.

Why map a process? A process map improves the visibility or transparency of a process. Increased visibility will improve communication and understanding of what has to be accomplished, who needs to do that specific activity and when. Process maps are a common reference for all the players in an organization and shows how the final product is done. Process maps help document a pathway to the success of a project. (Damelio 2006)

Browning explains below a few of the uses of a process model in Table 2-2 (Browning 2002)
Table 2-2: Uses of a Process Model

<table>
<thead>
<tr>
<th>Uses of a Process Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>- <strong>Program Planning</strong>: A process model helps determine the statement of work (SOW), the</td>
</tr>
<tr>
<td>work breakdown structure (WBS), the integrated master plan (IMP) and schedule (IMS), and</td>
</tr>
<tr>
<td>therefore the systems engineering master/management plan (SEMP). It also helps to estimate</td>
</tr>
<tr>
<td>cost, schedule, effort, resources, and risk. It is therefore useful for proposal</td>
</tr>
<tr>
<td>preparation.</td>
</tr>
<tr>
<td>- <strong>Program Execution</strong>: A process model helps identify the critical path, determine what</td>
</tr>
<tr>
<td>to work on this week, evaluate progress, coordinate deliverables, analyze the impacts</td>
</tr>
<tr>
<td>of changes and the value of options, and replan the remainder of a program.</td>
</tr>
<tr>
<td>- <strong>Baseline for Continuous Improvement</strong>: A process model helps analyze potential process</td>
</tr>
<tr>
<td>changes in terms of net value (investment costs vs. value added benefits) and helps</td>
</tr>
<tr>
<td>isolate root causes of problems.</td>
</tr>
<tr>
<td>- <strong>Knowledge Retention and Learning</strong>: A process model captures lessons learned when the</td>
</tr>
<tr>
<td>process does not work as expected. The model can account for &quot;system-level&quot; knowledge</td>
</tr>
<tr>
<td>about the interactions between areas of work. Importantly, the model also serves as the</td>
</tr>
<tr>
<td>basis for a common vocabulary of activities and work products [&quot;languaging the project&quot;—</td>
</tr>
<tr>
<td>Ring, 2001].</td>
</tr>
<tr>
<td>- <strong>Process Visualization</strong>: A process model helps people visualize where they are in a</td>
</tr>
<tr>
<td>process and what they need and must produce and when. It provides the basis for focused,</td>
</tr>
<tr>
<td>committed, and accountable collaboration between organizations, teams, individuals, and</td>
</tr>
<tr>
<td>even companies.</td>
</tr>
<tr>
<td>- <strong>Training</strong>: A process model can help new hires get oriented, see what they need to do</td>
</tr>
<tr>
<td>and why, and see where to go for more information.</td>
</tr>
<tr>
<td>- <strong>Framework for Metrics</strong>: A hierarchical process model serves as the framework for</td>
</tr>
<tr>
<td>organizing low-level measures and for rolling them up to feed high-level metrics that</td>
</tr>
<tr>
<td>directly to business goals.</td>
</tr>
<tr>
<td>- <strong>Compliance/Audits/Assessments</strong>: A process model helps an organization comply with</td>
</tr>
<tr>
<td>audit requirements and assessments. It can also help to convince a customer that the</td>
</tr>
<tr>
<td>users know what work to do and how to do it efficiently. It provides a baseline against</td>
</tr>
<tr>
<td>which to measure process adherence, which can provide a leading indicator of project</td>
</tr>
<tr>
<td>success.</td>
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</table>

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). If process waste is decreased in the delivery of green buildings, then sustainable strategies could be used without the higher first costs.

Process modeling will be used in this research as an integrative process to unify single processes from each organization into a larger process where the key participants and events are seen. For the purpose of this research the process modeling will be used as a deterministic model—what happened in the past is replicated in the process model.

Jeffrey Liker specifies in the book “The Toyota Way” that processes are “often complex and involve hundreds of thousand of activities”. If everything is mapped at once it leads to a mess and therefore a big picture map is required. (Liker 2004) The big-picture map or macro value stream map brings everyone together to agree on all the process, what improvements should be made and how to reduce waste in all the processes.

2.5 Summary

This literature review aims to review the critical points of current knowledge in the areas of greening healthcare in relationship to clinical and patient outcomes, lean healthcare in the delivery of healthcare facilities and process mapping as a critical step in understanding green building delivery processes. This chapter describes, summarizes and evaluates these critical issues in relationship to the goal of this research, thoroughly uncovering and understanding the most important factors in the delivery of a sustainable building.
Chapter 3: Research Methodology

To investigate the research problem, detailed case study research will be used to investigate the difference that exists in the building delivery processes for each of a LEED Platinum, the Dell Children’s Hospital of Austin, a LEED certified, Children’s Hospital of Pittsburgh and Hershey Children’s Hospital and a conventional children’s hospital, the Children’s Hospital of Philadelphia. The construction of LEED certified green hospitals is still limited at the moment, and therefore the case studies were selected based on availability of data and recent or near future date of completion. The projects can be followed through different stages in the delivery process due to their recent construction. The Dell Children’s Hospital is the first hospital in the nation to achieve LEED Platinum certification, and understanding its delivery process will be beneficial for future LEED certified hospitals. The other two LEED certified hospitals are part of the very few LEED certified hospitals in the United States. Moreover, the comparisons between the levels of sustainability being sought will be beneficial for the design and construction industry.

A multiple case study approach will be used for the collection of empirical data in order to understand the delivery process of the children’s hospitals examined. Case studies are advantageous approaches to investigate “how” and “why” (Yin). In this case, “how” the delivery process is accomplished and the different steps in delivering a green building, and also considering “why” certain processes were completed the way they were. “How” and “why” questions are explanatory, and the use of case studies is best suited for this research. Process modeling is used as a tool to understand “why” and “when”.
3.1 Research Questions

The following questions will be answered throughout this research:

- Are delivery processes used on green buildings different than processes on conventional buildings? Do these vary based on the level of sustainability being sought?
- What are the important steps in optimizing the design and construction process of a green children’s hospital? Are there key “ingredients” needed for project success?

In case study research, the research questions allow attention to the issues that are going to be examined throughout the research. These propositions will serve as a basis for the analysis within the scope of the proposed research.

3.2 Research Goal and Objectives

The goal of this research is to understand the building delivery process of children’s hospitals, based on the case studies available. An emphasis will be placed on how the project environment, the delivery process, and the stakeholders present in each project affect the final product.

This goal will be attained through the development of the objectives stated below and accomplishment of tasks related to each project.

1. To examine current literature and to identify the levels to which lean and green strategies are incorporated in hospitals and their importance for the children’s health, well-being, safety, and operation of the facilities. The expected benefits of a green children’s hospital will also be evaluated. This will be accomplished through a review of literature and attendance of various discussions, presentations and conferences.
2. To map the sustainable delivery process in children’s hospital projects with varying degrees of sustainability and conduct comparative analysis to identify any patterns and differences. The first step is to identify and map the steps used in delivering the projects. This information will be collected by meeting with key stakeholders and data will be analyzed in order to identify steps that add value or not. Mapping the delivery process will be accomplished using the process modeling protocol developed by the Lean and Green Research Initiative, here at Penn State University. This step will also focus on identifying key features that are most important in a children’s hospital.

3.3 Research Approach

This research is focused on the four case studies presented. The case studies are all children’s hospitals. The projects range from LEED Platinum, the Dell Children’s Hospital of Austin, to LEED certified, Children’s Hospital of Austin and Hershey Children’s Hospital and also a children’s hospital that will not be LEED certified, the Children’s Hospital of Philadelphia. The whole delivery process of the hospitals will be examined from the programming stages to design, construction, commissioning, and operations and maintenance. Stakeholders from each organization will be interviewed in order to collect the necessary data. The stakeholders interviewed include: the architects, construction managers and owners. Data will be collected regarding each stage of the project delivery and key issues in the delivery process.
3.4 Data Collection

Schramm notes that the essence of a case study is to illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what results. The set of decisions for the purpose of this study is contained in each step of the delivery process of the buildings investigated.

A comparative case study approach will be 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, life-cycle cost analysis if available.

Data will be 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. Specific questions will be asked regarding LEED points achieved and the reasoning behind each, sequence of processes and time spent for each, lean principles incorporated.

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. They will supplement the interview data collection.

3. Observations made on site visits or inside of the hospital if completed before visit. These observations include layout of facilities, design features specific for children’s
hospitals and also green design features. Users in the facilities will be interviewed in regards to their satisfaction with the green features in each children’s hospital and potential problems encountered.

**Interviews** are one of the most important sources of information in case study research. Two important aspects will be followed throughout the interview process:

a) Follow the line of inquiry

b) Ask the questions in an unbiased matter

The case study interviews were of an open-ended manner, where the stakeholders answered questions related to the facts of the project but also contributed their opinion about events, features and processes. These opinions are important in order to gain an understanding of the leadership mindset in relation to achieving complex sustainability outcomes. In a lot of cases the executive mindset is what drives sustainable projects to success. Most of the interviews were face-to-face interviews with only a few telephone interviews. In certain cases, where not enough time was available, the interviews were focused on the questions that need to be answered based on the case study data to be collected. Observations made during site visits to each hospital will be used to provide additional information about each case study. These observations are useful for backing some of the data collected during the interviews.

The use of multiple sources of evidence allows for an investigation of a broader range of issues, qualitative and quantitative. The sources of evidence in this study are reviewed and analyzed together so that the case studies’ findings are based on convergence of information of different sources, not qualitative and quantitative data alone.
The meetings and phone interviews have uncovered additional unique design and construction features of each hospital that each stakeholder interviewed believes are of importance. This data was used to fulfill the descriptive side of the case studies presented. Moreover, the interviews were guided conversations rather than a structured survey. The interviews followed a line of inquiry as reflected by the case study data collection tool but also asking conversational questions in an unbiased manner.

The interviews had a duration of approximately one to two hours. The interviewees were asked at first to give a quick overview of the project and their involvement. Then the interviewee was asked to answer questions regarding green aspects and each delivery phase. As an example, the interview protocol and transcripts from the interviews at Dell are included in Appendix A. The following issues in Table 3-1 have been identified as critical for the data collection process:

<table>
<thead>
<tr>
<th>Table 3-1: Key green issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Key issues/processes</strong></td>
</tr>
<tr>
<td>• Transparent delivery process in relation to green outcomes</td>
</tr>
<tr>
<td>• Early adoption of green</td>
</tr>
<tr>
<td>• Business case for green initiatives</td>
</tr>
<tr>
<td>• Owner commitment</td>
</tr>
<tr>
<td>• Architect and construction manager commitment</td>
</tr>
<tr>
<td>• Early team selection/ team experience</td>
</tr>
<tr>
<td>• Commissioning process</td>
</tr>
<tr>
<td>• Energy modeling</td>
</tr>
<tr>
<td>• Sequence of delivery phases</td>
</tr>
<tr>
<td>• Integrated approach</td>
</tr>
<tr>
<td>• Role of the construction manager</td>
</tr>
<tr>
<td>• Cost per square footage</td>
</tr>
<tr>
<td>• Delivery method</td>
</tr>
</tbody>
</table>

These factors have been identified through the literature review, attendance of conference presentations, review of previously published journal articles from the Lean
and Green Research Initiative database and discussions with academic researchers and industry professionals.

The respondents were identified based on their position and role within each case study. The data collection strategy was to obtain information from all key stakeholder perspectives. Thus, the stakeholders interviewed include an owner’s representative, construction project manager, lead architect, sustainability consultant and also engineers. The respondents’ contact information was obtained through the internet, networking opportunities or the advisors’ database of contacts. The number of respondents varies on each project. At the Dell Children’s Hospital of Austin all identified stakeholders were available to discuss the project, while for the other projects not all identified stakeholders were available to answer questions.

3.5 Response Bias

The research bias in this study was decreased by not becoming a supporter of the organization studied and losing objectivity. The researcher did not focus on what was expected to be seen or seeking data that would support the researcher’s point of view. Varying points of view were taken into account when collecting the data. Most interviews were recorded such that the data will not be filtered through time or forgotten. First-hand access to the information collected increases the accuracy of the data analysis.

The questions asked during the interviews were specific and normally encountered in construction research. Interviewing multiple people on each project will minimize the level of bias found in the interviews. Different team members’ perceptions and positions within each case study were taken into account in order to eliminate bias.
3.6 Data Analysis

Data analysis will consist of categorizing the data collected, examining, tabulating, and recombining the quantitative and qualitative data to address the research questions and the propositions.

The major unit of analysis in this research project is the delivery process as a whole. Different parts such as the programming stage or schematic design will be analyzed and compared between the case studies. 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.

The table below provides information on the data collection procedure and the purpose for analysis:

Table 3-2: Data collection and purpose in the analysis process

<table>
<thead>
<tr>
<th>Data collection instrument</th>
<th>Data collected</th>
<th>Purpose in the analysis process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interviews, project documents</td>
<td>LEED level &amp; points achieved</td>
<td>A description of the reasoning for going after each credit. Which points require the most effort?</td>
</tr>
<tr>
<td>Interviews</td>
<td>Sequence of processes</td>
<td>Were delivery processes well integrated?</td>
</tr>
<tr>
<td>Interviews, project documents</td>
<td>Energy modeling</td>
<td>Does the level of energy modeling done differ between a LEED Platinum and a LEED certified project?</td>
</tr>
<tr>
<td>Interviews</td>
<td>Owner integration</td>
<td>Was the owner the driver for LEED? Did the owner participate throughout the process</td>
</tr>
<tr>
<td>Interviews</td>
<td>Commissioning agent involvement</td>
<td>Does the project have a commissioning agent?</td>
</tr>
<tr>
<td>Observations on site, interviews with the users</td>
<td>Green features, integration of technical systems</td>
<td>Are the technical systems working appropriately?</td>
</tr>
</tbody>
</table>
Process mapping has been used to compare the projects and provide cross-case analysis. The data will be synthesized and process models will be created for each case study. The critical processes and events for each children’s hospital will be 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 where involved in what phases of the projects.

To prepare the maps the following protocol has be used (Klotz 2007):

- Level 1: a big picture map to understand the overall delivery process and organization. Interviews with an employee 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 or specific factor, for example programming stage or design, and interview members in each project who understand best the applicable process.

Process maps for the Children’s Hospital of Pittsburgh, Dell Children’s Hospital of Austin \ and the Hershey Children’s Hospital are included in the Chapter 5: Data
Collection–Microsoft Visio has been used to create the maps. An example from the Hershey Process Map is presented below.

![Figure 3-1: Extract from the Hershey Process Map](image)

The next step in the data analysis process is linking the data collected to each of the propositions developed. A criterion for analyzing the findings is to look at the patterns and see if they match the propositions, a technique called **pattern-matching analysis**.

The data is analyzed across all the cases in order to identify similarities and differences between them in relationship to the critical issues identified and the level of certification achieved. By identifying similarities and differences, further insight is provided into the green building delivery process of a children’s hospital.

The following tactics have been used to look beyond the initial impressions:

1. Select categories and look for within group similarities coupled with differences
2. Select pairs of cases and list the similarities and differences between each pair
3. Divide the data by data source

The categories selected represent the green building factors investigated, coupled together in some cases, while the data sources are the different stakeholders interviewed.

By using cross-case analysis to look for commonalities between the projects, steps are taken in advancing the knowledge base for the delivery process of green healthcare facilities.

The following approach will be used to analyze the data. These four tests will be used: construct validity, internal validity, external validity and reliability (Yin); they are explained below with specifics of this research.

1. **Construct validity**: establish operational measures for the issues studied. During this stage the types of changes to be studied (LEED credits achieved, owner and team commitment to green features, first and life-cycle costs etc.), will be selected and related back to the objectives of the research. This is accomplished in order to reflect that the selected measures reflect the specific types of changes. In order to increase construct validity four case studies will be used (multiple sources of evidence), establish a chain of evidence and have the study reviewed by key informants.

2. **Internal validity** is only a concern for causal case studies in order to determine if event x let to even y. This is not one of the main issues of this research, but it will be taken into account if encountered. For the purpose of this descriptive and exploratory research internal validity is not applicable.

3. **External validity** establishes if the studies’ findings can be generalized beyond the specific case studies. The construction industry differs greatly from on facility to the next and there are various activities with large variability so one must be careful when
generalizing specific issues. The findings of this research will serve as a way to articulate the issues presented and highlight the ones of relevance to all healthcare facilities and children’s hospitals.

4. **Reliability:** this ensures that if a later investigator follows the same procedures they would arrive at the same conclusions. This research will be examined by the committee advisors to ensure reliability. Outside parties will also be involved in order to make sure that the steps followed are adequate.

### 3.6 Expected Results and Contributions

The expected results of this research include an analysis, synthesis and comparison of the green building delivery process for the four children’s hospitals examined focusing on the following aspects for each project: owner, architect and construction manager commitment to green, transparency in relation to green outcomes, early adoption of green, the commissioning process, team experience, a business case for green initiatives and energy modeling. It is expected that these factors will be more dominant in the LEED Platinum project and less in a conventional project.

The contributions from this case study research are presented below:

1. A thorough understanding of the building delivery process focusing on how the project environment, the delivery process, and the stakeholders present in each project affect the final product.

2. A listing of the most crucial steps in optimizing the design and construction process in a green children’s hospital
3. An explanation for the level of detail needed for understanding green processes in children’s hospitals.
Chapter 4: Case Study Background

4.1 Introduction

The main goal of this research is to identify and verify the factors that are most important in the delivery process of a green children’s hospital. The factors considered crucial have been identified through the literature review, attendance of conference presentations, review of previously published journal articles from the Lean and Green Research Initiative database and discussions with academic researchers and industry professionals.

An emphasis is placed on how the project environment, the delivery process, and the stakeholders present in each project affect the final product. This research is exploratory in nature, and therefore a case study approach has been identified as the main research strategy. The case study approach provides the best opportunity for contrasting and comparing similarities and differences between each of the four children’s hospitals adopting varying degrees of sustainability. The four children’s hospitals are the Dell Children’s Hospital of Austin, the Children’s Hospital of Pittsburgh, the Children’s Hospital at the Hershey Medical Center and the Children’s Hospital of Philadelphia.

4.2 Multiple Case Studies

A multiple case study approach is the main research strategy for this study. The four case studies used are exploratory and empirical. The case study investigated is exploratory because they are one of the very few green children’s hospitals in the nation, and this study allows us to gain more insight into their building delivery process. This research is empirical in nature because it is:
Exploratory research helps determine the best research design, data collection method and selection of subjects. The results of this multiple case study exploratory design will provide insight into the delivery of green children’s hospitals. The empirically conducted case studies are used to document the delivery process in the four children’s hospitals, focusing on the factors that are most significant.

The four case studies are used for multi-perspectival analyses. This indicates that this research considers not just the voice and perspective of the stakeholders involved in the delivery of the projects, but also of the relevant groups of stakeholders and the interaction between them. The following section provides a summary and introduction to each case study investigated.

### 4.3 Case Study Projects

The following sections give an introduction and background information to the four case studies investigated.

#### 4.3.1 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 due to space constraints; therefore the new facility took into consideration the
planning for future generations, creating an environment that can grow through time. The new facility could be expanded without interruption of service. The area surrounding the hospital is in development (Muller Development) creating new jobs, houses and bringing businesses to the area. (Dell 2007)

The key stakeholders in the project are as follows:

Table 4-1: Stakeholders at the Dell Children’s Hospital

<table>
<thead>
<tr>
<th>Owner</th>
<th>Seton Healthcare Network, Austin</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Contractor:</td>
<td>White Construction Co., Austin</td>
</tr>
<tr>
<td>Architect:</td>
<td>Karlsberger Architecture Inc., Columbus, Ohio</td>
</tr>
<tr>
<td>Structural Engineer:</td>
<td>Datum Engineers Inc., Austin</td>
</tr>
<tr>
<td>Civil Engineer</td>
<td>Bury+Partners Inc., Austin</td>
</tr>
</tbody>
</table>

Seton, the owner, has always kept the goal of maintaining the health of the planet and children by incorporating healthy sustainable building practices. This facility, which will achieve LEED platinum certification, is a leader in sustainable building practices.

The children’s hospital uses sustainable building practices as follows (Dell 2007):

Table 4-2: Sustainable Building Practices at Dell

<table>
<thead>
<tr>
<th>Sustainable site planning</th>
<th>The site is part of the City of Austin’s Smart Growth Initiative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Conservation</td>
<td>The facility contains a rainwater collection system and is xeriscaped for water efficiency</td>
</tr>
<tr>
<td>Energy Efficiency &amp; Energy Plant on site</td>
<td>Solar panels and 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.</td>
</tr>
<tr>
<td>Conservation of Materials and Resources</td>
<td>Use of Recycled Materials and low VOC Minimize construction waste</td>
</tr>
<tr>
<td>Indoor Environmental Quality</td>
<td>Optimize natural daylight, eliminate airborne pollutants</td>
</tr>
</tbody>
</table>

The hospital is not-for-profit and is available to all children in a 46-county region, regardless of their family’s ability to pay. This is the only hospital for children in central
Texas. The entire building is wireless, and electronic records will replace paper documentation. (Dell 2007) This is a lean aspect that will reduce wasted paper documentation.

![Dell Children’s Hospital of Austin](image)

The facility got more than 225 doctors, nurses, staff and families involved in the design process. An energy-efficient design is used through an onsite combined heat and power energy plant using integrated energy systems. This system minimizes the building energy requirements and maximizes efficiency through electricity, steam and chilled water. The Plant exceeds the LEED efficiency requirement of 60%. The Muller energy center provides all the energy for the facility, including life-safety and emergency power. The energy center will provide chilled water to other facilities at the 700-acre Muller redevelopment site. A “whole design” approach based on life-cycle costs was used by children’s hospital and Austin Energy in order to deal with costs issues and risks involved. Environmental considerations were also a major aspect of the design process. This led to
power generation technology that meets the requirements of the Texas Commission on Environmental Quality, but moreover meets the requirements without emission treatment equipment typically required at power plants. Due to the very innovative nature of the project, the Texas Department of State Health Services approved the elimination of the emergency generator (Alford 2007)

Engineering services for the mechanical, electrical, plumbing and fire protection were provided by CCRD partners. CCRD work involves an on-site cogeneration thermal energy plant, with two electrical utility grids to provide power for the essential electrical system. The hospital uses Picture Achieving Communication Systems (PACS), which integrates imaging with the hospital interface and allows remote viewing by physicians, clinics and other healthcare providers.(Patterson 2006)

Karlsberger’s Companies, the architecture firm for this project, is a nationally recognized healthcare and design firm specializing in children’s hospitals. The firm has worked on more than 60 children’s hospitals, more than any other firm in the world.(Witcher 2007)

The project was fast-track, being on an aggressive 27 month schedule, and it opened in June 2007. The structure is spread on 32-acres to make it less imposing to the children.

The building was designed this way in order to break it down, compartmentalize each department with good adjacency and circulation flow and create an appropriate scale. From a construction point of view, the building being flat and big, lets the builders work on a lot of area at the same time—which helps being on this fast-track schedule. The
hospital also has a 145 ft-tower, a way-finding element that pays tribute to the hospital’s history. There are positive distractions at every corner of the hospital for the children – it is a journey of discovery. There has also been a strong emphasis on natural light, playing a healing role. The hub-and-spoke pattern of the hospital allows for a lot of natural light – there are no rooms farther than 32 ft away from an exterior wall, except the surgery room. The design of the hospital allows for an additional 250,000 sq ft of future expansion that will not disrupt hospital operations during construction.

Figure 4-2: Healing Garden at the Dell Children’s Hospital

The hospital is located in a brown field 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”. The decision to pursue green on this project was made mostly by the Board of Trustees Oversight Committee, Project Management Team and the Ball-in Court Team. Studies done by the project team reveal several reasons for going green from a business perspective: reduced maintenance and operation costs, improved productivity of the nurses and doctors, recruitment and retention of staff, reduced liability, environmental stewardship and enhancing the health and well being of staff.

A presentation offered by the Robert Bonar, the CEO, and Thomas Snearey of Karlsberger at the NACHRI Facilities Design Conference in Fort Worth reveals their studies performed and reasons for going green:

*Reduced Operating Costs*

1. Every dollar a non-profit healthcare organization saves on energy is equivalent to generating new revenues of $20 for hospitals or $10 for medical offices.
2. The facility will have $6-8 million savings in energy costs the first 20 years.

3. Lighting, HVAC, hot water consumes an average of 70% of the hospital’s annual energy consumption.

4. Annual electricity usage for a hospital is $1.67/sf.

5. Most green buildings are designed to use 25% to 40% less energy than required by code (some higher)

*Improved Productivity*

1. Productivity gains for healthier indoor environments can account for 1% to 5% of employee costs. Employee costs range between $3 and $30/s per square foot; energy costs are usually under $3.00 per square foot per year, productivity gains may exceed the energy cost of operating the entire building.

*Retention*

1. Turnover rates among hospital nurses average 20% annually and it can cost a hospital up to $64,000 to replace one nurse.

*Enhance Health and Well-being*

1. Evidence based design has shown that incorporating green strategies can reduce length of stay of patients, amount of medication used…add others from literature review.

2. Medical errors can be reduced if the staff is healthier. Healthy Building=Healthier staff=healthier outcomes

*Environmental Stewardship*

1. Buildings use about 40% of energy resources

2. Buildings account for 35% of CO2 emissions
3. Construction and demolition generate approximately 25% of municipal solid waste

4. 25% of virgin wood is used in construction

5. Buildings use over 75% of the manufactured polyvinyl chloride (linked to dioxin)

6. Hospitals account for 4% of the nation’s building square footage but consume 8% of the nation’s energy

**Reduced Liability**

1. Healthy building can reduce legal claims and liability for owners. “sick building” cases more common

2. Mold related claims. It is predicted that insurance companies will link lower premiums to high performance buildings.

Throughout the whole delivery process of the hospital an integrated design has been draw on. A few noticeable aspects include the owner led decision to pursue LEED Platinum, a 2 day LEED charette, LEED tracking documents, bid documents developed according to Platinum goal and quarterly construction LEED meetings. Other principle that drove the process is “no dumb things to achieve the points”.

The following list shows the point details to achieve the Platinum certification:

- Sustainable Sites: possible 13 out of 14 points
- Water Efficiency: possible 4 out of 5
- Energy and Atmosphere: possible 12 out of 17 points
- Materials and Resources: possible 8 out of 13 points
• Indoor Environmental Quality: possible 13 out of 15 points
• Innovation and Design Process: possible 4 out of 4

POSSIBLE TOTAL: 54 – platinum requirement= 52 points

Daylighting has been used abundantly in the design of the hospital. There are numerous daylighting courtyards based on regional influences. Dell’s children’s hospital serves a 46-country region with 7 distinct “eco-regions”: Coastal Marshes, Limestone Valley, Sandstone Valley, Granite Dome, Sandstone Plains, Lost Maples and Lost Plains.

Local/regional material use has been maximized in the process. Other notable features regarding materials and resources include low VOC products, no products containing formaldehyde, high recycled content and certified wood products.

Notable site features include a healing courtyard, xeriscape planting, foundation water collected for limited irrigation and gray water, cut-off light fixtures, storm water treated at a centralized water quality “lake” and 1 tree for every 4 parking spaces.

Benefits of the combined cooling/heating/power plant are stated below:

• 4.5MW natural gas-fired turbine supplies 100% of the hospital’s electricity
• 75% more efficient than coal-fired power plants
• Lower emissions of nitrogen oxides and carbon dioxide as a result of efficient combustion chamber technology
• Steam, a by-product of the conversion process is used in absorption chiller to produce all of the hospital’s chilled water needs
• Enhanced quality of power assuring smooth, continuous operation of clinical devices
• 2 electrical feeds from different substations in the surrounding power grid provide 100% electrical redundancy

• Emergency generator provided for the CCHP black start up provides a third back-up for Life Safety Systems

• Utility company, Austin Energy, funded and operated, reducing project capital costs

### 4.3.2 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 $555 million. 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)

Figure 4-3: The Children’s Hospital Pittsburgh

The key stakeholders in the project are as follows.
Table 4-3: Stakeholders at the Children’s Hospital of Pittsburgh

<table>
<thead>
<tr>
<th>Owner:</th>
<th>University of Pittsburgh Medical Center</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Contractor:</td>
<td>Dick Corporation</td>
</tr>
<tr>
<td>Architect/Engineer</td>
<td>Astorino</td>
</tr>
<tr>
<td>Site/Civil</td>
<td>KAG Engineering</td>
</tr>
</tbody>
</table>

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 grounded on five principles: family-centered care, technological advancements, quiet building, patient safety and environmental sustainability.

A few examples of the family-centered care features include:

- Inviting colors and soft fabrics
- A comfortable sleeping space for parents
- Caregiver stations located closer to patient rooms
- 20000 square foot Resource Center including an atrium, chapel, library, healing garden and business center for working parents.
- Outdoor garden areas
- Child-friendly furniture (Pittsburgh 2007)

The technological advancement will improve patient care, medical errors, safety and will also provide operating efficiencies for cost efficiency. This hospital will be among the first fully digital hospitals in the nation. The hospital has a infrastructure service that allows for power service that cannot be interrupted, a campus-wide data network for
access to health records, a secure access to the network from anywhere in the world, a campus wide wireless phone system, soft phone. (Pittsburgh 2007)

A few other noticeable applications and equipment include:

- Campus wide paperless record management system
- Online access to all images for diagnosis purposes from anywhere on campus
- Delivery of patient education on demand at the bedside
- Automated medication and department based supply control

The children’s hospital is designed as **environmentally sustainable**, and will use resources such as water, energy, materials and land more efficiently. The stakeholders of the hospital are aware that a green building improves the health of the patients, the comfort and productivity of the staff. The hospital is committed to using green practices beyond the construction process. The hospital will work with doctors, staff and the community in order to provide research related to sustainability and its effect on the children’s health.

A few features of the hospital include:

- Access to public transportation
- Bike racks
- Recycling of water
- Use of local building materials that have a high recycled content
- Use of daylighting and views
- A healing garden
- Reduce pavement outside and incorporation of large green areas
• Highly reflective membrane roof

The site design is considerate of the needs of the community, considering that it is in close proximity to residential houses. The lighting design of the hospital will avoid light spill and direct-beam illumination off of the property. (Pittsburgh 2007)

The team took into consideration LEED requirements and healthcare aspects in order to perform an MEP design that is efficient, of high-quality and controllable. The campus has a Central Plant that will help reduce energy consumption. Additionally, a commissioning plan will ensure that all the systems perform appropriately from the beginning. An Information Systems (IS) contractor will be in charge of the installation of low-voltage systems (building automation, telecommunication, fire alarm, security)

More than 25% of the structure will be reused from the previous hospital

The hospital is one of the quietest hospitals in the nation. Research has shown that a quiet environment promotes healing and satisfaction of patients and staff. Measures to reduce noise include:

• Masonry exterior walls
• Full height partitions, sealed and insulated
• Acoustic ceiling tiles
• Door seals and carpeting
• Use of vibration isolators
• Use of personal communication devices instead of overhead paging
• Silent notification of alarms and nurse calls
Another top priority for the Children’s Hospital of Pittsburgh is to keep the patients and staff safe and healthy. The hospital is designed to impact noise levels, infection rates and patient privacy.

A few noticeable features to improve the safety and quality of the patients include

- All operative services are included in one floor: operating suites, interventional radiology, procedures and infusion center.
- Specialized units, such as cardiac intensive care and oncology are close to labs and other services utilized by the specialists.
- On-site linear accelerator and PET/CT scanner that will eliminate the need for patients to go to other buildings.
- A computerized room-level observation center, a decentralized medication dispensing process and decentralized nurses stations
- Patient supplies located on each floor in order to decrease the time spent to locate supplies
- Wireless phones between caregivers and patients (Pittsburgh 2007)

The hospital will add almost 7000 jobs for the community.

Mr. Violi, former CEO of the hospital, estimates an higher price for the environmental initiatives of $5 million to $6 million. The short-term costs are outnumbered by the long term benefits. From a health perspective, there are no better projects to incorporate green building strategies than children’s hospitals.
Astorino used ZMET, a unique feature that helps in the design process to ensure all insights uncovered during surveys and interviews with patients and staff are translated into design, and respond to the user’s needs. This technique unveils the needs and feelings of the user groups.

### 4.3.3 Children’s Hospital at the Hershey Medical Center

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.

![Figure 4-4: Master Plan at Hershey](image)

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 160,000 square-feet. The hospital will have a total cost well in excess of $200 million dollars and is seeking to raise $65 million in philanthropy. (Hershey 2007)

Figure 4-5: Hershey Medical Center

The new four-level Children's Hospital will accommodate patient beds for medical/surgery, intensive/intermediate care, and oncology. Acuity-adaptable patient rooms is a given design parameter. It will also include an entire floor devoted to surgical procedures, in addition to amenity programs on the first floor. Capacity for vertical expansion of three floors will be built into the infrastructural systems. (Payette) – HealthcareDesignMagazine –change a bit.

4.3.4 Children’s Hospital of Philadelphia

In 2001, The Children's Hospital of Philadelphia began a five-year, $650 million facilities expansion. The plan will require another seven years to complete with an overall
cost in excess of $1.5 billion. When complete, this expansion is expected to double the size of the main campus.

- **New South Tower Inpatient Wing**

The South Tower is a new inpatient wing built immediately south of the existing hospital. A new nine-story atrium separates this building addition from the existing hospital building. The South Tower was constructed over the emergency department driveway and thus provides for a secure, screened, and "weatherproof" access to the emergency room.

New inpatient units are located on floors 3 through 8, with one additional floor (9) for future inpatient expansion. While only two of the floors are designated ICU level rooms, each patient room has been designed with the capability of becoming an ICU room in the future to address the increasing acuity of our patient population. The typical patient rooms are designed as all single rooms with enough room to accommodate a family zone within the room. Each floor has two playrooms, one for small children and one for teens, a family room, a family kitchen, dining area, and laundry facilities. The second playroom can double as a classroom to support our patient’s educational needs. Mechanical and electrical infrastructure upgrades completed in this phase will support all phases of the Hospital Expansion Project.

New Construction: 332,000 sf

Renovations: 68,000 sf

Total Project Cost: $175M

Completed and Occupied in phases through February 2004
• **Hospital Facade Remediation**

Children’s Hospital opened the doors of its fourth home, in West Philadelphia, in 1974. By 2000, the Main Building’s facade experienced leaks and clearly needed updating. Determining that repairs would be too costly, the Hospital worked with the world-renowned architectural firm, Kohn Pedersen Fox from NYC to both update and match the facade’s look with new construction associated with CHOP’s hospital expansion program. The project was deemed especially challenging, as whatever work was done had to have minimum, if any, impact. Following three years of complex construction, the results are stunning providing a beautiful new glass exterior and colorful glass panels that portray the Hospital’s new image as well as a new front door canopy and drop off for patients and a new plaza and green landscaping for all. A new lobby is currently being designed and will integrate with the new front entrance.

Total Project Cost: $55M

Completed in November 2006

• **New West Tower Diagnostic, Treatment and Inpatient Wing**

The West Tower project consists of a major building expansion located in a tight site between the Main Hospital building and the Wood Center. The primary purpose of this new building is to provide expanded diagnostic and treatment facilities to support both inpatient and ambulatory programs. Requiring complex engineering and construction techniques, this major building addition is woven into the existing hospital building on every floor.

The southwest portion of the West Tower is a new 9-story building which spans across East Service Drive on two levels and connects to the Wood Ambulatory Care
Building. It will house an expanded emergency department a new 39 bed NICU, expanded Radiology, OR PACU, and expanded inpatient facilities including CHOP’s new Fetal/Special Delivery Unit.

Phased occupancies from 2006 thru 2008

Expanded Emergency Department opened October 2006

New 39 – bed Neonatal Intensive Care Unit (NICU) opened in February 2007

Total Project Cost: Estimated at approximately $350M

Completed and Occupied in phases through February 2008

5.4 Summary

This chapter provides background information on each case study investigated. The location, costs of construction, phase in the delivery process are stated in this section. The issues facing each hospital and the need for a new facility are also uncovered in this section. A multiple-case study research approach is taken in order to investigate the factors that are most important in the delivery of a children’s hospital. The following chapter provides information on the specific issues and the data collection tool.
Chapter 5: Data Collection

5.1 Introduction

The data collection procedure and methods have been explained in Chapter 3. This chapter provides the data collected tool used to guide the interview and analysis processes. The data collection tool provides information about the specific attributes investigated and questions to be asked during the interviews. A summary of the tabulated collected data has been created for each case study. Additionally, process maps have been created to show how the delivery process occurred for the case studies investigated.

5.2 Data Collection Strategy

After an extensive literature review and recommendations from industry representatives and academic researchers, the issues identified in Table 1 and Table 2 are selected to be most important in the delivery of a successful green, LEED certified building. The factors considered crucial have been identified through the literature review, attendance of conference presentations, review of previously published journal articles from the Lean and Green Research Initiative database and discussions with academic researchers and industry professionals.

The specific attributes column gives additional information for the key green factors in the delivery process of a successful green healthcare facility. These issues will be compared between the four projects in the analysis section. Content analysis and pattern-matching techniques will be used to categorize, synthesize and analyze the data.
The stakeholders for each project, owner’s representative, lead architect and construction manager, were interviewed based on the issues below. The following table has been created as an initial strategy for the data collection:

Table 5-1: Data Collection Strategy

<table>
<thead>
<tr>
<th>Key green factors</th>
<th>Specific attributes</th>
<th>Data to be collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transparent delivery process in relation to green outcomes</td>
<td>Integrate sustainable project objectives well with other delivery aspects during programming, design and construction</td>
<td>Were all project members aware of the green outcomes? Good communication between stakeholders?</td>
</tr>
<tr>
<td></td>
<td>Sustainable attributes are not singles out as additional requirements</td>
<td>Was there any rework due to poor understanding of green strategies?</td>
</tr>
<tr>
<td></td>
<td>Thoroughly communicate the project's sustainable attributes to each project member</td>
<td>Were there delays due to poor communication of sustainable objectives in relation to other project requirements?</td>
</tr>
<tr>
<td>Early adoption of green</td>
<td>This enables a more clear understanding of project scope requirements and project needs</td>
<td>When was the notion of green first introduced? At what point in the delivery?</td>
</tr>
<tr>
<td></td>
<td>Saves project rework due to accurate project bids and costs</td>
<td>Who proposed the notion of green? (owner, architect, design-builder)</td>
</tr>
<tr>
<td></td>
<td>Saves time for incorporating sustainable objectives later in the project</td>
<td>Was the team trained on these sustainable objectives?</td>
</tr>
<tr>
<td></td>
<td>A sustainability filter can be applied to all decisions</td>
<td>Were green objectives discussed in relation to overall project goals and objectives?</td>
</tr>
<tr>
<td>Business case for green initiatives</td>
<td>Project budget aligned with environmental project goals</td>
<td>Was there a business case for going green performed</td>
</tr>
<tr>
<td></td>
<td>Life-cycle cost analysis data to justify operational savings</td>
<td>Is life-cycle analysis data available?</td>
</tr>
<tr>
<td></td>
<td>Payback period for sustainable objectives</td>
<td>What is the payback period for the sustainable aspects and LEED certification?</td>
</tr>
<tr>
<td><strong>Owner commitment</strong></td>
<td>Increased commitment from the owner side leads to better project planning and to better cost and schedule performance</td>
<td>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?</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Architect and CM commitment to green and a consistent approach</strong></td>
<td>Better delivery in regards to green aspects if teams are committed to sustainability.</td>
<td>Are these teams committed to sustainability as one of their core values regardless of owner commitment?</td>
</tr>
</tbody>
</table>

Table 5-2: Data Collection Strategy cont.

<table>
<thead>
<tr>
<th><strong>Key green factors</strong></th>
<th><strong>Specific attributes</strong></th>
<th><strong>Data to be collected</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Early team selection/team experience</strong></td>
<td>bringing the teams together early engages critical process integration and allows system and environmental knowledge to evolve as design begins</td>
<td>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?</td>
</tr>
<tr>
<td><strong>LEED points</strong></td>
<td>level of certification &amp; break-out</td>
<td>Why did you go after the specific points? Which specific points required the most effort?</td>
</tr>
<tr>
<td><strong>Commissioning process</strong></td>
<td>Quality assurance must be focused on the specifications phase, rather than after installation.</td>
<td>When was the commissioning process introduced to the project? Was commissioning performed by a separate consultant or contractor self performed?</td>
</tr>
<tr>
<td><strong>Commissioning process</strong></td>
<td>Commissioning should be specified early</td>
<td>Was there a commissioning contract to review the building operation with operations and management staff?</td>
</tr>
<tr>
<td><strong>Energy Modeling</strong></td>
<td>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</td>
<td>Who was in charge of energy modeling? What were the costs associated with it? Effort and rework? Was it done right from the beginning? At what stage in the design were energy simulations used?</td>
</tr>
<tr>
<td><strong>Sequence of delivery phases and timing of stakeholder involvement</strong></td>
<td>Timeline of building delivery processes: programming, design, construction etc</td>
<td>Provide a schedule of events and timing of involvement of stakeholders for comparison between projects; aid for process map</td>
</tr>
<tr>
<td><strong>Integrated Approach</strong></td>
<td>integrated approach</td>
<td>Were eco-charrettes conducted? How often? And who participated?</td>
</tr>
</tbody>
</table>
Role of the CM

value engineering input about green, documentation process, material procurement and selection, waste management and recycling plan, cost analysis and estimating during preconstruction

How did you accomplish the waste management, process, recycling plan - the issues in the other box

cost/ sq footage, construction cost, project delivery method

comparisons between costs, number of beds, and the project delivery method in each project

What was the total cost of the project? Square footage and number of beds?

5.2 Collected Data

The following tables, based on the data collection instrument provide a summary of the data collected for the four case studies investigated. Appendix A includes transcripts of the audio recordings from some of the interviews, LEED checklists and additional information

5.2.1 Dell Children’s Hospital of Austin

Table 5-3: Summary of Data Collected for Dell Children’s Hospital of Austin

<table>
<thead>
<tr>
<th>Key green factors</th>
<th>Dell Children's Hospital of Austin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transparent delivery process in relation to green outcomes</td>
<td>The project members were aware of the green outcomes. The project was going to be LEED Platinum from the beginning and all the team members were aware of this aspect. There were no significant delays or rework due to poor communication issues, but only a few minor issues during the documentation process that could be related to the team experience with green outcomes.</td>
</tr>
<tr>
<td>Early adoption of green</td>
<td>The notion of green was introduced during the programming stages - it was there from the beginning. The owner proposed that this hospital be LEED Platinum and took a &quot;do whatever it takes approach&quot; without sacrificing it or backing out. The green objectives were discussed periodically in relationship to the project goals and objectives and the team trained on the LEED certification process.</td>
</tr>
<tr>
<td>Business case for green initiatives</td>
<td>The project budget has been aligned with the environmental project goals and the corporate mission from the start. Life-cycle analysis studies were performed and found out that the facility will have $6-8 million savings in energy costs the first 20 years and that every dollar a non-profit healthcare organization saves on energy is equivalent to generating new revenues of $20 for hospitals and $10 for medical offices. The payback period is 6-7 years.</td>
</tr>
<tr>
<td>Owner commitment</td>
<td>The decision to pursue LEED Platinum was all based on the owner. The owner has been the green driver of the project and also introduced it. They never said it was too difficult and that they would be satisfied with silver.</td>
</tr>
<tr>
<td>Architect and CM commitment to green and a consistent approach</td>
<td>Both the construction manager and architecture team have worked on more LEED certified buildings after this project, and are committed to green and sustainability. The architecture team is greening their specifications, and feel it is the right thing to do even if the owners do not request it. They want to promote themselves as green experts.</td>
</tr>
<tr>
<td>Early team selection/team experience</td>
<td>The team was brought together through a LEED workshop in the beginning. The workshop was organized by Greg Franta from Ensara (now part of the Rocky Mountain Institute). All the teams were represented at this meeting. None of the teams had previous experience with LEED certified projects. The architect does a lot of work on healthcare facilities. The team does not have previous experience as a unit.</td>
</tr>
<tr>
<td>Selection of green features that naturally align with the other project goals</td>
<td>The team selected green features that aligned with the project goals and encouraged patient healing (daylighting, low VOCs). The team suggests these features should be done on every project – “it is the right thing to do”</td>
</tr>
<tr>
<td>LEED points</td>
<td>The project is on track for achieving Platinum certification with 53-56 points. They are going for all the 10 points in the Optimize Energy Performance due to the combined heat and power plant. There was an extensive amount of energy modeling performed.</td>
</tr>
<tr>
<td>Commissioning process</td>
<td>One of the owner's representatives had previous experience in consulting and commissioning so the facilities manager decided that the commissioning be done in house. The commissioning was specified early and overseen by the owner who is a mechanical engineer.</td>
</tr>
<tr>
<td>Energy Modeling</td>
<td>The energy modeling was overseen by the engineering firm on the project. At the end of the design development phase, the engineering firm was provided with the load profile - Austin energy helped with the energy modeling also. This is what made the difference in achieving platinum from the LEED point’s perspective.</td>
</tr>
<tr>
<td>Integrated Approach</td>
<td>The project had regular eco-charettes that were monthly at first and quarterly towards the end of the project. All the stakeholders were present: architecture team, sustainability consultant, construction management team, landscape architecture, subcontractors, Austin Energy.</td>
</tr>
<tr>
<td>Role of the CM</td>
<td>The biggest responsibility for the construction management team is the recycling and waste management plan which account for 2 points in the LEED certification. They achieved 92% recycling due to the site being a previous airport runway. The construction management team was involved from the beginning of the project doing construction budgets for the mechanical and electrical systems. They had weekly safety meetings where they would discuss construction waste recycling and LEED aspects.</td>
</tr>
<tr>
<td>cost/ sq footage, construction cost</td>
<td>Cost of project: $200 mill, 169 beds, 175000 sq ft.</td>
</tr>
</tbody>
</table>
### 5.2.2 Children’s Hospital of Pittsburgh

#### Table 5-4: Summary of Data Collected for Children’s Hospital of Pittsburgh

<table>
<thead>
<tr>
<th>Broad key green process</th>
<th>Children’s Hospital of Pittsburgh</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transparent delivery process in relation to green outcomes</strong></td>
<td>The project teams have been aware of the project outcomes. The architecture and general contractor teams were selected based on experience with healthcare and green facilities. Pursuing LEED took a significant amount of rework, mainly identifying appropriate points and changing the specifications and energy modeling.</td>
</tr>
<tr>
<td><strong>Early adoption of green</strong></td>
<td>The notion of green was introduced by the owner, but the architecture team has been the driver throughout the project. Green was not introduced from the beginning, but at the initial design process for the final site selection.</td>
</tr>
<tr>
<td><strong>Business case for green initiatives</strong></td>
<td>Green was part of the overall hospital vision and &quot;the right thing to do&quot;. While there is not a specific business case performed and life-cycle analysis data is not available some of the team members believe the project has 5%-10% higher first costs.</td>
</tr>
<tr>
<td><strong>Owner commitment</strong></td>
<td>The owner along with the lead engineer championed the green pursuit. The owner shows green commitment throughout the project.</td>
</tr>
<tr>
<td><strong>Architect and CM commitment to green</strong></td>
<td>The teams are committed to sustainability if the owner requests it.</td>
</tr>
<tr>
<td><strong>Early team selection/team experience</strong></td>
<td>The teams have previous experience with healthcare facilities and green buildings. Experience played an important role in the hard bid qualified selection of the general contractors.</td>
</tr>
<tr>
<td><strong>Sustainable compatibility - selection of green features that naturally align with the other project goals</strong></td>
<td>The green features aligned with the project goals: healing gardens (family centered care and patient quality), system integration (technological sophistication and quiet building.</td>
</tr>
<tr>
<td><strong>LEED points</strong></td>
<td>On track for LEED certification, 31 points. &quot;LEED is not a moneymaker for the architects. It costs time to develop the details and pursue the points and is not profitable.&quot; break-out of points is attached in Appendix A.</td>
</tr>
<tr>
<td><strong>Commissioning process</strong></td>
<td>Commissioning process is part of the green building aspect but also how they structure project. They used a division 17 system. Johnson controls is doing Division 17 and commissioning. Aramark is doing commissioning. The chief of facilities is in charge of commissioning from the owner’s side. They will achieve 1 point in the LEED check-list.</td>
</tr>
<tr>
<td><strong>Energy Modeling</strong></td>
<td>The engineering team believes that energy modeling is expensive. The expense is on the engineering side more than architectural. It costs to develop the details to pursue the points and it not profitable. There was a significant amount of rework due to the energy modeling.</td>
</tr>
<tr>
<td><strong>Integrated Approach</strong></td>
<td>Eco-charge-ttes were not conducted in the beginning. They have regular meetings now. The lack of an integrated approach resulted in delays and rework.</td>
</tr>
<tr>
<td><strong>Role of the CM</strong></td>
<td>1] NO recycling 2] We were not the CM [we are a GC] and we not involved with the design aspects of the job 3] We had no involvement with preconstruction [this was a traditional design, bid, build] 4] VE was not worth mentioning. We had a few alternates accepted but they were pretty much equipment issues 5] We did do a documentation process</td>
</tr>
<tr>
<td><strong>cost/ sq footage , construction cost + delivery method</strong></td>
<td>1,000,000 sq ft(300 parking spaces) , 296 beds, $420 mill ; fast-track CM at risk first and now design-bid-build</td>
</tr>
</tbody>
</table>
### 5.2.3 Hershey Medical Center Children’s Hospital

Table 5-5: Summary of Data Collected for the Hershey Medical Center Children’s Hospital

<table>
<thead>
<tr>
<th>Broad key green process</th>
<th>Hershey Medical Center Children’s Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transparent delivery process in relation to green outcomes</td>
<td>All the project members have been aware that this will be a LEED certified project. The project is in the schematic design phase right now and there having not been any delays or rework due to green. Green is not mentioned in any of the monthly meetings.</td>
</tr>
<tr>
<td>Early adoption of green</td>
<td>The LEED certification has been driven by a Penn State mandate that all new buildings achieve this basic measure of sustainability. The notion of green has been there from the beginning, but the green objectives have not yet been discussed in relation to overall project goals and objectives. The team has not been trained yet on the sustainable objectives.</td>
</tr>
<tr>
<td>Business case for green initiatives</td>
<td>A case has been made for infection control, but not for green in general. The Penn State LEED mandate is based on the business case for reduced life-cycle costs.</td>
</tr>
<tr>
<td>Owner commitment</td>
<td>Penn State (the owner) has been the driver of the project due to the university-wide mandate. The previous owner's representative was pushing LEED and GGHC.</td>
</tr>
<tr>
<td>Architect and CM commitment to green and a consistent approach</td>
<td>The teams have an average commitment to sustainability in comparison to other architecture and construction firms.</td>
</tr>
<tr>
<td>Early team selection/team experience</td>
<td>The teams have had experience with healthcare facilities and somewhat with green buildings also. The teams did not experience as a unit previously, nor do they have a sustainability consultant. There are LEED certified professionals in the architecture team taking care of the documentation,</td>
</tr>
<tr>
<td>Sustainable compatibility - selection of green features that naturally align with the other project goals</td>
<td>N/A</td>
</tr>
<tr>
<td>LEED points</td>
<td>LEED certification 31 points</td>
</tr>
<tr>
<td>Commissioning process</td>
<td>The commissioning has been specified early and there are funds allocated for it in the budget. Facilities Planning will perform it.</td>
</tr>
<tr>
<td>Energy Modeling</td>
<td>Energy modeling is performed by the architecture team -part of the contract.</td>
</tr>
<tr>
<td>Integrated Approach</td>
<td>The team had regular monthly stirring committee meetings and user group meetings, but no eco-charettes have been conducted.</td>
</tr>
<tr>
<td>cost/ sq footage , construction cost + delivery method</td>
<td>252000sf, $201 mill, design-bid-build with GMP</td>
</tr>
</tbody>
</table>
5.2.4 Children’s Hospital of Philadelphia

Table 5-6: Summary of Data Collected for the Children’s Hospital of Philadelphia

<table>
<thead>
<tr>
<th>Broad key green process</th>
<th>Children's Hospital of Philadelphia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transparent delivery process in relation to green outcomes</td>
<td>The Children's Hospital of Philadelphia had an experienced team of architects and professional engineers and although the hospital did not seek certification it would have been easy to achieve green</td>
</tr>
<tr>
<td>Early adoption of green</td>
<td>The notion of green was not proposed related to LEED certification, but the project was approached with sustainability in mind conducive to a healing environment for the children</td>
</tr>
<tr>
<td>Business case for green initiatives</td>
<td>The team invested in the indoor environmental quality aspects such as terminal HEPA filters and daylighting. Computational fluid dynamic studies were performed in relation to daylighting in the patient rooms. The façade is a &quot;European double wall&quot; with louvers on top and bottom, decreases AC load in the summer and heating load in the winter.</td>
</tr>
<tr>
<td>Owner commitment</td>
<td>The owner's representative is committed to green but believes LEED can be considered a &quot;waste of good money&quot;</td>
</tr>
<tr>
<td>Architect and CM commitment to green and a consistent approach</td>
<td>N/A</td>
</tr>
<tr>
<td>Early team selection/ team experience</td>
<td>The teams had previous experience with healthcare facilities.</td>
</tr>
<tr>
<td>LEED points</td>
<td>N/A</td>
</tr>
<tr>
<td>Commissioning process</td>
<td>They had a commissioning process in place from the start.</td>
</tr>
<tr>
<td>Energy Modeling</td>
<td>They had a commissioning process in place from the start. They performed energy modeling. The design uses diesel generators tied back to a peak-shave system. By using its emergency generators regularly during the air-conditioning season, the hospital has reduced its dependence on utility-supplied power. During Philadelphia's hot summers, the hospital saves 15 to 18% in power expenditures. 4 760KW natural gas generators provide cogeneration and shave peak electricity demand. The estimated savings are $240,000/year or 5% of the electric bill</td>
</tr>
<tr>
<td>Integrated Approach</td>
<td>The project had regular meetings throughout and approached it with the idea that healthcare facilities require a more integrated approach than regular office buildings.</td>
</tr>
<tr>
<td>Role of the CM</td>
<td>N/A</td>
</tr>
<tr>
<td>cost/ sq footage, construction cost + design</td>
<td>410$/sf 165 beds new emergency department + 1 floor of 24 beds</td>
</tr>
</tbody>
</table>
5.3 Process Maps

The important relationships, information and decisions concerning the delivery of the four projects are emphasized and communicated through these process maps. The maps are then analyzed and compared in order to identify possible improvements in the delivery of these hospitals. The depth of detail for the maps is similar for each case study, with the exception of the Children’s Hospital of Philadelphia where there was less data available to create the process map.
5.3.1 Dell Children’s Hospital of Austin

Figure 5-1: Dell Children’s Hospital Process Map
5.3.2 Children’s Hospital of Pittsburgh

Figure 5-2: Children’s Hospital of Pittsburgh Process Map
5.3.3 Hershey Medical Center Children’s Hospital

Figure 5-3: Children’s Hospital at Hershey Process Map
5.4 Summary

This chapter describes the data collection procedures and the rationale for each method. The data collection procedure provides information regarding the identification of respondents, the interview process and research bias in the interviews. A data collection instrument is provided with the key green factors investigated in this study. A synthesis and summary of the data collected is provided for each case study, and similarly process maps were created to identify the critical events in the delivery of each project.
Chapter 6: Data Analysis and Results

6.1 Introduction

Data analysis consists of categorizing the data collected, examining, tabulating, and recombining the quantitative and qualitative data for the four case studies investigated to address the research questions.

The major unit of analysis in this research project is the delivery process as a whole. Different parts such as the programming stage or schematic design will be analyzed and compared between the case studies. The different parts of the delivery process and issues, such as owner commitment, transparency in the delivery process, are analyzed and compared between the case studies, and they are considered individual embedded units of analysis. The first step in the analysis is linking data to the expected outcomes presented in Chapter 3. The main methods for analyzing the data are pattern-matching analysis, cross-case synthesis and comparisons between the process maps. These methods are thoroughly presented below.

6.2 Project Data Comparisons and Analysis

The main methods used to analyze the findings in this research study involve comparative analysis based on pattern-matching and cross case analysis. The data analysis uses the tables in the previous chapter to categorize, examine, tabulate and recombine the data. Prior to the actual analysis, the data has been manipulated in the data collection chapter by:
• Putting the information into different arrays
• Making a matrix of categories and placing the evidence within such categories
• Creating process maps for examining the data

Putting information into chronological order, such as the phases in the building delivery process of each case study

6.2.1 Data Collection Tool Comparisons

Using the pattern-matching and cross-case techniques, comparisons have been made between the four case studies for each of the factor investigated. The factors are divided into specific attributes, and their occurrence in each case study is depicted in the following tables

• "█" represents that the specific attribute is existent within the case study, based on multiple sources of evidence. For example, a sustainability filter has been applied to all decisions at Dell and that is represented by a “█”

• “▌” represents that the specific attribute was somewhat existent in that case study. For example, at Hershey the team had some previous experience with green buildings but they are not considered experts in this field and that is represented by a “▌”

• An empty box represents that the attribute is not specific to the case study, and it is not existent in the case study based on the interviews with the specific stakeholders
• N/A suggests that data is not available for the case study, or not applicable.

Multiple stakeholders were interviewed in order to arrive to these results.

• *Transparent delivery process in relation to green outcomes*

<table>
<thead>
<tr>
<th>Specific attributes</th>
<th>Dell CH</th>
<th>Hershey CH</th>
<th>CH Pittsburgh</th>
<th>CH Philadelphia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrate sustainable project objectives well with other delivery aspects during programming, design and construction</td>
<td>□</td>
<td></td>
<td>□</td>
<td>N/A</td>
</tr>
<tr>
<td>Sustainable attributes are not singled out as additional requirements</td>
<td>□</td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Thoroughly communicate the project's sustainable attributes to each project member</td>
<td>□</td>
<td></td>
<td>□</td>
<td></td>
</tr>
</tbody>
</table>

Process visibility in relation to green outcomes and strong communication of the project green outcomes to the team are important attributes in the delivery of a LEED certified building. As seen in the table above, at the Dell Children’s Hospital of Austin, achieving LEED Platinum was a top priority for the project team and well integrated from the beginning with the other delivery aspects during programming, design and construction. The hospital was to be designed LEED Platinum from the start, and the sustainable attributes were not singled out as additional requirements. They had monthly eco-charette meetings at first and then quarterly, where all the project teams were involved, and where the project’s sustainable goals were thoroughly communicated to each project member. In contrast, at the Hershey Children’s Hospital there are no discussions about LEED yet in the schematic design phase of the project. There are numerous monthly meetings, but the LEED aspects are not being discussed yet. At the Children’s Hospital of Pittsburgh, LEED was seen as an extra aspect of the project, and
that resulted in delays and rework. The LEED goals are well integrated now throughout the project in the construction phase at the Children’s Hospital of Pittsburgh.

- **Early adoption of green**

<table>
<thead>
<tr>
<th>Specific attributes</th>
<th>Dell Children's Hospital of Austin</th>
<th>Hershey Medical Center Children’s Hospital</th>
<th>Children's Hospital of Pittsburgh</th>
<th>Children's Hospital of Philadelphia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enabled a more clear understanding of project scope requirements and project needs</td>
<td>■</td>
<td>■</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Saved project rework due to accurate project bids and costs</td>
<td></td>
<td></td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Saved time for incorporating sustainable objectives later in the project</td>
<td>■</td>
<td>■</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Sustainability filter applied to all decisions</td>
<td>■</td>
<td></td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

The notion of green was introduced very early in the programming phases by the owner at the Dell Children’s Hospital and similarly at Hershey it is a campus-wide mandate for the Penn State campus. The owner at Dell proposed that this hospital be LEED Platinum and took a "do whatever it takes approach" without sacrificing it or backing out. The green objectives were discussed periodically in relationship to the project goals and objectives and the team was trained on the LEED certification process.

At the Children’s Hospital of Pittsburgh the adoption of green happened in the design phases of the project. A sustainability filter seems to have been applied to all decisions at the Dell Children’s Hospital, but not at the other children’s hospital. An early adoption of green enabled a more clear understanding of the project goals and needs at Dell, but due to lack of previous team experience with LEED there have been a few issues with bids and costs in regards to the LEED aspects. 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.

- *Business case for green initiatives*

<table>
<thead>
<tr>
<th>Specific attributes</th>
<th>Dell Children's Hospital of Austin</th>
<th>Hershey Medical Center Children’s Hospital</th>
<th>Children's Hospital of Pittsburgh</th>
<th>Children's Hospital of Philadelphia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project budget aligned with environmental project goals</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>N/A</td>
</tr>
<tr>
<td>Life-cycle cost analysis data to justify operational savings</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Payback period for sustainable objectives</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

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 the 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. Tom Sneary, the lead architect at Dell says “There were four basic guidelines: don’t do anything stupid, ensure that strategies meet a payback period of 6.7 years or 12 percent ROI, research and consider life cycle of components in assessments, and achieve LEED Platinum.” The Children’s Hospital of Philadelphia uses a combined heat and power plant, similarly to Dell, and life-cycle cost analysis calculations have been performed on operational savings and the payback period.
• Owner commitment

<table>
<thead>
<tr>
<th>Specific attributes</th>
<th>Dell Children's Hospital of Austin</th>
<th>Hershey Medical Center Children's Hospital</th>
<th>Children's Hospital of Pittsburgh</th>
<th>Children's Hospital of Philadelphia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased commitment from the owner side leads to better project planning and to better cost and schedule performance</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

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 at the Children’s Hospital of Pittsburgh was committed to green as part of the overall vision, and believes that the LEED certification is “the right thing to do” in a children’s hospital. In the case of the Hershey Medical Center, the LEED certification is a Penn State mandate. At the Children’s Hospital of Philadelphia, the owner was committed to green features that would reduce operational savings and therefore provide a more affordable healthcare cost for the patients.

• Architect and construction manager/ general contractor commitment to green and a consistent approach

<table>
<thead>
<tr>
<th>Specific attributes</th>
<th>Dell Children's Hospital of Austin</th>
<th>Hershey Medical Center Children’s Hospital</th>
<th>Children's Hospital of Pittsburgh</th>
<th>Children's Hospital of Philadelphia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better delivery in regards to green aspects if teams are committed to sustainability as one of their core values regardless of owner commitment</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Most of the teams are starting their involvement in LEED certified projects and are relatively new to the delivery of green building. The architecture firm for the Dell Children’s Hospital is greening their specifications, and they are promote themselves as green experts. They hope to achieve LEED certification in every project without the owner asking for it. The architecture firm at Dell is also the interior architecture firm at the Children’s Hospital of Philadelphia. In addition, the architecture firm at Philadelphia seems to be committed to sustainability and embrace it in every project. The construction firms are all at a similar level of commitment to green.

- **Team experience/ early team selection**

<table>
<thead>
<tr>
<th>Specific attributes</th>
<th>Dell Children's Hospital of Austin</th>
<th>Hershey Medical Center Children’s Hospital</th>
<th>Children's Hospital of Pittsburgh</th>
<th>Children's Hospital of Philadelphia</th>
</tr>
</thead>
<tbody>
<tr>
<td>bringing the teams together early engages critical process integration and allows system and environmental knowledge to evolve as design begins</td>
<td>![ ]</td>
<td>![ ]</td>
<td>![ ]</td>
<td>N/A</td>
</tr>
<tr>
<td>Individual experience of team members with healthcare facilities</td>
<td>![ ]</td>
<td>![ ]</td>
<td>![ ]</td>
<td>![ ]</td>
</tr>
<tr>
<td>Team experience with green buildings</td>
<td>![ ]</td>
<td>![ ]</td>
<td>![ ]</td>
<td>![ ]</td>
</tr>
<tr>
<td>Previous team experience as a unit</td>
<td>![ ]</td>
<td>![ ]</td>
<td>![ ]</td>
<td>N/A</td>
</tr>
<tr>
<td>Sustainability consultant from the beginning</td>
<td>![ ]</td>
<td>![ ]</td>
<td>![ ]</td>
<td>N/A</td>
</tr>
</tbody>
</table>

The whole team was brought together very early at Dell, through a 2 day LEED charrette. This eco-charrettes was facilitated by an experienced sustainability consultant, working for the Rocky Mountain Institute. The eco-charrettes took place every month afterwards, and all stakeholder groups were represented. In regards to team experience, 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 certain
individuals had limited experience. The owners were not experienced with LEED in any of the case studies. 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 Hershey team is the only team that had previous experience as a unit before; they are working together on the Cancer Institute at the Hershey Medical Center. The Dell Children’s Hospital had an experienced sustainability consultant throughout the project who guided the green aspects and the documentation process.

- **Commissioning process**

<table>
<thead>
<tr>
<th>Specific attributes</th>
<th>Dell Children's Hospital of Austin</th>
<th>Hershey Medical Center Children's Hospital</th>
<th>Children's Hospital of Pittsburgh</th>
<th>Children's Hospital of Philadelphia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality assurance must be focused on the specifications phase, rather than after installation. Commissioning should be specified early</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

At Dell, one of the owner's representatives had previous experience in consulting and commissioning so the facilities manager decided that the commissioning be done in house. The commissioning was specified early and overseen by the owner who is a mechanical engineer. Extensive commissioning was required due to the nature of the mechanical equipment and the combined heat and power plant. Similarly, at the Children’s Hospital of Philadelphia commissioning was an important aspect of the delivery process.
The commissioning has been specified early at Hershey and there are funds allocated for it in the budget. Facilities planning will perform it. At the Children’s Hospital of Pittsburgh, the commissioning process is part of the green building aspect but also how they structure the project. They used a Division 17 system. Johnson controls and Aramark are doing Division 17 and commissioning. The chief of facilities is in charge of commissioning from the owner’s side. They will achieve 1 point in the LEED certification, similarly to Hershey, while dell is on track to receive 2 credits.

- **Energy Modeling**

<table>
<thead>
<tr>
<th>Specific attributes</th>
<th>Dell Children’s Hospital of Austin</th>
<th>Hershey Medical Center Children’s Hospital</th>
<th>Children’s Hospital of Pittsburgh</th>
<th>Children’s Hospital of Philadelphia</th>
</tr>
</thead>
<tbody>
<tr>
<td>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</td>
<td>■</td>
<td></td>
<td></td>
<td>■</td>
</tr>
</tbody>
</table>

The Dell Children’s Hospital and the Children’s Hospital of Philadelphia 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 for Dell. 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 hospital and a few of the surrounding facilities. Both the Children’s Hospital of Pittsburgh and the Hershey Children’s Hospital had some energy modeling performed, but the Energy and Atmosphere LEED category section was not their main focus. Additional data on energy modeling at Dell is included in the appendices.
6.2.2 Pattern-matching analysis

Pattern-matching logic compares an empirical based pattern with a predicted one. If the pattern coincides, the results strengthen the internal validity of the case study research.

The predicted pattern for this research suggests that higher levels of transparency, owner commitment, early adoption of green, team experience, commissioning and energy modeling are required for a project to achieve LEED Platinum and be successful in terms of cost, quality and time. In other words, these levels of commitment based on the project teams increase as the LEED certification level goes up.

![Pattern-matching analysis diagram]

Figure 6-1: Pattern-matching analysis
Pattern matching techniques are widely used in computer science where input values are treated as patterns and matches are sought in the search database. Similarly in this research, the processes/factors are sought within each case study.

Figure 6-1 above shows a graphical representation of the results by matching the green building factors with each case study. This model was created using Microsoft Visio. The red arrows represent a high level of commitment from the team in respect to each factor; similarly, the black arrows are one step below red, representing an average level of commitment based on comparisons with the other projects in this case study and also project reviewed through the Lean and Green Research Initiative database and literature. The blue arrows represent a low level when compared to the other projects, while the white arrows indicate that data was not available or the respective factor does not apply for those projects.

The patterns, prior to performing the data collection and analysis, have been expected to be mostly red toward the top, for the LEED Platinum project and transitioning to blue towards the bottom, for the project that received no LEED certification.

In contrast to the expected outcomes, the project that did not seek LEED certification performed better than the projects that are LEED Certified in a few aspects such as energy modeling, commissioning process and the use of project teams that are committed to sustainability as one of their core values.

This graphical representation of the results shows that the key processes are found within each case study, but at different levels. There is a higher commitment and presence of the factors in the LEED Platinum project.
6.3 Comparisons of Process Maps

The process maps show how the building delivery process occurs for each case study and gives of explanation for “when” specific aspects of the project happened. The process maps are used in the analysis process along with the other methods discussed previously. The modeling approach described in the data collection chapter is used to map the delivery process from master planning through programming, design, procurement and construction. The process maps are used for these functions:

- To understand the sequence of events that make up the delivery process and the interactions between team members
- To understand key decisions related to greening and LEED certification
- To allow comparisons to be made regarding critical aspects in the delivery of a green children’s hospital

The project delivery system selected played an important role in depicting the sequence of delivery phases for each case study. The delivery systems for each case study are presented below:

- Design-bid-build or Design-GMP-Build at the Hershey Medical Center Children’s Hospital. This is a very traditional process in the construction industry, where the owner contracts separately with a designer and a contractor.
- Fast-track Design-bid-build at the Dell Children’s Hospital of Austin contractually but acted as a fast-track design-build due to the high coordination and integration.
• Fast-track Construction Management at risk at the Children’s Hospital of Philadelphia where the owner contracted with a design company to provide a facility design. The owner separately selected the contractor to perform construction management services and construction work in accordance with the plans and specifications for a fee.

• The Children’s Hospital of Pittsburgh started out as a fast-track construction management at risk, but because the budget number was rising and costs were soft, UPMC decided to stop design and construction and move away from this delivery system to a traditional design-bid-build.

**Delivery Phases and Stakeholder Involvement**

The notion of building a separate Children’s Hospital for the Hershey Medical Center began over ten years ago. Part of the master plan included two high profile buildings: the Cancer Institute and the Children’s Hospital. The programming phase took longer than a traditional project due to issues they had related to the addition of a surgical floor, costs involved and realization of growth in the number of beds. This oscillating process took two and a half years. In 2005 through 2006 the programming phase shaped up where user group meetings, site visits, and consultants developed a preliminary layout for the hospital. The hospital is currently in the schematic design phase focusing on space layout, theming, design in relation to security issues, IT services and departments in order to insure high levels of quality, safety and family-centered care.
The Children’s Hospital of Philadelphia considered several sites before selecting the final St. Francis site as the location for the new hospital. Schematic design has started for a previous Montefiori site, but due to concerns about traffic and impacts of construction during hospital operation UPMC purchased the current St. Francis Site where a new master plan and schematic design were prepared. The architectural engineer applied the Zaltman Metaphor Elicitation Technique (ZMET) to guide and solidify programming efforts. ZMET is based on the premise that 95% of thought occurs in the unconscious mind and it was used to capture the end users’ emotional, intellectual and experiential expectations and needs. Due to considerable budget escalations and unresolved value engineering decisions, the entire design and construction stopped in 2004. The project moved to a design-bid-build approach because UPMC believed it would provide them with a solid cost; this decision led to the selection of a new contractor. The construction is expected to be completed in 2009.

Similarly, the Dell Children’s Hospital of Austin went through a programming phase, schematic design, design development, issue of construction documents and construction, but in a much shorter period of time compared to the projects described above. The project started in 2002 with the programming phase and it was completed in June 2007. There were no significant delays, oscillations in spatial requirements or budget. Austin Energy, the city owned utility, played a major role in the project. They were partners with Seaton to build the combined heat and power plant, which provides all the energy to the hospital. Similarly to this project, the Children’s Hospital of Philadelphia worked with the local utility and is using a combined heat and power plant.
to provide the energy. There were 3 main bid packages in the project, similar to the Hershey project: site and foundation work, building shell, interiors and MEP work.

**Greening Aspects**

For the Children’s Hospital of Pittsburgh, the design essentially went through two design processes. During the first schematic design phase, greening was not introduced, but during the second design phase at the current site 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 be certified. The owner decided to pursue LEED certification for the hospital, and the decision process took about one year. A state grant of $5M allowed for the research building to pursue LEED silver, which was introduced early in 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, the codes, such as lighting, HVAC, and windows in patient room, drove the design, instead of LEED driving the design. The designer stated that the greening process was not unusual, but good design practice. Greening impacted the engineers’ work more than the architects’ work. It was important for the designer to make sure the building worked, rather than chasing points. The largest effort from the designer is calculating points, and changing specifications.

As noted earlier, the Hershey Medical Center Children’s Hospital is to achieve LEED certification a goal that has largely been driven by a Penn State mandate that all new buildings achieve this basic measure of sustainability. 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 previous owner’s representative 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 to pursue Green Guide for Healthcare Operations credits.

At Dell, the idea of a green LEED Platinum facility was part of the request for proposal put out by the owner. From the very beginning the concept was the same: the facility was to be designed and constructed LEED Platinum. They had a 2 day LEED charrette before schematic design, guided by the sustainability consultant Greg Franta from Ensara, now part of the Rocky Mountain Institute. The eco-charrettes continued throughout the delivery of the project. There have been a few delays in the process due to lack of team experience with LEED and green buildings.

In conclusion, the process maps aid the research analysis by depicting “when the most critical aspects happened in the delivery process of each project. Programming is the most crucial time for sustainability decisions to be made. Early involvement of stakeholders is correlated with project success in terms of costs, delays and timeline. Similarly, a sustainability consultant and early involvement of the construction manager and sub-contractors can add to the project success. For the case studies investigated, early adoption of green saved project rework at Hershey and Dell, but that did not happen at the at Children’s Hospital of Pittsburgh. Also, the commissioning process and energy modeling should be specified in the pre-design stages.
6.4 Results

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 four 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.

The results of the cross-case and pattern-matching analysis indicate that the factors investigated were very important in the delivery of the four children’s hospitals. The factors that showed to be most important happened in the pre-design and programming stages of the delivery process for each facility such as owner commitment from the start, early adoption of green and specifying commissioning and energy modeling early in the programming phases of the project. The owner commitment to green initiatives played a very crucial role in the successful delivery of the LEED Platinum Dell Children’s Hospital of Austin, along with a strong commitment from the rest of the team. A well integrated process during design and construction where sustainable attribute are not singled out as additional requirements is ideal in the delivery of any LEED certified project. Having an expert sustainability consultant from the beginning, who will guide the team through the LEED process is crucial for the delivery of a green children’s hospital and can save a lot of work and costs. Previous team experience with green and healthcare facilities showed to influence the projects positively at the Children’s Hospital of Pittsburgh and the Children’s Hospital of Philadelphia. The
lack of team experience with LEED certified projects has caused a few delays in regards to the certification process at the Dell Children’s Hospital of Austin.

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 teams at the Children’s Hospital of Pittsburgh and the Dell Children’s Hospital of Austin 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 throughout the design and construction process at Dell 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.

6.5 Summary

This chapter presents the methods used to analyze the data. A cross-case analysis was performed in order to identify similarities and differences between the projects and
the factors that are most important in the delivery of the case studies. Subsequently, a pattern-matching analysis was performed in order to identify striking patterns and models between the factors identified as critical and the level of sustainability achieved by each project. The last step in the analysis process involves comparisons between the process maps, with a focus on the delivery phases and greening aspects. Finally, the outcomes from this research are summarized and presented with a focus on the critical issues necessary for the delivery of a successful green children’s hospital.
7.1 Research Summary and Outcomes

The goal of this research has been to provide an understanding of the building delivery process of green children’s hospitals, based on the four case studies available. An emphasis has been placed on how the delivery process, the project environment and the stakeholders present in each project affect the final product. Critical factors in the delivery of green children’s hospitals have been identified through the literature review and the interviews with industry professionals. These factors have been researched into detail and analyzed to provide an insight into their importance in relationship to the delivery of green children’s hospitals and the level of sustainability and LEED certification being sought by each hospital. Process maps were modeled in order to identify the sequence in the delivery phases, timing of the stakeholder involvement and their relationship to the greening aspects.

The research findings show that the factors investigated are critical in the delivery of a successful green children’s hospital and are found in various degrees and levels in the 4 case studies investigated. The research findings show that a strong owner commitment to sustainability, family-centered care and a healing environment are very important in the delivery of a children’s hospital. Dedication, belief, commitment and executive mindset play a very important role in the delivery of the four case studies investigated. The factors investigated in this research, such as transparent delivery process in relation to green outcomes, adoption of green aspects early in the process, a business case for green initiatives, team experience with green and healthcare facilities, the commissioning process and energy modeling are common between the case studies but at very different levels. The study shows
that there is a stronger occurrence of these factors in the LEED Platinum projects than the other three case studies investigated.

The key factors in the delivery of a green children’s hospital are listed and explained below and outcomes resulting from each:

1) **Transparent delivery process in relation to green outcomes:** Integrating the sustainable project objectives well with other delivery aspects during programming, design and construction and not singling them out as additional requirements can reduce delays, rework and costs for the project.

2) **Early adoption of green** enables a more clear understanding of project scope requirements and project needs. The adoption of green early in the project saves project rework due to accurate project bids and costs and saves time for incorporating these sustainable objectives later in the future.

3) **Business case for green initiatives:** life-cycle cost analysis to justify operational savings, having the project budget aligned with the environmental project goals and knowing the payback period for sustainable objectives can decrease misconceptions related to green building costing more than conventional buildings.

4) **Owner commitment:** increased commitment from the owner’s side leads to better project planning and to better cost and schedule performance.

5) **Architect and construction manager commitment to green** and a consistent approach: there is better delivery in respect to green aspects if the teams are committed to sustainability as one of their core values, regardless of the owner commitment.

6) **Early team selection/team experience:** bringing the team together early engages critical process integration and allows system and environmental knowledge to
evolve. Previous team experience and having a sustainability consultant contribute positively to the success of green healthcare projects.

7) **Commissioning process**: the commissioning process should be specified early and the quality assurance should be focused on the specification phase, rather than after installation. The commissioning process can have an influence on the cost, quality and timeframe of the project.

8) **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.

9) **Integrated Approach**: high integration between project participants contributes positively to achieving project goals.

The following cases were worth noticing:

- The architecture and the construction management team had to learn the LEED process “on the job” at the Dell Children’s Hospital of Austin and there were a very few cases when that negatively affected the project, but their commitment to LEED contributed greatly to the success of the project.

- There are different levels of owner commitment, commissioning, energy modeling, early adoption of green and an integrated approach for each of the projects investigated. The higher the levels in these categories, the less delays and rework the project experiences. And similarly, a LEED Platinum children’s hospital requires more commitment to these factors than a LEED certified project.
A strong commitment to green does not necessarily mean a strong commitment to the LEED certification process. At the Children’s Hospital of Philadelphia the team was committed to green aspects and sustainability in general but the LEED certification and documentation has not been a focus.

The findings provide a detailed description of each case study, with strong emphasis on the delivery process. The research results show that the delivery attributes vary with the level of sustainability being employed for each case study with the top three process attributes, in order of importance being:

1. Owner commitment
2. Expertise of project team members with the delivery of sustainable healthcare facilities, such as a sustainability consultant
3. Early timing of sustainable objectives being introduced.

The owner commitment played the most important role in the successful delivery of the four projects investigated, and this is different from previous research and industry experiences that state the early introduction of sustainable objectives is the most critical aspect. This outcome leads to some intriguing and potentially significant future research for understanding and improving the delivery process of green children’s hospitals.

7.2 Research Contributions

The following research contributions have been identified:
The main contribution of this research is the comparative analysis of the green healthcare facilities based on level of sustainability being sought, LEED certification and critical delivery processes. The following aspects are worth noting:

- *A listing of the most critical factors and processes in optimizing the design and construction process in green children’s hospitals.* The critical factors identified in this study could benefit any other healthcare facility if incorporated at the right timing in the building delivery process. The research shows that these factors can positively affect the cost, schedule and quality of the projects investigated

- *Methods to analyze processes and factors between projects with different levels of sustainability and LEED certification.* The pattern-matching analysis and the tabulated cross-case synthesis is an approach not taken before. This approach is beneficial in identifying key “ingredients” in the delivery of healthcare projects with different levels of sustainability and identifying models and patterns existent currently in the building healthcare industry.

### 7.3 Limitations

The green building market is just starting to rise in the U.S. and therefore green building projects are still limited. Moreover, only 2% of all LEED certified facilities are healthcare facilities. This restricted size of projects available for study restricts the findings of this research, coupled with time constraints for data collection and completion of the study. There are only four case studies used for this research. The limited amount of case studies for this research could not provide rigorous statistical analysis using pattern-matching and cross-case analysis, which could provide generalized findings in
regards to the factors investigated. The validation for this research could be greatly improved if more case studies were investigated.

7.4 Future Research

The research results have identified several areas that require further research efforts.

There is a need for a more comprehensive list of factors with more detailed specific attribute in order to gain a better understanding of each critical issue in the delivery. A larger case study sample size can be beneficial in rigorously validating each factor using statistical analysis and other methods. Research on the effect of each factor or lack of it in the delivery process based on delays, costs and schedule performance could be conducted. For example, a much closer look at energy modeling in healthcare facilities and the use of combined heat and power plants is an interesting aspect for improved energy efficiency in a type of facilities that run twenty-four hours every day.

More insight can be gained by only looking at “great” projects, possibly only LEED Platinum, and making comparative analysis between the processes they encompassed with a closer look at lessons learned, improvements that can be made and problems that could be avoided.

Another aspect to be researched in the future is the allocation of budgets for greening strategies in the pre-design phase, combined with an evaluation of individual experience of consultants with sustainable projects.

Owner commitment plays a very important role in the delivery of a green healthcare facility and therefore future research could include an analysis of the executive
mindset and what really drives sustainable projects to success. One question to be asked is “what steps are required for organizations to become sustainable-driven innovators?”

One interesting research aspect could be a more thorough look at the person, manager who oversees the green building delivery process and also the integration of management style in the team. The person who is responsible is key for success. personality; how they are leading and who is leading.
References


MacInnes, R. (2002). The Lean Enterprise Memory Jogger. Salem, Goal/QPC.


Appendix A: LEED check –lists

Hershey Medical Center LEED checklist

### LEED-NC Version 2.2 Registered Project Checklist -- 12/5/07
Hershey Medical Center Children’s Hospital
Hershey, PA

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### Indoor Environmental Quality

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### Innovation & Design Process

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### Project Totals (pre-certification estimates)

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**If all of the 'Yes' credits marked are achieved, we are on the threshold between Certified and Silver; by converting just a few 'Possible' credits into 'Yes,' we could achieve a Silver building!**
**Dell LEED Overview Transcript from Conversation with Dylan Sigler**

**On track** for Platinum:

**Sustainable Sites:**
Possible Points: **13 out of 14**

- **EXCEPT 5.1 Site Development: Protect or Restore Habitat**
- Reduced site disturbance to restore habitat: setting a large portion of the area to be restored with native plants; all native though and adaptive. Texas bioregion landscaping: design with local plants.

Not much underground parking, but flexible for construction of a parking garage.

Heat island effect: high albedo concrete, reflective.

**Water efficiency**
Possible Points: **4 out of 5**
- **EXCEPT**: innovative waste water technologies credit 2

Landscape irrigation water: both credits. Using no potable water for irrigation
Using only 95% non potable water from a municipal reclaimed system. Courtyard area: water not free of pathogens – 5% potable water

Extremely Low flow fixtures: 30% reduction in domestic water.

Dual flush toilets

**Energy and atmosphere**
Possible Points: **15 out of 17**
- Except: on site renewable energy Credit 2 Designed so it can accept PV panels later.
- Except Credit 6: Not eligible for the green power credit: purchasing the power from a green power source.

Combined heat and power plant provides the energy for the hospital.

Using a renewable source through the CHP

Attempting all 10 points for optimized energy performance through energy modeling

**Materials and Resources**
Possible Points: **7 out of 13**

- Except Credit 1.1, 1.2, 1.3 for building reuse because it is new construction
- Except Credit 7: Certified Wood
- Except Credit 2.2
- Except Credit 3.2

Not achieving building reuse because it is new construction. Materials reuse: contractor was adamant, didn’t want to do

Not achieving the certified wood credit due to value engineering

Exemplary performance on recycled content and regionally extracted materials: count as innovation and design credits.

Almost made it for construction waste management 92%...to make it, it would have to be 95% divert from landfill 95% of construction waste
Durability: not using products that couldn’t take hardware
Used rapid renewable materials: cork, composite wood containing wheat – materials that are soft, low maintenance and low-voc.
Interior of hospital a big issue: children are not little adults so they need a specific design aesthetic.

**Indoor Environmental Quality**
Possible Points: **13 out of 15**
- Except Credit 3.2 and Credit 8.2
- 2 credits the project will not be attempting
- Construction Indoor air quality management not attempted.
- Construction: filters that didn’t have the right filter …were replaced after occupancy so didn’t get credit. Incorrect filters installed in the air handling units before occupancy. They were replaced with the right ones shortly after occupancy but still didn’t get the credit.

- I can of spray paint .Spray paint that was not approved for the project: certain VOC apparent at that time before occupancy..
- White construction’s first LEED
- Indoor air quality big deal: pay attention to.
- Daylighting not achieved.
- Daylighting views for 90% - window in all patient rooms. Windows around perimeter. A lot of occupied areas, nurses, operating rooms do not have views to the outdoors. Natural lighting through a skylight.
- Daylighting difficult to achieve in a hospital. Use draft of LEED for healthcare.
- Achieve points in LEED for healthcare and submit for documentation for this credit.
- Restored habitat: use of building: a lot of floor area on treatment area…but they set aside a lot for contemplation, greenery and outdoor areas remarkable. LEED credit set up: you’re going to build your building and next to it set aside an open field and restore the field with native plants. Design goal to speak for its occupants worked against LEED.
- Fit tat into the whole scheme of the master plan.
- Recycled runway: construction waste diversion. Chopped up runways and used them as road base. Owners on site paired up with the Texas Commission on indoor environmental quality to remediate site. Contamination that was on site was due to runway deicer. Remediate all soil and then demolition happened.

**Innovation and Design credits**
Possible Points **5 out of 5**
- Many LEED accredited professionals
- Project designing an environmental education display will be bilingual and child focused
- Integrated pest management
- Recycled content and regionally extracted materials
DELL SUMMARY OF INFORMATION FOR DATA COLLECTION TOOL

Interview with Stephen Zilles – architect

1. Involvement of company with the project:
   In 2003, the vice-president of Seaton healthcare called the CEO of Karlsberger to interview for the job. Karlsberger worked with Seaton on other projects previously. This was when Karlsberger found out this was going to be a LEED project – right from the start.

2. Was this different design wise from any of the other projects?
   The products they used were not different than any other products – probably none were long lead items. From the beginning, they knew this was going to be a LEED Platinum, and it was very important that the owner decides the green aspects. The timeline for design was not different than other projects, lasting approximately 1 year with approximately 5 months for schematic design and 6 for design development. Stephen pointed out that they could have used more time for design planning and development.
   LEED did not affect the departments and their layout; it worked together with the concepts.
   Karlsberger also did the design for CHP.
   There is a lot of new construction in the area, part of the master plan. People can walk to work and such. The hospital was the first project in the Muller Development area.

3. Did the firm and the team have previous experience with LEED and healthcare facilities?
   This was the first LEED project for Karlsberger. They heard about it first back in 2002-2003 and at the time they were investigating it. After they got on board with the project, they also got involved with LEED.
   65-70% of their work is healthcare and they do a lot of children’s hospitals. He worked on projects in Phoenix, Louisiana and Philadelphia.
   They are getting more LEED projects now because of the Dell on which is getting a lot of publicity.

4. Does LEED go in any circumstances against the concept of patient healing…human perspective?
   Nothing comes to mind!
   Lo VOCs benefit it and so does recycling materials and dayligting. Boy, we should be doing that in any facility. The more daylighting you have –that’s a great healing environment. There are lots of courtyards, natural light and healing gardens. If you walk into a normal hospital you will not see a fraction of that daylighting.
Families are saying that it is so nice, it doesn’t look like a hospital and the patient rooms don’t look as

5. **Green Initiatives and features**
   - They needed to have a certain payback. They had a model set up and it was like “we will not do dumb things just to get a point”. Some things were no brainer such as the bicycle racks, same point for daylighting. They went after the easy ones, but also if they made sense. What came into play more was electrical and HVAC, they really impacted cost. 5-7 years for payback.
   - A big advantage for this project was Austin Energy, who did the combined heat and power plant which saved them costs – back-up generators they wouldn’t normally have.
   - Children’s hospitals are unique to their environment. They used local materials; materials that everybody is familiar with. The healing gardens have a feel of familiarity with local materials from Texas.
   - There are six healing gardens; they provide a way for daylighting – people can go to a different courtyard everyday if they wanted to.

6. **Studies after occupation**
   - They plan on doing research at Dell on evidence-based design and similar issues. They have an office in Ann Arbor that focuses on research. It is a matter of collecting the data. How do you see the difference between LEED and a conventional building? Research has to be done.

7. **Eco-charettes and sustainability consultant**
   - Greg Franta guided them through a LEED workshop in the beginning – mainly trying to see what’s involved in the whole process. He was one of the first people - he brought a few people with him at the workshop. Greg was with Ensara which is now part of the Rocky Mountain Institute. That’s how they met Gail Vittori. Bob Moroz knew Gail since they were both in Austin.

   - They had LEED charettes throughout. They had a monthly meeting for design in Austin and they were holding LEED meetings as part of all the meetings. They were giving updates on each particular LEED point: yes, no, maybe. The stakeholders at these meetings were: architecture, engineering, landscape architecture, owners side, plant operations person, and contractor.

8. **Priorities and goals**
   - First priority was to get a new facility, but LEED was very high and they didn’t want to sacrifice platinum. They didn’t want to sacrifice other things either for the platinum –financially it all came together.

   - First goal –all about the care and children make it state of the art. They thought from the beginning that the LEED certification would benefit the patients and the staff. It was not easier or harder compared to a regular hospital.

   - Most important advantage is for the patients- they only have good things to say.

9. **Owner commitment: the most important?**
   - Yes, all based on the owner. Never said it was too difficult and they would be satisfied with silver. They never wanted to back down from it. All the credit goes to the owner’s desire to have this happen. Karlsberger was committed to do that for them but it would not be surprising if the owner said, you know what, we have a budget problem here and to be satisfied with silver.
You need to have an owner that’s committed for a project like this. The owner said “this is what we want to do and we have to figure out a way to get it and we’ll help in whatever way we can”.

They could have easily backed down since it was the first LEED project for everybody. – a team of dedicated people who believe in LEED.

10. Indoor Environmental Quality
They had to meet the Texas Department of Health guidelines for infection control. They used linoleum flooring that is good for infection control; low VOCs; mechanical system with all filtration, makes a huge difference when flushing the system out; protect ductwork during construction – keep everything clean, a lot less dust due to requirements to minimize that; occupancy sensors – payback really good, no light switches.

11. Sustainability requirements/documentation/fees
They didn’t know what was involved. The amount of fee they collected was a lot less than it should have been for the effort. They were supposed to do all the documentation and then the owner hired Gail to do the consulting. Gail had a consulting fee and then a separate documentation fee – and Gail’s documentation fee was ironically a little bit less than what Karlsberger’s entire fee was so the owner said Gail is supposed to be doing the documentation.

They went back to talk to the owner and point out they didn’t know what to expect and wanted an additional fee. Their goal was to do a good job for the owner, and considering this was their first job they would have a higher fee if they had to do it again.

When contractors submit shop drawings they need to submit all the data required for the process. For this process manufacturers were not providing the data and the contractors were not trying had enough to get it. Hard information to pull out since this was a fast-track project. The construction manager was not good at forcing the contractors to get the information. Gail and Karlsberger struggled to get documentation from contractors.

12. Lessons learned
• The daylighting credit is just frustrating how they could not attain it. There is so much daylighting, a lot more than any other hospital.
• They used a lot of new materials that are not tested for durability, the particle board over plywood that has formaldehydes. They used wheat board instead and they don’t know how it will hold up. They also stopped making it through out the process. They couldn’t get some
• Great project to work on! no more difficult than just a normal project; nothing like “this is killing us because of the platinum”

13. Commitment to green
The office is greening their specifications. They feel it is the right thing to do even if owners don’t want to do it. They want to promote themselves as green experts.

They are pulling out specifications and replacing them with appropriate LEED materials and making sure products have been tested and have a track record. Hospitals are intended to last a long time – products have to be proven to last.

They can get almost every project LEED certified without having the owner ask for it. That is the way it should be – you have to start in the office; a lot of things don’t cost money and they can change them and it would benefit everybody.

14. Lean healthcare
It was not discussed this way but that is the way they design. They always try to minimize waiting times and being on display. All registration areas are out of the way. The patients should not be on display, because it makes some of them uncomfortable.

Hospital administrators are looking at this project to see if it gets platinum. “If you can do it, why shouldn’t we be doing this?”

Interview with Phil Risner – the owner

1. **Involvement with project:**
   He started working for Seaton during programming. Project managers at Seaton are set up to be the interface between administration, architecture and construction management. The owner was involved from the beginning. They have never done anything like this before in magnitude and size. The decision to go LEED Platinum has been driven by facilities management. “Do it all the way” approach.

2. **Did this being a children’s hospital make a difference?**
   This children’s hospital is the only one in the area. You would have to go to Houston or Dallas for a facility like this. This being a Children’s Hospital had a role in achieving platinum. They received a lot of donations. One of them is pretty substantial – if they don’t get LEED they will not get the donation. Fundraising and philanthropy played an important role in this being a children’s hospital.
   It made a difference that this is a children’s hospital; philanthropy to get donations had to do a lot with it – it is harder for a regular hospital to get people to donate. They are not-for-profit so it is a big deal. Seaton is part of a larger catholic healthcare network and this is the only hospital that is LEED. This was a special project.

3. **How did LEED evolve?**
   Before schematic design they had a kick-off meeting with all the project members. They had a consultant at first and then Gail was brought it. The project benefited from being in Austin due to the Austin Energy Green Building Program, which had a great participation from the beginning.
   They had LEED meetings every month at first and then quarterly. Everybody was involved in these meetings: architect, contractors, CM, engineers, landscape architects.

4. **First cost**
   Close to 5% as an estimate. Would have been almost $0 if certified or silver.

5. **Selection of arch/CM**
   Phil was not involved in the architecture selection. Karlsberger did another project for Seaton, smaller than this one. The CM was selected using an RFP process. LEED did not play a part in the selection – it should have but it did not.

6. **Commissioning**
   Phil has experience doing commissioning so the facilities manager decided that the commissioning be done in house. Phil is a mechanical engineer and a consultant. He was the commissioning agent and oversaw all the work.

7. **Energy modeling**
They wanted to do photovoltaics, looked into Austin Energy and also did some research on a fuel cell project downtown. Austin energy had a presentation at the time regarding a CHP plant, and they knew Austin Energy wanted a district cooling plant. They talked about a cogeneration plant—they did one on North Lamar. The plan was to make it a telecommunications center with a gas turbine. They looked at leasing the land and contractual issues. After that they looked at the LEED aspect of it. They wouldn’t be able to get the points because of the chiller. The air handlers were an issue also so they started looking into CHP with USGBC. They decided that’s what they were going to do and get the 8-9 points of the CHP plant.

CCRD helped with the energy modeling. At the end of DD, they were provided with the load profile. They showed Austin Energy what they had and this went back and forth—making the building perform to the standards, meeting the energy performance. Phil is trying to work the energy to the performance required. It is cheaper for them to have their own chiller plant. If they can meet the model 17% better than ASHRAE 9.1 the payback period is 6-6 years, but that is still work in progress.

Austin energy has a rebate program. 5% renewable energy is a lot so they will do a little demonstration project. Energy modeling costs: $50-75 K

8. Indoor air quality issues
2-3 months into the project, they had some issues with the filters and also with occupancy, and finishes with the windows—it cost them 25K.

Cost of project: 200 mill; number of beds: 169 beds 175 000 sq ft.

9. Green goals
“If they get Platinum they achieve it, if not they didn’t”

10. What would they do differently if they had to do it again?
They would do a better job with a more experienced team. They lost points with the hick-ups they had, and these should have been a given. Things like that are frustrating, but you can’t do much better.

Construction manager and architect with a bit more experience, a few more LEED projects. They would have had certification by now. Documentation played a big role—they did not know what they had to do. They would have had certification by now. Experience had to be learned on a big project like this. Learn from other smaller projects instead of this one.

11. Surveys/occupation phase
Surveys for staff, nurses and doctor—the owner embraces the idea of research during occupancy.

There are volunteers with dogs walking around and a lot of interactive, playful activities for the children. These playful activities were started by the administration and staff. A lot of local individuals helped with the project.

12. Mindset of owners on LEED
The low number of LEED healthcare facilities has to do with expenses and high healthcare costs and public perception. Administration focus on “takes too long, takes too much—cheaper, faster” that mentality is hard to compete with. You have to go with the mindset that the facility will be there for 50 years, wanting to retain staff and the experience of the patients is all major. There are not that many studies done on the benefits of green hospitals. The success has to do with planning early on like they did it there and approach it with a knowledgeable administration that wants to do this.
The administration kind of went back to “cheaper, faster”

13. **Push for green**

It was the facilities manager that started the push for green, Bob Moroz who is no longer with Seaton. Bonar, the CEO was very supporting and wanting to do it, which made all the difference in the world. The push came from the facilities management and had a great proposal to the administrative management.

Interview with Alan Herbert - Construction Manager

1. **How did you get started with the project?**

They were originally hired before being a construction manager to provide pre-construction services on a preliminary contract basis, back in 2002. They went for an RFP for CM. WC (White Construction) with several other construction companies went for that and the top two candidates went for an interview. WC was selected in 2003 and construction was started in October 2005 – a year and a half was for pre-construction before the construction started.

2. **Start of LEED**

The idea of a green facility was part of the RFP put out by the owner was the goal to achieve LEED Platinum so from the very beginning the concept was the same.

Once they were selected...as a team with Karlsberger and Seaton they had a 2 day LEED charrette before schematic design. White Construction had assisted the project even in programming with Karlsberger: budgeting and scheduling on a contract basis.

Programming + pre-construction + construction.

Seaton had a vision of having a LEED Platinum and hoped that it would be economically feasible. The LEED charrette proved that this project was going to be economically feasible as a LEED Platinum project.

Alan became a LEED accredited before the project but this has been the one and only LEED project for him. “You don’t have to have a lot of LEED projects to get involved in a project of this scale.”

3. **LEED APs**

There were a number of LEED APs on the project team: with Karlsberger, Seaton 1-2, Gail, Dylan. Alan, the only one from White Construction.

Austin has a Green building program that started before LEED. Alan got his LEED AP in 2003 after GreenBuild.

4. **Involvement of Austin Energy**

Austin Energy, the city owned utility, played a major role in the project. They were partners with Seaton to build the CHP, which provides all the energy to the hospital. They have a cogeneration plant that produces energy on site. The steam, hot water, chilled water and electricity. The hospital was a combined project for the CHP and the children’s facility and White Construction was the manager for both. Seaton build the CHP for Austin Energy and sold
it to. Austin Energy hired another company to do the process engineering. Austin Energy was very involved – they were involved in the LEED charette – integral component of the project. They thought it would be more efficient to have a separate plant and buy energy from Austin Energy.

5. First Cost
First cost: difficult question to answer. It never was designed as a conventional project in the first place so there’s no way. One of the things at the beginning of the LEED charette – Bob Moroz was the LEED advocate with Seaton.

6. Recycling and waste management
92% recycling: 2 points biggest responsibility for the construction manager…has to do with the actual site being built on an airport site. High grade cementitious asphalt for the airport with crushed limestone base – tons and tons of the material to be taken up. Stocked piled all asphalt and crushed limestone and all of it was reused. They were able to use the asphalt in the recycling waste management calculations. This allowed them to reach the 92%– without the asphalt a little over 70%. Brownfield remediation was done prior to WC’s involvement. The recycled asphalt was used as base under parking lots; while the crushed limestone was used as structural fill. Cost studies on the parking lot elevation.

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Studies about how if you raise the parking lot 6 inches it can dramatically affect cost – studies done during preconstruction.

7. Value Engineering for green
Value engineering for green: they looked at products, linoleum as a rapidly renewable material: over 400000msf of linoleum which is a significant number.
Cost associated with wheat board: wanted to make sure that the cost associated with using some of these materials would not be prohibitive. Using certified wood did not make economic sense: hundreds and hundreds of wood doors: a dramatic premium to have fact wood. Sources for all door manufacturers…the design team and owner decided not to use it.
Local and regional materials: concrete structure, cement, the aggregate, gravel has to be local – there was a significant cost associated with the concrete structure. Significantly with the steel.

8. Design-bid-build and the phases
Technically not a design build project. This was a design-bid-build. Karlberger had a different contract: it was a fast track design-bid-build. Several bid packages that Karlsberger produced: 3 main bid packages:
1. Site and foundation work: good budget developed after DD drawings. They knew they had a budget that would work
2. Building shell came 4 months afterwards. Structure and super structure: did not include any of the MEP which was a challenge. All of the MEP that needed to be incorporated in the concrete structure such as all of the sleeves, for concrete slabs…sleeves for conduit. That requires MEP – they hired an electrical subcontractor and mechanical to evaluate what was
known from DD drawings. They did the sleeves and provided construction power. They didn’t have the mechanical and electrical subcontractors

3. Interiors and MEP: had a different electrical subcontractor. Mechanical was a successful contractor.

One challenge was coordinating MEP without having contractors on board. The construction started Oct 05 and was completed in May 07. It was planned for 27 month construction duration –went to 30 months for design changes. But that’s the nature of a fast track project. Landscaping package didn’t come out until landscape package 3 which delayed the project.

There is landscape inside courtyards. They had 3 tower cranes and had to leave one till after the structure was completed and had to leave on till after the structure to get some of the materials into the courtyards. Some things were carried through the building. Hoisted up in buckets. The healing gardens were completed after the structure.

9. Training of staff and meetings related to LEED

They had pre-bid meetings with all the bidders and part of the bid documents …discussed what the recycling program would be. Once the subcontractors were selected they had a pre-construction meeting with them and reviewed that aspect.

They had weekly safety meetings: all the workers every week –they would discuss construction waste recycling in addition to safety. They had segregated dumpsters for different materials –pros and cons for both approaches but this approach of separate dumpsters made more sense.

10. Rework due to green

Rework due to green: since they were cm on the team in the beginning they were able to do a lot of the planning and get it into the specifications and the bid documents. They worked with the architect to make sure the specifications had the right requirement for performance. If bidders don’t know what they are bidding they won’t know what the impact will be on the cost for sustainable materials to support the LEED credits. This has to be written in the specs, otherwise there are a lot of change orders. All of documentation had LEED thorough out and one of the most important aspects was to integrate LEED through out.

11. Integrated process and experience

Integrated process: regular LEED meetings. Early in the project they had LEED meetings monthly and then it went to quarterly.

This was the first LEED project for Alan and White construction –very steep learning curve.

Alan working on several proposed projects on federal government projects. One project for whole foods. Lots of work for whole foods.

Each bid package –prepare a schedule. 1 for site work and foundation.

Refers to various sides of the building.

16 people from white construction working on the project. This was the biggest project for white construction and the only one of that size.

This is the crown jewel for Seaton, and also for white construction.
The contract is 140 million for construction. They build the original children’s hospital that this replaced. The superintendent worked on that one. They did work on Saint David’s. Alan had a lot of experience with healthcare working for a constructor in Alabama before joining white construction. Healthcare is more complex construction. They provided construction budgets during preconstruction for the mechanical and electrical systems. They don’t have the in house expertise to do a lot of that in house. They get subs to help with that.

All the subcontractors were competitively bid: they had a very extensive pre-qualifications process. This project used an owner controlled insurance program which- Seaton offered all liability and owner’s insurance was under a policy that Seaton provided so that reduced the costs for the subs. In order to qualify for that they show min requirements for safety records. They had a very extensive program for potential bidders in order to qualify so it wasn’t an open bidders list. It was a select bidder’s list.

11. Commissioning
Phil Risner was the commissioning agent – he’s a mechanical engineer: real hands on as far as an owner’s rep. they assisted with mechanical and electrical. For pre req commissioning and after comm.

12. Energy modeling
Energy modeling: one of the factors for achieving LEED Platinum. As Karlsberger said it’s designed for LEED platinum. It’s registered under LEED 2.1 which is not designed for healthcare. The biggest factor that got them where they are is the energy plant and being able to get all the possible points in that area: which is where it makes the cut. First costs associated with that which most owners are not willing to go. From the very beginning platinum was the goal. They were all motivated to achieve that goal.

13. Green and this being a children’s hospital
Big initiative at WC to get more accredited professionals. – one of the plans is to get much more involved. In a few years it becomes the norm. if you don’t become involved in that you will be loosing business. Also it’s the right thing to do!

Alan’s niece has kids: a 9 month old baby that became critically ill and he was at the intensive care unit and hospitalized for about a week. He got to know the facility from a patient’s side and staff: got really good feedback from staff. Seaton’s goal was to have a facility that enabled good recruiting for medical personnel and retention for personnel. Happy workers, happier patients. Personal benefits: took family on a tour. It was a personal experience. Benefits of doing a children’s hospital: stakeholders-end0users are major, the children are real special. This was a guiding principle for the entire team, the design and. keeping in mind the end users.

Elements in design: embedded in concrete columns, molds of children’s hands and form of the columns –impressions of children’s hands and feet that you don’t see in other hospitals.
No other projects with karlsberger, a lot of collaboration between teams. Like a design-build, but not contractually.

13. Lessons learned

Things that would have been done differently looking back: knowing more about documentation requirements about LEED, make sure that the subcontractors as part of the shop drawings and submittal process include all the LEED documentation—they didn’t do that so it was much more difficult later to do that – to extract the LEED documentation. Single biggest lesson.

14. Vision

Initial statements: at the beginning. They weren’t going to be throwing any money in order to get points. It needed to make economic sense every step of the way as well as being the right thing to do. That’s one of the advantages of starting early and to make sure you weren’t going to make anything stupid. there are lots of stupid things done in order to get a few LEED points. “Wrap a green blanket around a conventional building” on other projects and this doesn’t make economic sense to do that. Seaton didn’t pay a very high premium for getting LEED platinum. There is a premium to go from silver or gold to platinum. Probably no premium if silver