Commissioning of New Schools: A State Funded Study of the Costs and Benefits

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ABSTRACT

Industry insiders know intuitively that commissioning benefits exceed the costs. Anecdotal evidence supports this intuition. However, there is little concrete documentation of the benefits. In 2003, the State of Texas funded a study of the costs and benefits of commissioning of new school facilities. The study involves close investigation of two schools: one school that was commissioned, and a similar school that was not commissioned. The complete study will include modeling and monitoring of both buildings to evaluate energy savings, as well as detailed interviews, surveys, and audits. It will also looks at impacts on the building's design, construction and turnover processes, as well as improvements in operations and maintenance, and other aspects of building acceptability. Although the study includes only two buildings, the richness of the data collection and the analysis will make this a unique study with results that will shed light not just on the magnitude of the savings, but on the nature of the benefits and on the appropriateness of the commissioning process.

This paper reports on early findings of the study. It provides a detailed description of the methodology used to document the benefits, since the industry is presently searching for more appropriate methodologies. It presents a set of metrics for evaluating the performance of the baseline school (to be used in the future for comparison with the commissioned school). The paper also shares the experiences from the early design stages of the commissioning project and what lessons have so far been learned to benefit other Texas schools engaging in commissioning.

Introduction

Commissioning is defined as "a quality oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria." (ASHRAE 2002). It has many similarities to quality assurance efforts in other industries, although the fact that each new building is unique makes quality assurance both more important and more difficult. The Commissioning process ideally begins in the early planning stages of a building, and continues through the turnover and post-occupancy. In commissioning, a Commissioning Authority (CA) coordinates, communicates, and documents efforts by others in the design and construction teams, and is a champion for quality for the owner. While commissioning, as a clearly-defined process, has been available for some time, it is still far from being business-as-usual. One of the difficulties in promoting this technology is the difficulty to

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estimate the potential savings from commissioning, and even to estimate the cost for commissioning. It is difficult to convince an owner to spend an uncertain amount of money to purchase an unknown service with unknown savings. Any effort to rigorously document the costs or benefits of commissioning will be helpful in making this technology business-as-usual.

Interestingly, it turns out that a key to understanding the benefits of commissioning is understanding where costs are incurred in a *conventional* building. The design process, communication and management in the construction process, changes made throughout the process, and ongoing maintenance are important contributors to the cost of delivering a building. These are the kind of costs that will be affected by commissioning, so it is instructive to describe these costs in a conventional building and a commissioned building.

The Texas State Energy Conservation Office (SECO) has funded this study of costs and benefits of commissioning, because of their interest in promoting energy efficiency technologies in buildings throughout the state, as well as their desire to ensure the appropriateness of any technologies they promote. They provided funding directly to the Northside Independent School District to pay for both the commissioning and the study. The school district, then, with money from the state as well as some of their own cofunding, contracted with the Brooks Energy and Sustainability Laboratory, who is conducting the study and has acquired the services of Testing Specialties, Inc, a Commissioning Authority (CA). The objective of the study is to provide documentation of the costs and benefits of commissioning in one school, and in doing so, to learn more about how the benefits appear, and how the benefits can be maximized in other schools. Because commissioning provides benefits in a sometimes complex and abstract way, there is also a need to develop the methodology for identifying the benefits, and to define metrics for quantifying them.

Methodology for Identifying Benefits of Commissioning

The objective of this study is to identify the benefits of commissioning. There are two typical methods to identify the impact of a process such as commissioning. The first would be to identify a statistically significant sample of commissioned and uncommissioned buildings, to normalize for any differences in the samples, and to compare their average performance. This is quite difficult to do in practice, because of the small number of commissioned buildings available to be studied, the wide range of variables that would have to be controlled, and the significant cost of such a large data collection effort. The second method would be to identify a set of buildings that are identical except for the presence of commissioning. It is quite difficult in practice to find such a closely matched pair of buildings. The difficulties in conducting these types of studies have resulted in very few rigorous studies of commissioning benefits.

In this study the overall approach to investigating the benefits of commissioning was to commission the Mechanical, Electrical, and Plumbing systems (MEP) in a building and evaluate its performance, and to also evaluate the performance of a similar “baseline” building. Rather than conduct a statistically significant or carefully controlled experiment, we attempted to design a more qualitative study: to identify and document the nature of the costs and the benefits in great detail, rather than to expect to prove them quantitatively. Our goal was to quantify benefits where possible, to estimate their magnitude when quantification was not possible, and to simply identify their presence when estimation was not possible. For quantification, metrics have been defined that will help in the comparison. With a sample size of two, any generalizations will have to be drawn carefully. Table 1 describes the types of information that was collected and

analyzed for this evaluation. It is important to note that this was a research project, and the data collection effort is in much greater depth than would be expected in a typical evaluation effort.

Table 1. Information Sources from Baseline and Commissioned Schools

Construction Documents	Specifications, as-built drawings, initial and final project schedules, change orders, requests for information, design review minutes, and construction meeting minutes. These were all used to establish a narrative description of the construction process in the baseline school, and to identify the cost and schedule impacts of issues that were encountered.
Construction Process Interviews	Interviews with key actors were conducted to interpret the documents and to provide other information as to what took place and the impacts. Interviews included the architect, district Construction Director, Engineering Director, Maintenance Director, and the Energy Manager.
Lessons Learned Workshop	Part of the process we are recommending for commissioning is to hold a Lessons-Learned workshop for a previously constructed facility, if applicable. Therefore, as a part of the commissioning for the new school, we are holding a Lessons Learned Workshop for the baseline school. This serves a dual-purpose: to provide valuable lessons to improve the commissioned school, and to provide information for the study of benefits that would have been gained at the baseline school. We will also hold a workshop for the commissioned school (for the study, and also as input for the next commissioned school, if applicable).
Occupant Satisfaction Interviews	We conducted in-depth interviews of key personnel halfway into the first year of occupancy. These interviews helped us to identify some of the issues that occurred with the building during the "shake-out" period, while the issues were still fresh in the informants' minds. These interviews covered topics such as thermal, lighting, and air quality acceptability. The interviews were conducted with the school principal, several representatives of the teachers or administrative staff, and the head custodian.
Occupant Satisfaction Survey	In addition to the in-depth interviews, a quick survey was conducted of the entire school staff, covering the same topics, in order to obtain more comprehensive response. This was done at about the same time as the occupant satisfaction survey.
Work Orders	Work Order data was a source of quantitative information regarding the amount, nature, and cost of maintenance required. It will also used to evaluate and document any reduction in operating costs due to reduced maintenance. These data were obtained halfway through the first school year of occupancy, and will be reviewed again at the end of the year, and at the end of the study.
Utility Bills	Gas and electricity bills are collected by the district, and tracked in an energy accounting system. Reports were generated from this system for our analysis. These data will be used to evaluate the difference in energy intensity and costs. Data were collected after the first six months of occupancy, and on an on-going basis thereafter. They will be reviewed for the first school year of occupancy for the both schools, and for the first three school years of occupancy for the baseline school. For analysis, the energy use data were normalized for the number of days in the reading, square footage, weather, occupancy, and schedule differences.
Metered Data	Evaluating reductions in energy costs requires more detailed energy consumption data than monthly utility bills can provide. We are collecting 15-minute data for the utility meters for both schools.
Building Walk-thru	We toured the school about halfway through its first year of occupancy, with an eye towards any deficiencies in the design, installation, operation, or other factors that could affect building operation.
Observation	In addition to the qualitative and quantitative data described above, many of the benefits were documented through direct observation. The observations of the study and commissioning team were logged using a database to collect information regarding the nature of the observation, the area in which it was observed, and the expected implications of the observation. These observations were "mined" to identify the most repeated or significant issues.

This was not expected to be a study of the "best case" for commissioning. A best case scenario would probably involve an owner who had conducted commissioning many times and design and construction teams who were already familiar with commissioning. This was not the case for this study. A best case might also involve a school district where the current policies and procedures were very poor, and commissioning would prove a more significant improvement over standard practice. However, in this project, the school district already had very disciplined construction management procedures in place. We were unsuccessful in implementing some of the elements we considered important for commissioning, because of the need to respect the district's current procedures. Therefore, in addition to the benefits we actually observed, we identified the benefits we thought could be achieved under more ideal circumstances. The owner is considering implementing commissioning in future schools, based on only the preliminary results of this study.

The commissioning study was conducted in a suburban school district in San Antonio. This is a very large school district with over 71,000 students and 88 facilities comprising over 7 million square feet. This area is growing rapidly, and bond issues of almost a billion dollars have been passed in the last decade for facility construction. Over a million square feet of facilities have been constructed within the last two years or are currently under construction.

Significant consideration went into the selection of a suitable baseline school to serve as a comparison to the commissioned school. The considerations for a baseline school were that it be recently built, have similar style, size, schedule, and mechanical systems. It would have been ideal to have the same architect, MEP designers, general contractor, and significant subcontractors. It is of course unrealistic to expect that a school could be found that would meet all these criteria. One of the most beneficial similarities would have been to have the same general contractor (GC). Since the GC is not selected until after the design stage, it was impossible to use this as a criterion. It is not known at this point who the GC or the major subcontractors will be. The next most significant characteristic was that it be recently built, so that any differences in the district's policies and procedures would be minimal. The next most significant was that it be similar size and use. Both schools were initially designed to house 660 students, although early in the design stage a decision was made to add 140 students to the commissioned school. Both schools had the same architect, a well-respected firm in the area, who had designed no other new schools for this district, although they had done several other smaller projects. Since the same designer was designing schools with similar requirements within two years of each other, it is possible that the commissioned school would benefit from any mistakes or poor design choices that were made in the first school. Table 2 describes the characteristics of both schools, and how good of a match they were.

Findings

Metrics for Performance of Baseline School

How well did the design and construction processes work at this school? Overall, the baseline school is a very good school. The occupants are very happy with the school, and its energy performance is good. In order to evaluate the performance of the school (and the process that delivered it) more precisely, we have to go beyond comparing energy use, and attempt to describe other aspects of the building's performance quantitatively. To do this, we define key performance metrics. These metrics are introduced here, although their significance will be

much more evident when the analogous metrics are available for the commissioned school, for comparison. The definition of metrics is described more fully in Heinemeier, et al. 2004.

Table 2. Characteristics of Baseline and Commissioned Schools

Characteristic	Baseline School	Commissioned School
expected floor area	80,000 sqft	100,800 sqft
number of students	660	800
expected construction cost	$10,400,000	$11,200,000
year design was started	2001	2003
year of first occupancy	2003	2005
type of mechanical system	air-cooled chillers, air-handling units, fan-powered boxes,	same type of systems
air conditioned gymnasium	initially designed to be ventilated, conditioning added as change order	air conditioned
energy code	not applicable	IECC 2000
architect	first new school for this district	same architect
general contractor	well established with district	unknown at this time
major subcontractors	well established with district	unknown at this time

Requests for information. The request for information (RFI) is the formal mechanism for the contractor or subcontractors to ask for clarification on a design element, to comment on items that may not work as designed, or to suggest an alternative design or specification. RFIs are submitted during a construction meeting, a date for clarification is requested, and a response is issued. All of these steps require paperwork, tracking, and some amount of time at a construction meeting to discuss or resolve. For example, even a simple RFI may take a half hour to prepare, 10 minutes to discuss it at a construction meeting with 10 individuals in attendnce, and 10 minutes at the next meeting to discuss the results. This equates to almost four person-hours of effort.

RFIs can be the result of unclear designs, inappropriate designs, incomplete understanding of the documents by the contractor, or understandable improved perspective of the contractor once the building is underway. Hence, RFIs can be seen as a negative (unclear or incorrect design), or as a positive (everyone working as a team to come up with the best design). It can be expected that commissioning will facilitate the design review and construction communication processes, so that unnecessary RFIs can be reduced and constructive RFIs can be facilitated.

At this school, there were 92 RFIs submitted, of which 22 were related to MEP. The number of days in review for the MEP-related RFIs ranged from 0 to 32, with an average of 9 days. Of these RFIs, several resulted in change orders, and it appears that several of the issues could have been addressed during the design stage.

Change orders. Change Orders accommodate situations where the work required by the contractor is different from what was assumed during the bidding process. This can be due to unforeseen circumstances (such as unforeseen materials at the site), a change in requirements by the designer or owner (such as a desire to add new equipment), or a response to an RFI. In this district, the project budget includes a contingency allowance to pay for any change orders that arise. When a proposed change order is issued, the contractor is asked to provide a proposal to supply the additional labor and materials. If accepted, the cost is either deducted from the contingency allowance, or added to the contractors contract.

This construction project had approximately 90 change orders. Of these change orders, 37 were related to MEP, at a cost of almost $95,000, or about 1% of the construction costs. Some of the most significant change orders included resolving problems with drainage, adding air-conditioning to the gymnasium, resolving conflicts between ducting and piping, adding a pressure-reducing valve, and adding exterior door weatherstripping.

Punch list. The punch list is the result of an on-site inspection, including both contractors and owner's representatives, near the end of the construction phase. Any last items that are not complete are noted, and a long list is created. All of these items must be completed as a part of Substantial Completion. At the point of creating and working through the punch list, the contractors are typically very eager to be complete on the project, and the owner is very eager to take possession of the building, so it is tempting on both sides to overlook issues that should be resolved. Needless to say, everybody is happier when these issues are dealt with earlier in the project, and not left until this date to be raised.

At the baseline school, "punch lists" include both Above-Ceiling Inspections and a Final Punch list. There were a total of 214 issues identified at the above-ceiling inspections, and 372 in the punch list. On average, there were about two and a half issues noted in each room at each of the inspections. The comments range in severity from "Caulk around temperature sensor" and "Clean light fixture lenses" to "the light fixture is not operational" and "replace the damaged supply air device" and "The installed flexible conduit system is not acceptable. Properly replace all fan final connections with [another form of] conduit." Most of the items are simply the final steps in completing a project, and one would not expect them to be complete prior to the inspection. There are other items, however, that could have been averted with more of a quality assurance process during the design or construction phases.

Schedule. One of the most significant expected benefits from commissioning is the improvements to the schedule. Commissioning should help anticipate and eliminate scheduling conflicts, and help everyone keep to the schedule. Commissioning may also affect the schedule for the design phase. It may improve the schedule, since potential problems are addressed in the early stages of design rather than the later stages. However, it could potentially lengthen the schedule, since the CA may require that any identified design flaws are addressed prior to issuing the plans.

In order to define impacts on the schedule, we have to define the expected duration of the design and the construction phases, and the actual durations. The starting and ending points must be clearly and consistently defined.

- *Beginning of Design*: This can be an abstract concept, since there may be a lengthy period of getting the project underway. The milestone we used was the review meeting for the schematic design. Although this is not the actual starting date of the design, it is a clearly defined date that indicates when design begins in earnest.
- *End of Design/Beginning of Construction*: This milestone could be indicated by a 100% review meeting, the bid package release, the bid due date, the pre-bid conference, the contract award, or the first construction meeting. We felt that the pre-bid conference was the most defined date, indicating clearly that the design stage was complete (although changes can still be issued after the pre-bid conference, in the form of addenda). At the schematic design review meeting, the anticipated construction begin date should be

announced, which pins down the *expected* end of design/beginning of construction, for comparison with the *actual*.

- *End of Construction:* The actual end of the construction phase is best marked by the date of Substantial Completion, which is a key milestone contractually. Although there may still be work to be done after that point, the endpoint of that activity is quite vague, and the date of Substantial Completion is a more well-defined endpoint. The expected end of construction is estimated at the schematic design stage, but the most reasonable date for defining the expected end of construction comes from the contractor's first schedule, issued at one of the first construction meetings.

At this school, the expected design phase duration was 237 days, and the actual duration was 224 days: the design was complete 13 days or 5% ahead of schedule. The expected construction phase duration was 405 days, and the actual duration was 513 days: a 27% difference.

Cost. Of course, the most significant metric is the cost of the design and the construction. Ideally, the design and construction costs could be compared on a per-square-foot basis. Design costs should include the entire project, from beginning to end. The construction costs should include all costs, including contingencies and change orders. Construction costs estimated at the beginning of the project—indicating the owner's initial intent—can be compared to the bid cost, to indicate how well the design meets the owner's first cost expectations. The final costs can also be compared to the bid cost, to indicate cost over-runs that take place during the course of construction.

It is sometimes difficult to obtain this information, since it is so sensitive. If so, it may be easier to obtain the information in a ratio form, to provide the necessary metrics. The ratio of actual to expected costs for design and construction are the key metrics. At this school, the actual design costs were 4% less than expected. The construction *bid* costs were 5% less than the *originally anticipated* construction costs, but the *actual* construction costs were 1% above the *bid* cost.

Occupant interviews and surveys. We obtained information about the performance of the school from the occupants in two separate ways: in a survey of all staff members, and in an interview with the principal and the head custodian. The survey was administered at a staff meeting, where our team described the study briefly, and handed out a one-page survey, which asked the following questions:

> The district is studying new ways to design and construct school heating, cooling, ventilation, electrical and plumbing systems. In relation to these systems, please provide a description of any problems you have encountered at this school since it opened. For each category (Health, Comfort, Equipment reliability, Time to get problems fixed, Interruptions when repairs are done, Energy waste, Other), please describe the problem in detail, indicate how severe (Noticeable, Inconvenient, or Disruptive), indicate how frequent (Daily, Weekly, or Monthly), and indicate whether problem was ever resolved. Also indicate your job category (teacher, food service, librarian, administration, custodian, and other).

Unfortunately, the teachers did not provide much input. The survey was administered just prior to the winter break, which probably contributed to the teachers' lack of input. The most complete response was from the head custodian.

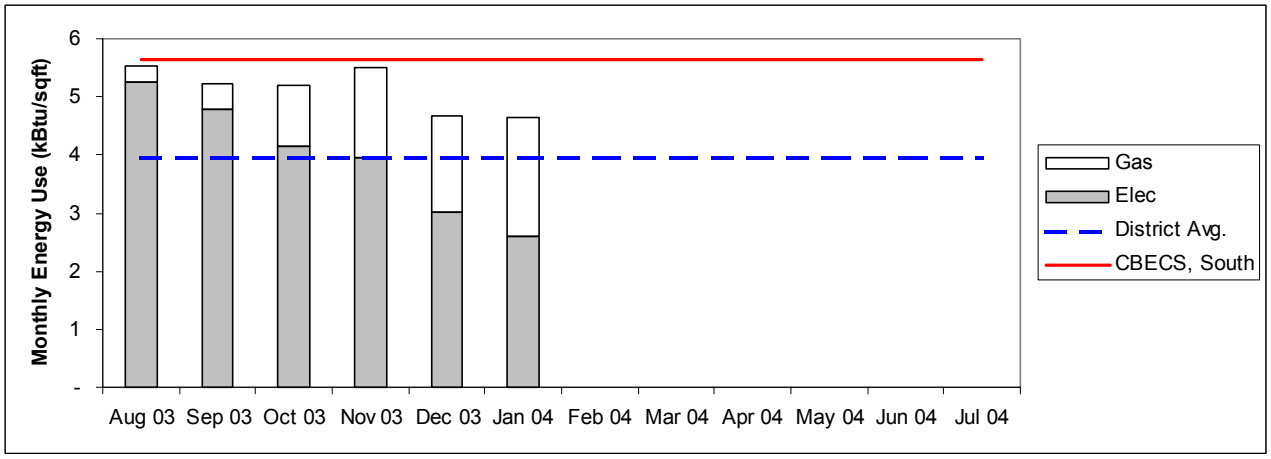
We asked essentially the same questions during an interview of the principal and the head custodian, and received much more complete response. The issues raised during this interview included significant problems in achieving comfortable conditions in the gymnasium (where the air-conditioning was added as a change order), several problems with plumbing systems bursting (causing the pressure reducing valve to be installed as a change order), significant leakage of water into the occupied space because of lack of weatherstripping (causing it to be added as a change order), premature ballast failures, and dusty rooms. Most of these issues could have been avoided with commissioning in the design or construction stages.

Work orders. We obtained a log of all work orders for the baseline school about midway through the first year. The work order log includes 278 items total, with an associated cost of about $10,000 for materials and $23,000 for about 1400 hours of labor (including both contractor and M&O Department personnel). For just MEP-related issues, there were 122 items, with a cost of about $1,600 for materials and $7,500 in labor (400 hours). The issues included in this list includes items such as preventive maintenance, routine maintenance repair, warranty issues.

The work orders issued include work such as addressing the problems with leaking water, the AC in the gym, and the ballasts, which were reported by the occupants. Other items include work related to getting the school ready for occupancy and for the dedication, and hot and cold calls. Some of the issues that had to be addressed, particularly the warrantee issues, and the routine maintenance issues, could have been avoided with commissioning.

Utility bills. We obtained the utility bills for the baseline school, and information about the bdistrict's average energy use. Figure 1 shows the energy consumption for the first six months of occupancy. The average monthly energy use is about 5.1 kBtu/square foot—4.0 kBtu/sqft for electricity and 1.2 kBtu/sqft for gas. Monthly energy costs were about 9 cents per square foot, or about $7,200. For comparison, the school is using somewhat less than the 5.7 kBtu/sqft average for an educational building in the southern part of the US from CBECS 1999. The average monthly use so far is somewhat higher than the 3.9 kBtu/sqft average for elementary schools in this district, although it is likely that the average will be somewhat lower when a full year of data are available. On the other hand, one might expect this school to use more energy than other elementary schools in the district, since it is the first to have an air-conditioned gymnasium.

Figure 1. Energy Consumption for Baseline Building During First Year of Occupancy



Metrics. Table 3 summarizes the preliminary metrics described in the earlier sections. To facilitate comparison of the metrics with other facilities, all the metrics have been normalized in a reasonable way—by floor area or by construction cost—and only MEP-related items were included. After we have completed commissioning of the new school facility, we will compile these same metrics and compare the performance of the two schools. We hope to find significant improvements in some of these factors.

Table 3. Summary of Metrics for MEP-Related Performance of Baseline School

RFIs	Number of MEP-Related RFIs (per 10,000 sqft)	2.6	
	Average Number of Days in Review	9	
Change Orders	Number of MEP-Related Change Orders (per 10,000 sqft)	4.4	
	Cost of MEP-Related Change Orders (% of Construction Cost)	0.9%	
Punchlist	Average Number of MEP-Related Punchlist Issues per Room	2.7	
Schedule	Difference between Expected and Actual Duration of Design Phase	-5.5%	
	Difference between Planned and Actual Duration of Construction Phase	26.7%	
Cost	Difference between Expected and Actual Design Cost	-4.2%	
	Difference between Expected and Bid Construction Cost	-4.7%	
	Difference between Bid and Actual Cost	1.2%	
Post-Occ Eval.	Number of Significant MEP-Related Issues Identified in First Year	5	*
Work Orders	Number of MEP-Related Work Orders in First Year (per 10,000 sqft)	14.5	*
	Cost of MEP-Related Work Orders in First Year (per 10,000 sqft)	$1,079	*
Energy Use	Electricity (annual kBtu/sqft)	23.7	*
	Natural Gas (annual kBtu/sqft)	7.0	*
		* = first six months	

Preliminary Results from Commissioned School

A new school is now being constructed, and it is being commissioned as a part of this study. The building has the same architect as the baseline school, and similar characteristics. As of the writing of this paper, the building has just completed the design and bidding phases, and is now in the early pre-construction stage. Commissioning of the building is being conducted as a part of a research project. Funds for commissioning and for the study were provided by the State Energy Conservation Office to the school district directly. The school district is also providing a significant amount of in-kind assistance to the project. The study and commissioning tasks are being conducted out of the Engineering Services department, although the Assistant Superintendent and all related departments (Facilities Construction, Operation and Maintenance, Energy Management, and Engineering Services) are directly involved.

The school commissioning is a part of a research project, and the intent was to implement and study a first-rate commissioning process. We wanted to implement a process that was repeatable by other school districts, however, so it is also a fairly typical commissioning project. We present here only a discussion of the Performance Objectives Workshops (which were the only way that the study team has supplemented the process typically employed by the CA) and a summary of the impact that commissioning made on the design process and results.

Performance objectives workshops. One of the first steps in the commissioning process is to document the Owner's Design Intent through a series of interviews or a workshop. When initially discussing this with the owner and the design team, there was very considerable resistance to the idea. The owner felt that their existing design guide captured their intent, and

the architect and engineers felt that they "knew their customer" enough to know what was required. We recast this activity as documentation of "Performance Objectives." One advantage to using this term was that it put the activity more squarely in the responsibilities of the CA, since the CA is understood to have the objective of improving the building's performance. Another advantage of this term is that it allowed for a more broad definition of "performance." Commissioning is expected to result in a building that performs better, as well as a *process* that performs better for delivering the building. Therefore, the focus of the Performance Objectives workshops included not only what the stakeholders expected from a well-performing building, but what they expect from a well-performing building design and construction process. This was very effective.

Although we would have liked to schedule a large workshop at which different categories of stakeholders could hear from other stakeholders, this proved impossible to schedule, and we opted instead for a series of four workshops. At each of the workshops, we asked a series of questions and captured the brainstorming responses. We asked them to prioritize their responses, and summarized their most significant answers. Table 4 shows the questions that were asked.

All of the individual responses and the summarized responses were provided to all attendees, and to the Owner's Commissioning Team and the CA. The responses were used somewhat informally in the design review, and will be used as applicable in the construction and turnover phases. Unfortunately, the process took a considerable amount of time, and the responses were not provided to the design team in time to be used in guiding the design. The responses will be used, however, in future buildings.

Table 4. Questions from Performance Objectives Workshops

Engineering / Construction Managers:

- *In what specific ways can the design process can be improved to produce an effective building?*
- *In what specific ways can the construction process can be improved to produce an effective building?*
- *In what specific ways can the turnover process can be improved to produce an effective building?*

Energy Managers:

- *What specific technologies, processes and/or principles should be implemented to reduce energy usage?*
- *In what specific ways can you reduce energy use through management for energy efficiency?*
- *What role should Energy Management staff have in design, construction, turnover and operations?*

Occupants:

- *In what specific ways can a building perform well in terms of comfort, health and security?*
- *In what specific ways can building occupants interact with district Facilities and Operations departments during the planning, design, construction and turnover phases?*
- *What are specific ways can building occupants interact with district Facilities and Operations departments during the routine operations?*

Maintenance and Operations Managers:

- *In what specific ways can you maximize the efficiency and effectiveness for O&M through resolving problems that lead to increased workload in the O&M department?*
- *In what specific ways can you maximize efficiency and effectiveness for O&M through balancing the design / construction process to optimize in-house and outsourced resources?*
- *What role should O & M staff have in design, construction, turnover & operations?*
- *In what specific ways can you maximize efficiency and effectiveness for O&M through reducing facility / system downtime in newly constructed schools?*

Preliminary results of design-stage commissioning. The results of the commissioning during the planning and design stage were mixed. While the activities of the CA had some impact on

the building's design, there were several missed opportunities that will limit the success of the project.

- While there were some minor comments made on the design of the building, the biggest impact is probably on the requirements in the specification. Details were provided as to the contents of the O&M manual, and the requirement to submit a draft O&M manual early in the process will have a significant impact on the ability of the O&M staff to understand the building during the construction phase, and to maintain it after occupancy.
- A requirement was added to the specifications for early submittals and a process for approving submittals. This will greatly help to avoid problems with inappropriate equipment being delivered to the job site. He also recommended that the specifications include more guidance for building acceptance. He recommended a table of Acceptance Criteria, a clear process for proceeding if criteria are not met (eg, if test fails), penalties for not meeting criteria, and linkage between payment applications and acceptance criteria. These recommendations were not incorporated.
- The CA attempted unsuccessfully to encourage the owner to consider energy efficient motors. However, he was successful in keeping the issue on the table, so that it can be considered at a later date.
- The design moved very quickly, and the District did not have full buy-in to the commissioning process at the beginning of the design, so there were very few opportunities to influence the design. Ideally, the CA would conduct a full design review and include issues such as life cycle impacts of design choices. The CA should also ask the owner to provide a firm timeline for providing response to the CA's comments made during the design phase.

Summary

This paper has described the methodology used to document benefits from commissioning, the metrics used to define the benefits, and some of the early results of commissioning in one school. Although it is a work-in-progress, the approach taken and the early findings contribute to the industry's understanding of how to document the benefits of commissioning.

The methodology used to document benefits is a detailed side-by-side case study. Although only two buildings are included, the depth of the analysis provides the opportunity not just to collect key metrics, but to understand what happened and why. Commissioning is a very complex process, providing benefits in sometimes abstract ways. A detailed understanding of the process of designing and constructing a building, and the ways that commissioning improves both this *process* and the resulting *building*, are key to communicating the benefits.

To describe the quality of the *process* and the *building* in more than an anecdotal way, however, requires more than a qualitative analysis. Metrics for performance of the process and the building must be defined. This paper has defined a set of metrics that are not difficult to collect, and that seem to capture the performance of the process and the building in one conventional construction project. These metrics should be a useful way to compare this project with the commissioned school, when it is complete. Hopefully, these metrics will be the basis for an expanded understanding of performance, and for future guidelines for collecting performance data to support comparisons of commissioned and uncommissioned buildings

nationwide. For example, the California Commissioning Collaborative has developed a Case Study Protocol for collecting information on the costs and benefits of commissioning in California buildings (PECI 2002). It is hoped that metrics such as those presented in this paper can be incorporated in this and future protocols, and that large data collection efforts can be undertaken. Additional work should be done, however, to investigate how reliable these proposed metrics are for comparing different projects.

Although the school commissioning project is still in its early stages, it is showing promising signs of documenting significant benefits. In addition to the issues that were described throughout this paper, we have several general recommendations regarding improving the success of commissioning. Communication should be early and often, using clearly-defined procedures for communication. The commissioning agent should start early and be nimble and persistent, and should reassure everyone involved in the process about their roles. Every organization is different and the roles will be different, so the commissioning agent should be flexible. There are a lot of toes to step on, so the commissioning agent should be creative, considerate, and persistent. Performance Objectives should be captured and communicated early, and should form the basis of acceptance criteria, which should be in the specification. A Lessons Learned workshop from a recently completed project would be helpful.

The results of only one case study can have only a limited impact. We hope that others in the industry will take the time to document the benefits of commissioning, so that other owners can engage in commissioning with confidence that commissioning will provide them significant benefits.

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