

The Dollar Value of Commissioning

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Synopsis

Environmental Health and Engineering promotes building systems commissioning as a quality assurance process. In new construction the commissioning process is implemented to ensure that equipment and systems perform as intended, and it is generally accepted that commissioning is most effective when applied as early in the construction process as possible to have maximum impact. All buildings and their integral systems are created in layers from concept through operation, and verification of each component of each layer in the process becomes paramount in order to ensure 'performance as intended'.

All aspects of the construction contract hold value. The installation of walls, windows, floors, air handling units, piping, pumps, fans, etc. are tangible and their 'first cost' to the project is usually detailed clearly on the contractors schedule of values. However, the value of these items includes intangibles, such as: asset life, warranties, maintainability, and performance which are not always apparent, but every bit a part of the 'first cost' value. Furthermore, these intangibles could be impacted during any stage of the construction process.

Commissioning addresses the verification of both the tangible and intangible aspects of materials, equipment, and systems. This paper will review commissioning issues identified on two projects and analyze their impact from a Life Cycle Cost perspective, as well as emphasize why commissioning is so strategic in assuring that owner's receive "all" that they bought.

The dollar value maybe derived from capital cost, energy use, operations, and maintenance costs, or operational productivity. Many issues identified during the commissioning process may not prevent the building from operating but do impact their originally promoted value.

About the Author

Mike Della Barba is the Commissioning Program Manager for Environmental Health and Engineering (EH&E), Newton, MA. EH&E is an engineering firm specializing in commercial and institutional building sciences, including: Environmental Health and Safety, Indoor Air Quality, Indoor Environmental Quality, Engineering and Commissioning Services. EH&E has commissioned over 9 million square feet of space. Mike holds a B.S. in Economics and has extensive construction project management experience. While serving as a senior analyst at New England Power Service Company (a division of the NEES companies, now National Grid, USA) Mr. Della Barba designed, developed and managed their Building Commissioning program, which emphasized functional testing and performance data analysis as key tasks to ensure system performance and energy savings.

Introduction

Commissioning, in essence, is a quality assurance process, a process that benchmarks the project design intent against the actual installation. All deviations resulting from the field verification become commissioning issues (EH&E commissioning action list). Commissioning action list (CAL) items are a product of third party verification at all phases of the construction process: design, construction, turnover (testing and acceptance), and warranty period. The ultimate commissioning goal is to document that all equipment and systems perform as intended upon completion and capable of sustaining that performance throughout their expected lifetime.

Construction milestones such as 100% design development documents, 100% design construction documents, construction start, completion of structural steel or superstructure, building envelope completion, fit-out, life safety acceptance, and certificate of occupancy are all visual signs of a project's progress. Visual signs, however, can be deceiving. These "milestone" completions may hide flaws, errors, or "bugs" which may not be readily apparent to the casual observer.

Commissioning (Cx) applies a process of review, verification, and documentation to ensure that the "final product" conforms to the project design requirements in every way. It should be understood that the "final product" is developed and constructed in layers over time in an "uncontrolled" or "discontinuous" environment¹. Commissioning is most effective when applied to all construction phases or "layers" with an "inchstone" mentality to ensure that by the time of system acceptance, individual components have been "debugged" and that system testing is being performed on a system of "bugless" parts.

When VFDs trip off line under high heat conditions two issues are apparent: 1. The fail safe mechanism internal to the VFD, which causes the unit to shut down, performed as intended; 2. The condition, which allowed the VFD environment to get hotter than allowed for safe operation, went previously undetected. The designed ventilation was insufficient for the application. The impact to the project included: temporary rental equipment to cool the VFD vestibules; a redesigned mechanical cooling system dedicated to the VFDs; time delays; and significant added cost to the project. Somewhere during the construction process a layer was added that went unchecked, but could have been avoided.

¹ "Out of Control", K. Kelly

Penalties or Benefits

Flawed or “bugged” components may not necessarily prevent equipment and systems from operating, nor prevent occupancy. They may, however, eat away at the value of the final product originally expected or cause unexpected capital and O&M expenditures in the future. What is the penalty for: missing insulation; duct leakage; building envelope leakage; unlabeled piping or electrical panels; missing piping unions; defective or faulty control sensors; missed condensate traps, and under-ventilated confined spaces (and the list goes on)? The answer can come from most any building facilities or operations and maintenance department and will include occupant comfort, increased energy usage, premature equipment replacement, increased maintenance time and expense, and more.

The application of quality assurance in the building construction process is methodical, deliberate, and necessary to prevent a never-ending string of headaches to the future building operators that were invisible when the doors were opened for occupancy.

Real Issues, Real Costs, Real Value

Table 1 represents a breakdown of commissioning action list items by type on Building 1, a 420,000 square foot university building, inclusive of classroom, research, assembly, and athletic spaces.

Table 1

	Type				
Phase	Code	Installation	Construction	Performance	Total
Design					
Construction	24	197	62	0	283
Testing Acceptance	5	0	16	178	199
Total	29	197	78	178	482

For the purposes of this paper, the CAL issue types are defined as follows:

- *Code* – A deviation from a city, state or federal jurisdictional requirement
- *Installation* – A deviation resulting from the contractor purchase, delivery or installation of the issue in question
- *Construction* – a deficiency more likely the result of general building construction rather than the installing contractor.
- *Performance* – An issue uncovered during performance testing

As has been EH&E's general commissioning experience, the 482 action list items ran the gamut from design clarifications (or enhancement recommendations) and electrical code issues, to incomplete installations and system performance issues. As we discuss the impact and ramifications of these 482 deviations from the intended purchased product, keep in mind that only a few of them could have potentially prevented the building from operating.

It should also be noted that commissioning was not applied to the project's design phase and due to schedule delays and budget issues, the scope of performance testing was reduced.

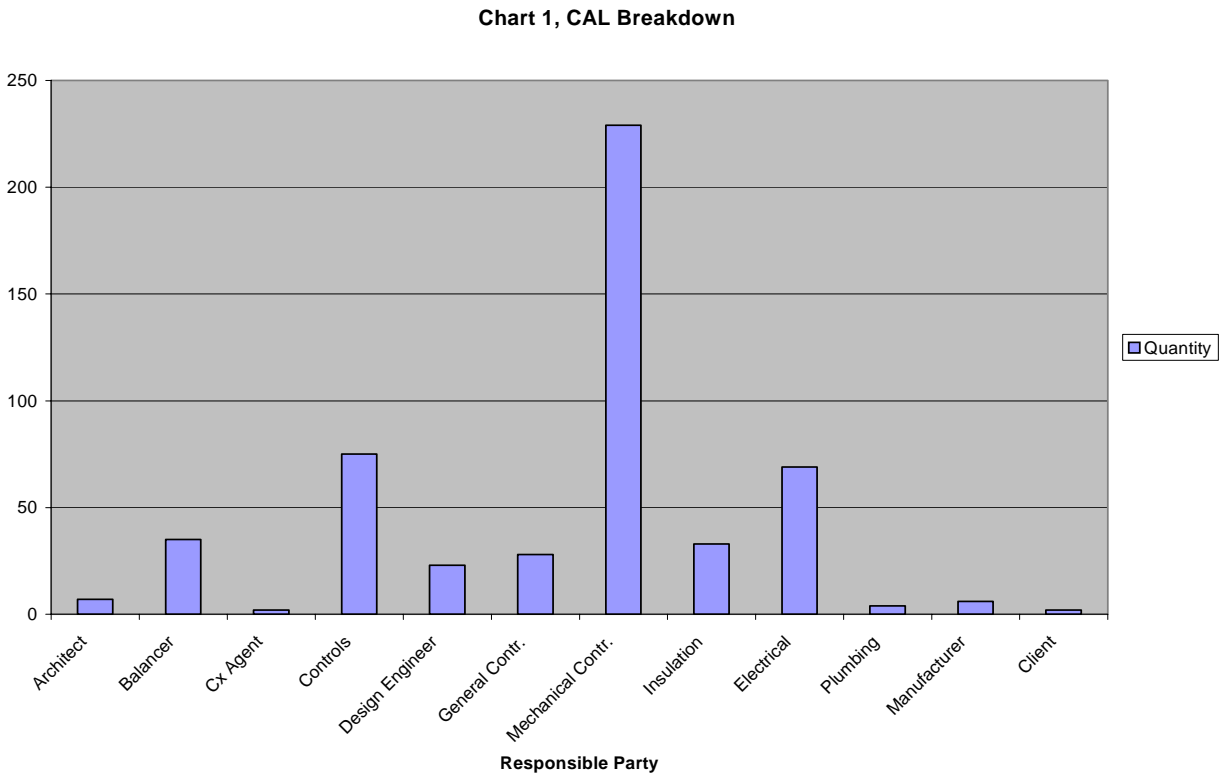
As a comparison, Table 2 details Cx experience on other campus buildings. One important aspect of Table 2, which will be discussed, is the amount of time required post occupancy to complete commissioning.

Table 2

FACILITY TYPE	TOTAL Sq.Ft.	TOTAL ACTION LIST ITEMS	OCCUPANCY	Cx COMPLETION	Cx DURATION
Dormitory	93,000	217	Sept. 2001	August 2002	16 Mo's.
Athletic Facility	162,000	112	Sept. 2002	March, 2003	18 Mo's
Dormitory	412,395	296	Sept. 2002	Dec. 2002	
Dormitory	193,000	265	Sept. 2002	April, 2003	21 Mo's
Science Building/Student Center	430,000	482	March, 2004	March, 2005	45 Mo's
Laboratory	195,000	214	June 2003	Dec. 2003	18 Mo's
Teaching Lab	150,000	0	-	-	-
Laboratory / R&D	420,000	378	Sept., 2005	-	-

Chart 1 characterizes the CAL by responsible party. The fact that the mechanical contractor dominates this chart is influenced more by the commissioning scope of work (dominated by HVAC equipment and systems) rather than a direct reflection on the mechanical contractor relative to all other contractors. Furthermore, in reality the balancer, controls, and insulation contractors all work under the mechanical contractor's umbrella, which accounts for a total of 77% of all action list items.

Chart 1



Impact

There are two undeniable truths to CAL items: *indiscriminate, and inheritable*. The existence of an action item is unique to no one discipline or function, and all unresolved issues will be passed on to user groups, facilities departments, and operations & maintenance staffs.

The number of action list items is more influenced by scope and building type than any unique project construction characteristics. The length of the Cx process (how early in the construction process it is implemented) and the equipment intensity and controls complexity will be much more influential in the amount of CAL items than the actual construction team members.

A newly completed building is transitioned from the project and construction team to the user groups and O & M staff. So too are any underlying deficiencies bequeathed to those who will occupy and maintain the facility. *Owners purchase buildings that will meet their performance criteria and do not intentionally purchase deficiencies and sub performance.*

Life Cycle Costs

Along with helping to ensure operation as intended, commissioning helps to ensure the full project value by emphasizing delivery of both the tangible and intangible elements of the design. To properly assess the intangible elements such as performance, energy consumption, and operations and maintenance, a Life Cycle Cost perspective needs to be applied.

Facility Life Cycle Costs (LCC) can be defined as the sum of initial and future costs (operations and maintenance costs) associated with the construction and operation of a building over a period of time². “Life Cycle Cost Analysis is an economic evaluation technique that determines the total cost of owning and operating a facility over a period of time”³.

The three elements to LCC are:

- Initial Investment (All costs associated with Design & Construction & prior to occupancy)
- Operational Costs – annual costs involved in the operation of the facility (exclusive of maintenance and repair costs). Most of these costs are related to building utilities and custodial services.
- Maintenance & Repair Costs
 - Maintenance costs – scheduled costs associated with the upkeep of the facility
 - Repair Costs – unanticipated expenditures that are required to prolong the life of the building

Understanding Life Cycle Cost analysis allows insight into the full value of a construction project regardless of whether a formal LCC process was used in evaluating the feasibility of the project initially to go forward. There is a direct relationship between the final “value” of a facility’s initial cost and the projected “value” of both operational and repair and maintenance costs. I’m defining “costs” as the actual dollar amount expended, and “value” as the actual total deliverable received.

Lost Opportunity

Once a new building is “completed” and occupied, the emphasis is on productivity, operations and maintenance. Once occupied, a building’s energy consumption takes a back seat to the building’s use and productivity. The “user” becomes paramount and maintaining building systems to satisfy the user’s need is the inherited focus of the operations staff. Maintaining building systems to satisfy the building’s user group becomes the “modus operandi” of the maintenance staff. The opportunity to achieve “performance as designed and intended” from an efficiency and life cycle investment perspective is all but lost after occupancy.

² The National Institute of Standards and Technology Handbook 135, 1995 Edition

³ State of Alaska, Department of Education and Early Development, Alaska School Facilities, Life Cycle Cost Analysis Handbook

Lost opportunities not only include increased energy consumption and maintenance costs in a new building which lacks full commissioning, but increased maintenance in one facility can directly result in increased deferred maintenance in other facilities of the same campus. Just as a building system is directly influenced by its components, so to is a multi building maintenance plan impacted by unplanned demand from a new facility.

In a January, 2004 article for Energy User News regarding barriers and opportunities for building controls systems, authors Kurt Roth and Karen Benedek put the “drivers” for building systems selection in perspective. “Energy costs represent only a small portion of expenditures for most buildings (about 1% of total annual expenditures for an office building). Most building owners put a low priority on reducing energy expenditures.”⁴ Therefore it would follow that any opportunity to realize energy efficient operation (designed or otherwise) should be pursued and verified at project completion (preferably prior to occupancy) lest the performance advantage (one that may have been paid for) be lost. *An energy efficient design does not automatically ensure energy efficient behavior and performance.*

One major unresolved issue on Building 1 at occupancy was the lack of modulation on the Air Handling Unit (AHU) fans. Due to issues with air leakage and static pressure control, the variable volume system, representing approximately 700 kW of connected load, basically ran full time at 100% load. This significant energy use (and cost) was secondary to the performance issues associated with uncomfortable space temperatures.

Recent increases in energy costs have again raised the importance of energy efficiency in commercial building operation. However, as long as energy costs remain a small percentage of a facilities total cost of operation, operational issues such as tenant comfort and indoor air quality will take precedence. In other words, energy efficiency (at least at current prices) will fall victim to the pursuit of higher tenant satisfaction and less maintenance intensity.

Using this argument, however, a case can be made to increase the emphasis on facilities operations in two ways to help ensure optimal facility productivity:

Increase the facility maintenance budget – this will ensure a greater maintenance capacity per square foot of building space to address tenant comfort and IAQ issues expeditiously;

Increase the commissioning scope - emphasize a greater degree of operator staff training on building systems and system performance from both an educational as well a controls perspective. Also include both operational aids (system one line diagrams for mechanical and control rooms) and “trouble shooting hints”. This investment in the maintenance staff may also deliver an inherent benefit. I have stated in previous papers that energy efficiency is a byproduct of performance: consume the amount of energy necessary to perform an operational function in response to that function’s demand, and no more. To invest in the resource (maintenance staff) and a more intensive and comprehensive training of that resource should inherently increase the odds that systems will perform (and consume) as intended.

⁴ Roth, Benedek; January 26, 2004, Commercial Building Controls: Barriers and Opportunities; Energy User News

So, where are we?

Charts 1 & 2 detail the Cx Action List impact on energy, productivity, repair& maintenance, and equipment life.

Chart 2

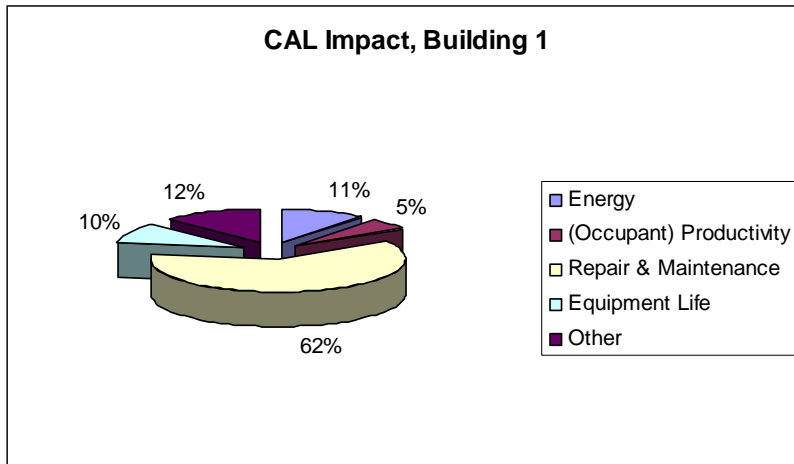
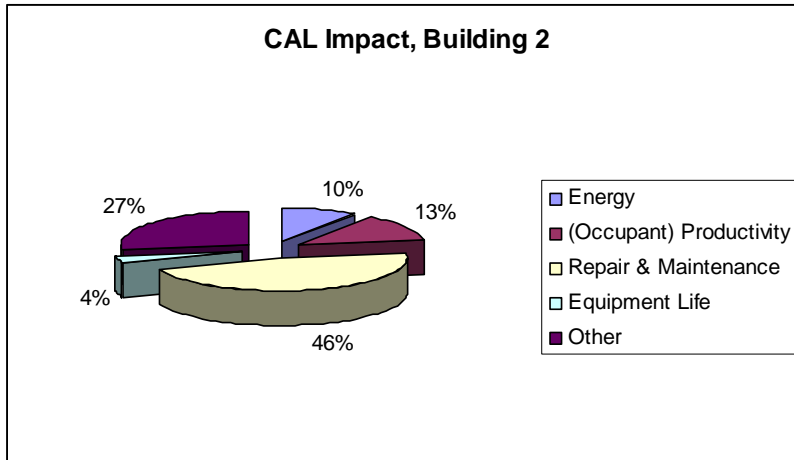


Chart 3



The two projects analyzed show clearly that the majority of issues identified on the Cx Action List (CAL), if not reconciled, become burdens to the maintenance staff. This will inherently take place at occupancy, even if the owner hasn't officially accepted the building. Realization of purchased benefits such as energy efficiency and equipment life will loom in the shadows of incomplete and/or defective systems.

Building 2 is a 46,000 square foot university science center (different university from building 1). The main reason for the impact profile difference is that Cx was applied to the design phase and several items were questions or recommendations that were not acted upon by the design

team, and therefore categorized as “other”. Also, several performance testing issues involved fume hood operation and were categorized as having a productivity impact.

These two charts clearly demonstrate the significant impact on the repair and maintenance staffs of unresolved Cx issues. Relative to the building asset life, the burden on the maintenance staff will eventually surface as increased O&M costs, deferred maintenance, or in reduced building productivity. And there appears to be a trend towards decreased maintenance intensity. According to the Building Owner’s and Manager’s Association (BOMA), there was one maintenance worker per 69,500 square feet of office space in 1994 and five years later there was one maintenance worker per 77,200 square feet (11% increase in area to be addressed per worker)⁵.

Simultaneously O&M costs are rising. As reported in a General Services Administration (GSA) workshop on “Building Performance and Customer Satisfaction” for the New England Region⁶, average O&M costs were at historically high levels in the decade ending in 2000 after a decline in O&M costs for the previous two decades following the energy crisis of the 1970s. This appears to be the result of increased utility costs and building stock.

For all new building issues, which remain unaddressed after occupancy, an endless cycle of additional costs is created. With less staff per square foot to address unanticipated issues, facility managers have no choice but to defer proactive maintenance and optimization opportunities. Energy use and system optimization play second fiddle to occupant complaints and more obvious and tangible problems such as a water leaks or snow removal.

Unresolved Cx issues at occupancy that don’t directly impact productivity are less likely to be resolved due to the transfer of priorities from purchase and construction to production and maintenance.

Value

As discussed, the quality assurance commissioning provides will impact first costs, energy costs, maintenance costs, and more!

Charts 1 & 2 clearly show that the burden of unresolved issues will fall on the shoulders of the operating staff as well as severely impact their overall efficiency. The Building 1 experience was as follows:

- Over 300 unresolved CAL issues at occupancy
- Occupant IAQ/comfort complaints took precedence over excessive energy use.
- 2100 trouble calls were generated to O&M staff in a nine-month time frame during the warranty period.
- O&M took on the added burden of correcting many performance related issues that were impacting occupant productivity. It was easier for the O&M staff to make certain changes to satisfy the occupants and wrangle with the contractor about costs later.

⁵ ESOURCE Multi-Client Study

⁶ GSA Building Performance and Customer Satisfaction Workshop, Peter Smeallie, 2000

Staying focused on LCC after occupancy, a presentation for the GSA titled “Building Performance and Customer Satisfaction, a Private Sector Perspective”⁷, an LCC calculation estimated future O&M costs on a 300,000 square foot building with an expected 30-year building life at \$170 Million (using an undiscounted \$8.50 per square foot) versus a construction cost of \$45 million. Why then overburden an already significant O&M LCC with issues and headaches that should have been resolved under first cost purchase.

This same presentation additionally emphasizes that total LCC typically breakdown as follows:

- Design and Construction - 5%
- Operations & Maintenance- 10%
- Personnel Salaries - 85%

“No Mas”! Construction costs, although significant, are dwarfed by future functional operating expenses from a Life Cycle Cost perspective.

Building 1 had a rash of operational deficiencies that were known but unresolved, due to occupancy requirements (many construction delays, some beyond the contractor’s control). The Cx process documented the outstanding issues and the owner was able to make informed decisions going forward. Leading us to ask: *What are the unknowns on projects where commissioning is absent?*

Conclusion

Building owners are due everything, both tangible and intangible, they pay for. Utilize the quality assurance that commissioning provides to document the intangibles and deficiencies, get them resolved under the design and construction contract, and avoid a legacy of headaches and unplanned costs for the occupants and building staff.

The true dollar value of commissioning is not represented purely by first cost value, but also by future cost impact, which can be staggering.

⁷ Presentation, “Building Performance and Customer Satisfaction, Private Sector Perspective”: McChesney, Rytter, Schoeneborn