The Costs and Benefits of Commissioning Oregon Public Buildings

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ABSTRACT

The Northwest Energy Efficiency Alliance (NEEA), through the Oregon Office of Energy (OOE), has funded commissioning demonstration projects in eight public buildings in Oregon. Information from these projects formed the basis for detailed analyses of commissioning costs and benefits for each case. This paper presents the methodology and preliminary results and ramifications of these analyses. The analyses estimated the quantifiable costs and benefits of commissioning for each project, and also summarized the perceived qualitative benefits and drawbacks. The results of the analyses showed that the cost-effectiveness and perceived benefits of commissioning varied widely. The analysis process has also shed further light on the uncertainties inherent in quantifying cost and savings, including the importance of assumptions about future avoided costs and savings persistence.

Background

Building commissioning is the systematic process of ensuring that building systems, such as HVAC and lighting, are designed, built, and operate according to the owner's operational needs. Commissioning for new buildings typically involves design review, construction review, testing, adjustment, and maintenance planning. Retrocommissioning can restore existing buildings to high productivity through renovation, upgrade and tune-up of existing systems (OOE 2002).

NEEA is currently undertaking a long-term effort to expand and institutionalize the practice of commissioning among state and local governments in the Pacific Northwest (Jennings 2000). An important component of this effort is providing government officials with detailed case studies of commissioned buildings and their demonstrated benefits, including reduced operating costs, increased comfort and productivity for occupants, and energy savings (NEEA 2002). Both commissioning service providers and potential recipients of commissioning services place high value on case studies that target buildings of interest to them, and provide well-documented, reliable estimates of the achieved benefits (SBW Consulting 1998).

In 1998, OOE began recruiting commissioning projects to serve as subjects of case studies. Their selection took into account project timeframes, the willingness of the public agencies to participate, the size of the agencies, and whether the agencies had long-term building programs and/or past exposure to commissioning. Because of these constraints, the pool of suitable projects was small, and thus some of the selected projects might not have been optimal candidates for commissioning. The eight demonstration projects that OOE has established are listed in Table 1. As of the first half of 2002, commissioning activities for seven of the eight projects were essentially complete. The remaining project is expected to be complete by the end of 2002. Of the seven completed projects, four were new commissioning projects and two involved retrocommissioning. One project involved commissioning a chiller retrofit.

Table 1. Commissioning Demonstration Projects in Oregon Public Buildings

	1	2	3	4	5 (in progress)	6	7	8
Site	Lane Community College	Marion F. Miller Elementary School	Beaverton City Library	Courthouse Square	North Clackamas High School	Sexton Mountain Elementary School	Public Service Building	Portland State University (Science 1 Bldg.)
Building type	Daycare Center	Elementary School	Library	Office/ Transit	High School	Elementary School	Office	University
Location (in Oregon)	Eugene	Salem	Beaverton	Salem	Clackamas	Beaverton	Salem	Portland
Commissioning Type	New Building	New Building	New Building	New Building	New Building	Retro	Retro	New chiller
Floor area (ft2)	18,300	49,000	69,500	160,000	250,000	65,000	172,400	213,000

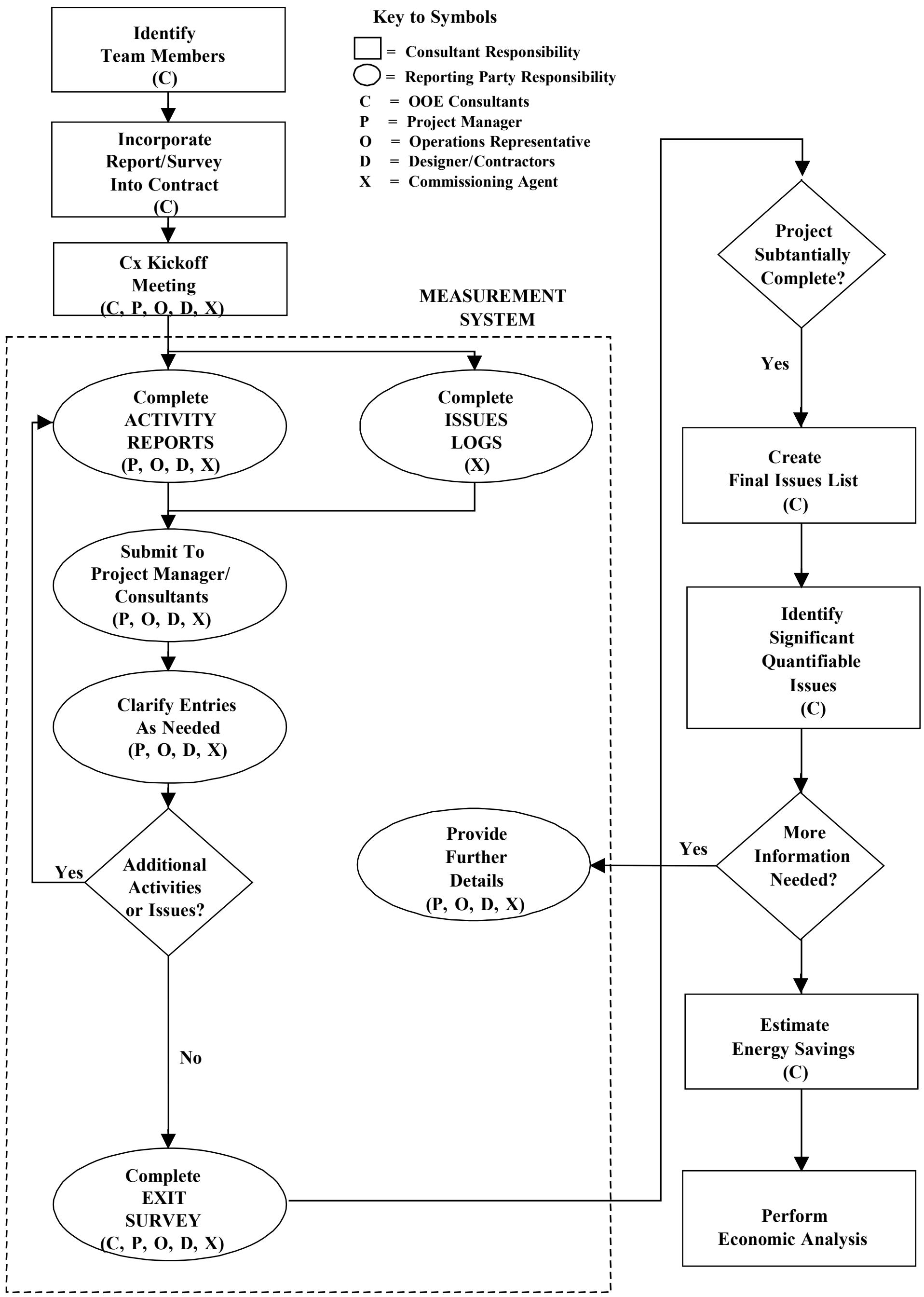
Analysis Methodology

To support the development of effective case study reports for each demonstration project, we quantified costs and benefits of the commissioning services provided through this demonstration program. The analyses relied on information from key members of the commissioning team—agency project managers, facilities operations and maintenance representatives, designers, contractors, and commissioning agents. These project team members were identified early on, and, in most cases, attended a special kickoff meeting that explained the data collection system in detail so that they had a good understanding of the nature and goals of the analysis. Subsequently, each project had an extended data collection phase and an overlapping engineering-economic analysis phase towards the end of the commissioning effort. The flowchart in Figure 1 provides an overview of the entire analysis process.

Data Collection

The data collection system was designed to obtain a comprehensive breakdown of commissioning costs, while minimizing the bureaucratic burden on commissioning team members. This system provided a means for team members to break out their commissioning costs by construction phase, as well as to distinguish between the fixed costs of the commissioning process, as opposed to the variable costs associated with resolving issues identified by the process. The measurement system consisted of three main components: (1) activity reports, (2) issues logs, and (3) exit surveys, each of which is described in more detail below.

Figure 1. Data Collection and Analysis Flowchart



Activity reports. Activity Reports allowed team members to document information about the portion of the commissioning process that led to identifying commissioning issues. On a regular basis throughout the project, each reporting party estimated the portions of the costs related to commissioning activities beyond what they would have charged had commissioning not occurred. The Activity Report only captured that incremental cost of identifying commissioning issues. The costs incurred for resolving commissioning issues were documented separately.

The distinction between identifying and resolving issues is very important. Identifying activities consists of the search for potential problems. These activities—for example, a design review—may or may not actually uncover a specific problem. Resolving issues only happens after a problem turns up—for instance, if the design review revealed an inoperable control sequence. The time the commissioning agent spent pointing out the error to the contractor, and time the controls contractor spent fixing the control sequence, would be recorded in the Issues Log by the commissioning agent.

Issues logs. The commissioning agents completed Issues Logs throughout the commissioning process. Their purpose was to collect information about the portion of the commissioning process devoted to resolving commissioning issues. For example, if a commissioning agent uncovered a potential problem, he or she would document the following in a one-page log sheet:

- Description of the commissioning issue and the likely effects of resolving it.
- Actions taken to resolve the issue.
- Whether the issue would have been identified if the project did not have a commissioning agent, and if so, when and how it might have been resolved.
- Affected project aspects (e.g., design, construction, or operation).
- Whether the issue fell outside of contractual scope for any team members (whether out-of-scope issues resulted in actual project cost increases was treated elsewhere in the analysis).
- Overall costs to resolve the issue, along with estimates of the costs to resolve it if commissioning had not occurred.

Exit surveys. Near the end of the project, we administered a telephone survey to obtain a better understanding of how the commissioning process unfolded, as well as to identify substantial qualitative benefits or drawbacks associated with commissioning on the project. We categorized team members' responses and comments into standardized lists of potential effects.

Engineering Economic Analysis

Our analysis to date for each project consisted of the following steps:

1. Review issues logs and exit surveys to produce a final list of issues identified by the commissioning process and descriptions of the actions taken to resolve these issues. We flagged issues that likely had substantial, quantifiable effects on the cost of design, construction, or operation of the project facility.
2. Estimate first-year cost savings that result from resolving commissioning issues. We asked reporting parties, especially the commissioning agent, to provide details about specifications and operations for affected building systems before and after actions were taken to resolve commissioning issues. We then estimated first-year energy savings using commonly accepted engineering methods, such as bin analyses. To estimate energy cost savings, we used average Oregon energy rates of $0.0494/kWh for electricity (USDOE 2001a, Table 15) and $0.755/therm for natural gas (USDOE 2001b, Table 22). For quantifiable non-energy savings, such as reduced operations

and maintenance expenses, we calculated approximate values using the best information readily available.

3. Calculate commissioning costs. We reviewed and, as necessary, sought clarification of the costs that team members recorded in the activity reports and provided in the exit surveys. These formed the basis of the total commissioning costs. These were primarily up-front expenses associated with identifying commissioning issues, along with the costs of resolving any issues that fell outside of designers' or contractors' scope. The costs of resolving problems that would not have existed had team members adhered tightly to their contractual scope of work were not counted as commissioning costs.
4. Tabulate qualitative benefits and drawbacks. We classified exit survey respondents' comments into standardized tabulations of the most significant qualitative benefits and drawbacks of commissioning on the projects.

Life Cycle Issues

The methodology for rendering the existing analysis results into life-cycle costs and benefits is still being cooperatively developed by the Northwest Energy Efficiency Alliance, Oregon Office of Energy, and SBW Consulting. NEEA is considering sponsoring a Delphi process to determine acceptable values for key life-cycle analysis parameters. Such a process generally involves bringing together a broad group of experts and, through multiple rounds of communication, reaching consensus on the best approach for a given issue.

A simplified, less rigorous approach to these problems would be to assign reasonable best-case and worst-case estimates to key parameters to produce a range of life-cycle savings.

Important parameters to be resolved include the following:

- Study life: The number of years over which commissioning benefits can be expected to accrue. This number may vary depending on building type.
- Measure life. How long equipment affected by the resolution of a commissioning issue might be expected to remain in service in the facility.
- Issue resolution in absence of commissioning. Whether or not a commissioning issue would have been found and resolved had commissioning not occurred. The life cycle benefits that accrue because of commissioning can vary dramatically, depending on whether or not we assume particular issues would have been resolved without commissioning. For example, if a commissioning agent uncovers a broken thermostat that maintenance staff most likely would have found and repaired a few months later, then the life cycle cost savings would be very low. On the other hand, if the agent finds, say, an improperly programmed cooling tower fan motor VFD that would likely have never been found without commissioning, then the savings would stretch over the life of the building, and the life-cycle cost savings would be high. In many cases, the issues logs that commissioning agents prepared for our analyses contain their best answers to these questions. These types of questions, by definition, require a great deal of personal judgment to answer.

After these parameters are established, then the resultant ratio of aggregated life cycle commissioning benefits to the aggregated life cycle commissioning costs will be the primary index of the cost-effectiveness of commissioning for each demonstration project.

Findings

Total Commissioning Costs

Total commissioning costs include the direct costs to the project of the commissioning agent fees, as well as the estimated "indirect" costs for other team members' time. The latter only includes time spent identifying issues through activities such as commissioning coordination meetings and functional testing. It specifically does not include the time spent fixing issues that the commissioning effort revealed. These costs do, when appropriate, include the additional costs from out-of-scope changes that resulted from commissioning. Table 2 breaks down commissioning-related costs by group and project. Note that these costs incorporate project-specific labor rates and travel costs. As a result, similar projects that occur at other locations and times might incur different commissioning costs.

On average, the four new and two retrocommissioning projects had normalized costs of $0.88/ft^2 and $0.21/ft^2, respectively. Note that Project #8 (University, chiller Cx) did not fit either the new or retro categories. Not surprisingly, commissioning agent costs comprised the bulk of the costs, accounting for 83% and 74% on average of new and retro projects ($0.73 and $0.15/ft^2, respectively). Costs for key designers and contractors made up about 15% of the total commissioning cost ($0.13/ft^2) for new projects. Their role was not applicable for retro projects. Agency staff expenses made up from 11% to 41% of retrocommissioning costs, but were minimal for new commissioning projects.

Commissioning Benefits

Table 3 summarizes the issues identified as a result of the commissioning process. Note that the definition of an "issue" was rather loose, and depended on the discretion of the commissioning agent for each project. The four new commissioning projects had 20 to 104 issues (0.7 to 1.5 issues per 1,000 ft^2 of floor area), or an average of 63 issues per project. Of these, almost half improved occupant comfort or indoor air quality, and about a third improved building operability and maintainability. An average of 21 issues reduced energy use, but 13 increased it. The two retrocommissioning projects had an average of 29 issues per project, or 0.4 issues per 1,000 ft^2 of floor area. Again, about half improved occupant comfort or indoor air quality. An average of 10 issues reduced energy use, but six increased it.

Table 2. Commissioning Cost Breakdown

#	Building type	Cx type	Total cost	$/ft2 Cx agent	$/ft2 Designer/ contractor	$/ft2 Agency staff	$/ft2 Total	% of total cost Cx agent	% of total cost Designer/ contractor	% of total cost Agency staff
1	Daycare Center	New	$14,900	0.68	0.10	0.04	0.81	83%	12%	5%
2	Elementary School	New	$43,455	0.67	0.19	0.03	0.89	75%	22%	3%
3	Library	New	$94,073	1.20	0.15	0.00	1.35	89%	11%	0%
4	Office/ Transit	New	$71,480	0.38	0.07	0.00	0.45	85%	15%	0%
6	Elementary School	Retro	$18,604	0.17	0.00	0.12	0.29	59%	0%	41%
7	Office	Retro	$23,480	0.12	0.00	0.01	0.14	89%	0%	11%
8	University	Chiller	$14,046	0.05	0.00	0.01	0.07	80%	0%	20%
	AVERAGES	**New**		**0.73**	**0.13**	**0.02**	**0.88**	**83%**	**15%**	**2%**
		Retro		**0.15**	**0.00**	**0.07**	**0.21**	**74%**	**0%**	**26%**

Table 3. Summary of Issues Identified by Commissioning

Effect of resolving issue (Line 1=# of issues, Line 2=% significant & quantifiable)

#	Building type	Cx type	Reduced energy use	Increased energy use	Improved occupant comfort/IAQ	Increased equipment life	Improved building operability / maintainability	Improved safety	**Total number of issues ID'ed**	**Issues per 1000 ft2**
1	Daycare Center	New	**3**	**1**	**5**	**2**	**13**	**2**	**20**	**1.1**
			100%	0%	60%	0%	15%	0%	20%	
2	Elementary School	New	**30**	**15**	**37**	**16**	**20**	**0**	**74**	**1.5**
			30%	27%	14%	31%	5%	--	16%	
3	Library	New	**19**	**8**	**21**	**16**	**26**	**4**	**55**	**0.8**
			32%	38%	19%	25%	4%	0%	20%	
4	Office/Transit	New	**30**	**27**	**55**	**14**	**38**	**2**	**104**	**0.7**
			13%	19%	11%	21%	5%	0%	9%	
6	Elementary School	Retro	**12**	**9**	**16**	**16**	**13**	**0**	**37**	**0.6**
			58%	44%	38%	19%	38%	--	30%	
7	Office	Retro	**7**	**3**	**13**	**2**	**4**	**1**	**20**	**0.1**
			71%	0%	0%	0%	0%	0%	25%	
8	University	Chiller	**3**	**0**	**0**	**14**	**44**	**2**	**55**	**0.3**
			100%	--	--	14%	9%	0%	13%	
	AVERAGES	**New**	**21**	**13**	**30**	**12**	**24**	**2**	**63**	**1.0**
			27%	24%	15%	25%	6%	0%	14%	
		Retro	**10**	**6**	**15**	**9**	**9**	**1**	**29**	**0.3**
			63%	33%	21%	17%	29%	0%	28%	

Significant quantifiable issues. We worked with the commissioning agent for each project to identify the issues that seemed likely to have significant, quantifiable effects on design, construction, or O&M costs. Anywhere from 13% to 30% of all issues were deemed significant and quantifiable. Table 3 shows the percentage of significant, quantifiable issues by issue effect and overall. On average, we identified 14% of all new commissioning and 28% of all retrocommissioning issues as significant and quantifiable.

Figure 2 portrays the distribution of cost savings, in first-year cost savings per square foot of floor area, for the 54 significant and quantifiable issues identified among the seven projects. These costs savings are based on average Oregon energy rates, as discussed above, and project-specific labor costs. Of the 54 issues, 34 (63%) resulted in cost savings. Savings for all but one of these issues were up to \$0.047/ft^2, with one outlier of \$0.151/ft^2. Six issues (11%) yielded no first-year cost savings, and the remaining 14 issues (26%) actually increased costs (but in many cases improved comfort). Figure 2 also shows that the majority (86%) of the cost savings come from increased or reduced electric or gas usage, with only a small percentage (14%) from changes to labor or other O&M costs.

Table 4 summarizes the overall savings of the significant quantifiable issues on each project. Energy usage savings ranged from -0.51 to 2.34 kWh/year/ft^2 and -0.03 to 0.21 therms/year/ft^2 among the projects. On average, electric savings were 0.19 and 1.60 kWh/year/ft^2 for new and retrocommissioning projects, respectively. Average gas savings were 0.06 (new) and 0.01 therms/year/ft^2 (retro). Overall, average cost savings were \$0.05/ft^2/year and \$0.10/ft^2/year for new and retrocommissioning projects, respectively.

Figure 2. First-Year Cost Savings Distribution from Significant Quantifiable Issues

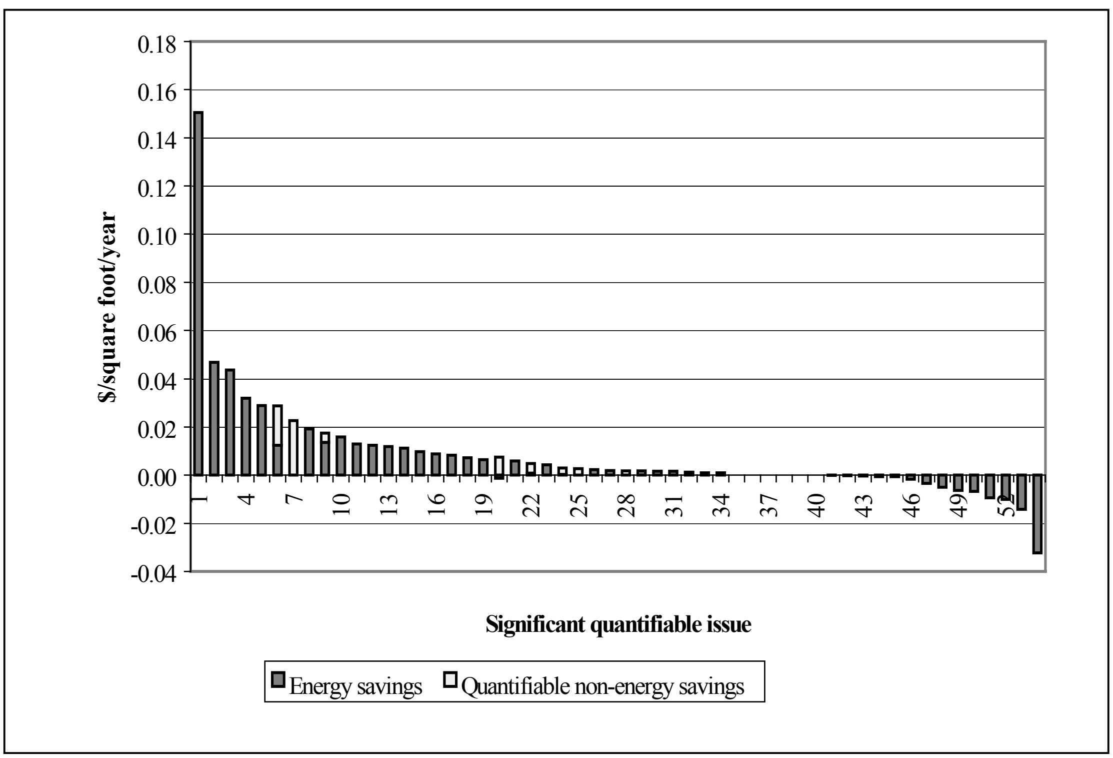


Table 4. Energy and Cost Savings from Significant, Quantifiable Issues

			Savings					Normalized Savings				
#	Building type	Cx type	kWh	therms	Energy $	Non-energy $	Total $	kWh/ft2	therms/ft2	Energy $/ft2	Non-energy $/ft2	Total $/ft2
1	Daycare Center	New	5,487	-	271	425	696	0.30	-	0.01	0.02	0.04
2	Elementary School	New	9,107	10,174	4,616	-	4,616	0.19	0.21	0.09	-	0.09
3	Library	New	(35,255)	2,708	303	773	1,076	(0.51)	0.04	0.00	0.01	0.02
4	Office/ Transit	New	127,744	1,289	6,974	-	6,974	0.80	0.01	0.04	-	0.04
6	Elementary School	Retro	152,362	2,375	11,244	-	11,244	2.34	0.04	0.17	-	0.17
7	Office	Retro	147,946	(4,570)	3,858	-	3,858	0.86	(0.03)	0.02	-	0.02
8	University	Chiller	48,167	4,795	6,000	5,752	11,752	0.23	0.02	0.03	0.03	0.06
AVERAGES			**New Commissioning**					**0.19**	**0.06**	**0.04**	**0.01**	**0.05**
			Retrocommissioning					**1.60**	**0.01**	**0.10**	**-**	**0.10**

Qualitative benefits and drawbacks. Table 5 summarizes feedback about the commissioning efforts that we obtained from 34 respondents. Of these, eight were commissioning agents, 13 were designers or contractors, and 13 were agency staff. Individual opinions of particular commissioning efforts ranged from extremely positive to highly negative, although in general, respondents appeared to provide honest, unbiased assessments. Across all groups, the most commonly mentioned benefit was "fewer operational deficiencies (62%)", followed by "greater energy efficiency (50%)." The most mentioned drawback was "coordination difficulties," which about a third of respondents who were not commissioning agents mentioned. The commissioning agents did not identify any drawbacks.

Benefit-Cost Comparison

Table 6 provides an interim comparison of costs versus benefits. Total commissioning costs divided by total first-year savings provide simple payback figures. We provide these numbers as intermediate results until the life-cycle savings parameters are finalized. Once we are able to obtain the latter, then we will calculate life-cycle cost-benefit ratios that will more accurately determine the cost-effectiveness of commissioning.

Table 5. Respondent Opinions of Qualitative Benefits and Drawbacks

	% Identifying Benefit/Drawback			
	Cx agent	Designer/ contractor	Agency staff	**All**
Total # of respondents*	8	13	13	34
QUALITATIVE BENEFITS				
Design & Construction				
a. Fewer contractor call-backs	33%	38%		**24%**
b. Fewer change orders or warranty claims	33%	54%		**31%**
c. Less time to optimize systems		31%	20%	**21%**
Operations				
d. Fewer operational deficiencies	75%	54%	62%	**62%**
e. Better system documentation	13%	8%	8%	**9%**
f. Improved knowledge for O&M staff	50%		23%	**21%**
g. Greater energy efficiency	50%	38%	62%	**50%**
h. Increased equipment lifetime	25%	15%	8%	**15%**
i. Reduced O&M expenses	25%		31%	**18%**
Occupants				
j. Improved comfort	50%	38%	31%	**38%**
k. Improved indoor air quality	25%	8%	15%	**15%**
QUALITATIVE DRAWBACKS				
a. Project delays		15%		**6%**
b. Coordination difficulties		38%	23%	**24%**
c. Increased conflicts between team members		15%	8%	**9%**

* Design & construction percentages only include pertinent respondents (29 total).

The table shows that the four new commissioning projects had simple paybacks ranging from 9.4 to 87.5 years, for an average of 18.3 years. Paybacks for the retrocommissioning and unclassified commissioning projects appear significantly more attractive, averaging 2.2 years in the retrocommissioning case, and 1.2 years for Project #8.

Table 6. Interim Benefit Cost Comparison--Simple Payback

#	Building type	Cx type	Total Cx cost ($/ft2)	Total Cx savings ($/ft2/yr)	Simple payback (years)
1	Daycare Center	New	0.81	0.04	**21.4**
2	Elementary School	New	0.89	0.09	**9.4**
3	Library	New	1.35	0.02	**87.5**
4	Office/Transit	New	0.45	0.04	**10.2**
6	Elementary School	Retro	0.29	0.17	**1.7**
7	Office	Retro	0.14	0.02	**6.1**
8	University	Chiller	0.07	0.06	**1.2**
	AVERAGES	**New**	**0.88**	**0.05**	**18.3**
		Retro	**0.21**	**0.10**	**2.2**

Conclusions

The methodology we developed successfully provided a comprehensive framework for analyzing the economics of commissioning. Analysis of the seven selected commissioning projects has shown that at least with the four new commissioning projects, the quantifiable cost savings from energy and labor savings do not offset the commissioning costs sufficiently to make commissioning cost-effective on those bases alone. The cost-effectiveness of the two retrocommissioning projects appeared considerably better.

Many of these projects did, however, result in other non-quantifiable benefits, such as improved occupant comfort and reduced O&M problems. Assigning values to these benefits, however, was beyond the scope of this study, and is inherently highly speculative.

We emphasize that the seven projects analyzed by no means are a representative sample of the population of commissioning projects. Our approach could, though, be applied to a statistically valid sampling of projects to obtain more definitive sense of the cost-effectiveness of commissioning.

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