Existing Building Commissioning:
Market Transformation for Persistence of Savings

Recognizing and Formalizing the Role of Operator Training

Michael Bobker, CUNY Institute for Urban Systems, New York, NY

ABSTRACT

Research on persistence of savings from commissioning of new and existing buildings is found to point towards operator involvement and training as a key variable. A logical model for commissioning work supports this finding and is found to be distinct from the traditional energy retrofit capital projects model. Suggestions are made for program design to take this finding into account. Incorporation of formal training design, development of training centers, and alignment of program rules for appropriate incentives is recommended.

KEYWORDS: persistence of savings, training, performance monitoring, feedback loops, process evaluation, behavior effects

Introduction

The nascent commissioning industry has revolved around the new construction process. Perhaps this is natural, as the original naval usage also implies the process of testing and de-bugging a new ship. Nevertheless, the market for commissioning of existing buildings is much larger. Compared to the handful of new commercial projects in any given year, there are hundreds of operating properties.

This paper has developed out of a NYSERDA project oriented towards the existing commercial building market. Commissioning of existing buildings is thought to have a large potential for energy savings but to not yet have the necessary market infrastructure in place to realize the opportunity. Market infrastructure is understood to mean, on the one hand, the capabilities to provide the necessary technical services and, on the other, the demand for services. Without demand, the services would be under-valued in the market and without profit opportunity, firms will not develop and offer the services. For this reason a not-for-profit, the American Council for an Energy Efficient Economy (ACEEE), developed the market-transformation project with the New York State Energy Research and Development Authority (NYSERDA), teaming with another not-for-profit, Portland Energy Conservation Incorporated (PECI) that has been a leader in the development of commissioning services.

The NYSERDA Pilot Project recognized both sides of the demand/supply equation. In the project design direct outreach emphasized the demand-side of owners and property managers while the supply-side of technical service providers was addressed, primarily through a training opportunity. The two sides were tied together through the availability of an incentive payment for an initial "scoping" study. This incentive was available only to service providers completing a one-day training and submitting suitable qualifications. While the precise nature, scope, and sequence of technical services is still developing, it can be said that the methodology is essentially an engineering approach. This paper proposes that a formal role for a training approach needs to be incorporated.

Early-on the project team debated names. There is a family of terms describing commissioning work in existing buildings that while subtly distinct are broadly overlapping: Continuous Commissioning, Retro-commissioning, Enhanced O&M, Building Optimization, Tune-up. Retro-commissioning was retained from the original proposal as it had NYSERDA recognition and resulted in a "prescription-like" logo, RCx. Continuous Commissioning is trade-marked by its originators at the Energy System Lab (ESL) at Texas A& M University and may be subject to licensing requirements.

Continuous Commissioning was developed starting in the late 1980's under the Texas state energy conservation program, LoanSTAR. The program asked the ESL to evaluate and report on the program's savings, in absolute terms, in relation to projections, and in an on-going manner on persistence. Much of their work was subsequently incorporated into procedures developed as the International Performance Monitoring and Verification Protocol (IPMVP). An important finding was that ***the M&V work itself contributed significantly to the maintenance of savings***. The Texas A&M researchers found that M&V procedures rigorously applied as a part of enhanced O&M, without capital projects, could itself reduce energy consumption on the order of 10-30%.

Especially in so far as the Continuous Commissioning (CC) and Retro-Commissioning (RCx) approaches grow out of a specific involvement with M&V and attention to maintenance-of-savings, it is ironic to hear program administrators wondering about funding these activities due to skepticism about Persistence. The line of thought, though, is clear: ***since there is little or no hardware involved, what is the reliable basis of savings?*** It is this question that the present paper seeks to address.

Literature Review

Work on the persistence of commissioning benefits is being conducted by a small community of practitioners and researchers. The limited literature suggests consensus that commissioning results do persist with a high degree of reliability over at least several years but that there are significant discrepancies in performance to account for. Work led by senior researches Daniel Turner, David Claridge and Jeff Haberl at the Texas A&M Energy System Lab (ESL) is documented in an extensive series of papers listed on their website (http://www-esl.tamu.edu/esl_home_page.html) and in the proceedings of the annual ICEBO conference. Their overview discussion of CC distinguishes the process from normal building commissioning by the level of operator involvement and by repeated feedback loops, that account for as much as 30% variations in performance and persistence. Portland Energy Conservation Incorporated (PECI) researcher Hannah Friedman has examined the success in achieving savings projected for commissioning in both new and existing buildings. She also finds that a key variable is the degree of operator involvement in the process. Work by the Commercial Building Systems Group at the Lawrence Berkeley National Lab (LBNL) similarly suggests the importance of operator involvement. However, in the conclusions to a recent "meta-study" of Commissioning suggestions for continuing research conspicuously lack any reference to behavioral and learning aspects. Thus, while there are suggestive findings and an underlying model that identifies altered operator behavior as the key to Persistence of Commissioning Savings, there does not appear to as yet be any formalization upon which program design and evaluation can be based.

A distinct but related literature has been exploring enhanced functionalities for building monitoring and control systems. These include advanced data visualization techniques, trending, and automated diagnostics. This work has been led largely from the same set of organizations, with connection to the International Energy Agency (IEA) Annex 40 group on Building Energy Management Systems. Work in California (see Piette, et.al, LBNL) has made the connection to demand-response programming for electric utility systems. Another related area of exploration along these lines, led by LBNL, is attempting to specifically incorporate these advances into community college curricula for building service technicians (Crabtree et.al 2004).

Persistence: A Logical Model and Its Implications

A logical model of "savings persistence" after changes are made to a building reflects the dynamic nature of building performance. Even hardware-based changes are subject to under-performance from projection or degradation of performance over time. System performance deteriorates for a variety of reasons. We know that controls drift out of calibration for physical reasons as well as for behavioral ones as they are reset or over-ridden. Valve or damper actuators fail. Belts loosen. Leaks occur. Schedules change. We can think of these all as causes of "performance drift or excursion" from a target state to a sub-optimal state, as shown in Figure 1. The sub-optimal state or "SOS" we might conveniently think of as a "cry for help", if only there are ears educated to hear it.

Figure 1 Performance Drift or Excursion from Target State to Sub-Optimal State ("SOS")

The model for the persistence of commissioning benefits has a central behavioral dimension. A variance from intended or best practice operation or a degradation of performance is recognized through a testing or monitoring activity and a corrective response is initiated. Persistence depends on some form of regular maintenance awareness and intervention. Without such recognition, the sub-optimal state can exist for the long-term and can eventually come to be seen as normal and correct. The degree of persistence depends on how quickly recognition and interventions occur to address the development of sub-optimal conditions. The speed and effectiveness of recognition and response are subject to training. It is interesting to note that the effectiveness of intervention is measurable.

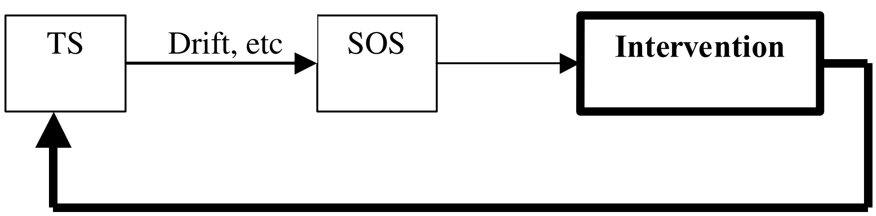

Figure 2 Intervention (Behavioral) Added to Return Operation to Target State

Explorations of Persistence from New Building Commissioning (NBC) emphasize this behavioral model. It might be said that NBC looks at the building as a product and the commissioning team is involved in a quality control process, assuring conformance to specification. Commissioning is completed and the product sent on its way. But examining the persistence issue drives the model back towards something more like that of Continuous Commissioning, where operational performance rather than compliance with specification is emphasized:

> In the limited number of buildings studied, persistence of commissioning benefits seemed to be dependent on the working environment for building engineers and maintenance staff. A working environment that was supportive of

> persistence included adequate operator training, dedicated operations staff with the time to study and optimize building operation, and an administrative focus on building performance and energy costs....Only a few of the buildings studied seemed to operate in this supportive environment, and the measures investigated at these facilities had a high level of persistence. (Friedman p.11)

The LBNL team comes to a similar conclusion from their review of retro-commissioning projects:

> Four sites....listed training as the primary non-energy benefit from retrocommissioning. The table 5 results show that these four sites have good energy savings and persistence. Conversely, office 3 reported no training value and it has the least persistent energy savings....Commissioning agents are most effective when they are both an expert and a teacher. (Bourassa, et.al p).

These findings strongly suggest support for what we might think of as the appropriate "logical model" for persistence, emphasizing a continuing feedback loop between building and building operator. If the early research findings cited accurately portray what can be expected to be the broad, general case for commissioning persistence, then **program practitioners must consider how these elements of behavior, learning, and feedback can be systematically incorporated into program practices**.

A Program Design Gap: Reflecting The Persistence Model In Program Practice

Thus far in the evolution of commissioning programs, there is limited formal incorporation of behavioral and learning dimensions. Design of state and utility retro-commissioning programs to date emphasizes the identification and correction of "deficiencies," based on engineering observation, usually by outsiders (consultants). These are quantified as improvement projects and treated much as capital improvement recommendations under the older, familiar model of energy audits. In addition to the NYSERDA pilot, leading-edge programs for the City of Oakland, CA and the utility-sponsored program for the region of Denver, CO take this approach. Engineering focus is mobilized, problems found, and solutions implemented.

Engineering observation and findings are embodied in a report, generically described as the "Performance Assessment" in Figure 2. The engineering review sits on top of the normal maintenance practices, seeks to identify sub-optimal operating conditions and facilitate corrective responses. The model ignores the repetitive nature of this loop. The SOS-Intervention linkage cannot for the long term depend on an outside Performance Assessment. This step must be internalized by building operators.

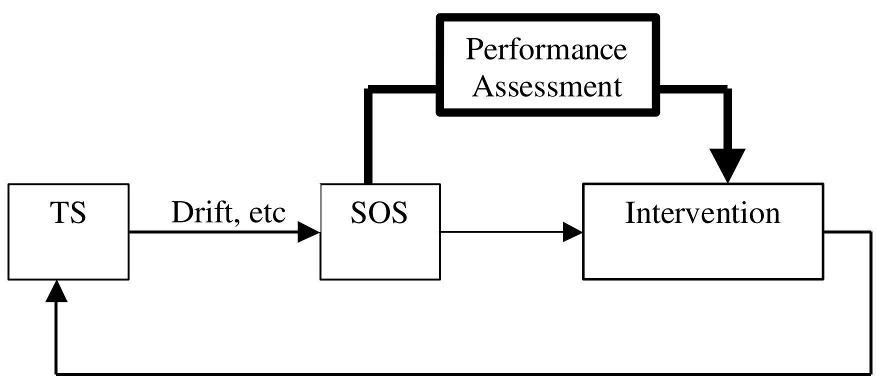

Figure 3 Engineering Assessment Added to Facilitate SOS Recognition and Response

Thus far in program development practice, the operator behavior/learning dimension is recognized but left outside of quantified program metrics. For example, in the scoping study evaluation of the NYSERDA Pilot, the RCx consultant is asked to comment on whether the operating staff has sufficient skills to make it capable of cooperating with a retro-commissioning process. No criteria are provided for making this determination. No areas are suggested for evaluation. No skills remediation is sought. The determination is treated as a threshold condition such that a "no" makes the building ineligible for further work – ironically, just the kind of building that might be expected to show the greatest need and where operating staff improvement could show the greatest benefit.

Equally significant, for projects where staff is considered sufficiently capable for the project to move forward, there is no formal procedure for identifying and specifying operating staff training needs or instructional activities that should be part of the commissioning agent's work. By necessity, operating staff is involved in problem identification and in the execution of functional tests. They are primary sources of information to the RCx agent and necessary support in the set-up and operation of equipment for testing. But what they learn is left to chance and the particular attitude and behavior of the RCx consultant.

When the applied program design fails to address a key variable that affects the maintenance of outcomes, there certainly *should be* doubts about whether outcomes will persist. If retro-commissioning outcomes are to persist, the program designs need to specifically address operator learning and behavior. This point, made repeatedly in the Continuous Commissioning literature, seems to have escaped the design parameters in more recent existing-building and retro-commissioning programming.

Incorporating Operator Learning Into Program Design

The formal evaluation of learning needs is a discipline outside of engineering. It is relatively easy to say that a learning needs assessment and learning design should become part of retro-commissioning programs. It is much more difficult to expect that the retro-commissioning agents, typically consulting engineers, will either readily accept or have the ability to meet such a requirement. Some engineers enjoy working and communicating with operators; given the time and the direction, they can be expected to be reasonably good trainers. This, no doubt, has been occurring relatively informally in the field in successful projects. Consistent program performance on a large scale cannot, however, rely on such undefined procedures. Figure 4 suggests the addition of a training level to the Persistence Model.

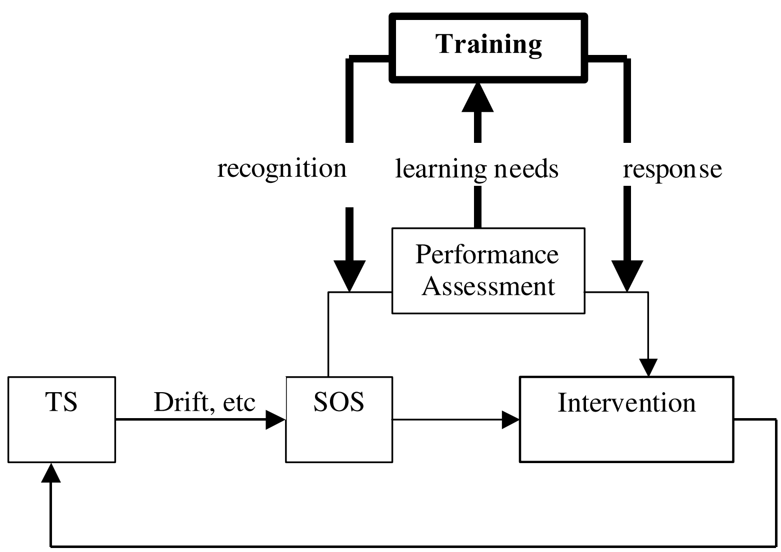

Figure 4 Addition of a Training Level to the Persistence Model

The Performance Assessment now identifies not only system response needs but also operator learning needs that should be addressed by training. This step is critical if the Performance Assessment capability is to be successfully transferred from outside engineering consultants to internal building operators. Proper training will enable operators to both recognize "SOS" conditions more readily and to respond more efficiently and effectively. The outcome, then, should be a more reliable and faster corrective response to drift and excursion and, therefore, better persistence of savings.

From an evaluation perspective a program design that includes specifically identified training and learning should be expected to provide better performance results and persistence. This certainly seems to be the case with results from the TAMU ESL, where on-going feedback and interaction with operators has been most emphasized. The presence and adequacy of a training process in the program design overall and in any specific project can be seen as another intervening variable. If we accept this conclusion from the logical model, then the challenge becomes how to operationalize the concepts into actual programs.

Formalization of Training Objectives: Interfacing Engineering with Training

Formalizing this part of RCx programming will require the involvement of training experts. Development of standardized assessment tools would be an important step. Such tools could be developed in coordination with guidelines for diagnostics and their use, based in building automation systems. Bourassa et al suggest along these lines that "additional research is also needed to develop tools and methods to allow building engineers and operators to obtain feedback on savings associated with retro-commissioning." Development could be undertaken on a collaborative basis by multiple entities interested in promoting existing building commissioning.

What Would Training Program Design Look Like? The sought-after training should be a combination of on-site and off-site work. There is much to be said for learning through one's own day-to-day experience with familiar systems and equipment. However there is a level of generality and theory that is better achieved when the learner is taken out of their familiar surroundings. It is also important to keep in mind that from a market transformation perspective, we are training a workforce (of building operators) to new practices across an industry, not as any individual is ties to a specific building. To accomplish this, overall program design should support the development of formal training opportunities and should credit participation in them.

While the above emphasizes the importance of formal training, it is equally true that learning will occur informally, through the process of evaluation, testing, and work. In fact, for the mechanically-oriented audience under consideration, formal classroom training without a substantial hands-on component will be ineffective. Working lab facilities are of key importance but equally important is that work in the subject buildings should be seen as a key part of the learning process.

For this to occur consistently a Training Plan should become a part of the report, connected to the physical findings and recommendations of the engineering review. Training Plans include learning objectives that would be tied to the specific kinds of measures to be implemented. Quite often, for example, learning would include the theory and practice of advanced building automation functions.

Formulating Learning Objectives by RCx Measure. To assist in the preparation of Training Plans the program should provide short curricula for the most common areas of building performance improvement. These would include basic theory, practical skills (such as for monitoring, testing, adjusting), savings impacts, comfort and health considerations. Learning assessment tools would also be extremely useful and could then be combined with learning diagnostics-objectives, exercises, and referral to formal offerings. A customized plan would be assembled at least in part by drawing upon these resources. Development of this kind of standardized resource would be most important to compensate for the general lack of expertise in this aspect of the work on the part of the engineers who serve as primary service providers.

Certification Standards: Coordination with Industry. In many locales commercial building operators have certification standards to meet. In NYC, for example, Local 94 of the International Brotherhood of Operating Engineers (AFL-CIO) provides training for various certifications. Through a series of discussions the union has shown considerable interest in training for existing building commissioning and enhanced O&M that could extend and deepen services to members. The idea of connecting building commissioning practices with building operating certification was previously forwarded by Price (2001) and has been discussed as an area of interest of the Northeast Energy Efficiency Partnership (Hinge, 2004 personal communication) and is the subject of on-going work by the national and local chapters of the Building Operators and Managers Association (BOMA). A national labor-environmental coalition called Apollo21 has also shown interest in promoting new training and skills for its building sector members to adapt to emerging requirements for green, high-performance equipment and buildings.

If the new buildings market is any indicator, commercial property owners will increasingly see LEEDS or EnergyStar certification as a desirable credential. Requirement or points for development of a training plan and its implementation could be a significant market driver.

Training Centers and Labs: Providing Focal Points. Agencies with a responsibility for optimizing energy performance should allocate program funding to creating regional and/or local centers where this kind of operator training can be conducted. The value of such training goes beyond the retro-commissioning program itself, to impact the persistence of savings in a wider range of programs. In discussing findings about persistence versus degradation of retrofit savings in the Texas LoanSTAR program, Haberl et al point out that "studies by the Laboratory have shown that 20 to 30% of the savings will erode over time if these buildings are not carefully monitored, which would amount to an annual $2 to $3 million savings shortfall."

Program Rules: Small Changes for Large Effects. In the NYSERDA case, for example, relatively small rule changes can make a substantial difference in how in-house work on the retro-commissioning project is perceived. Presently, under Technical Assistance rules through which RCx is funded, in-kind contributions are not accepted towards the required match of state incentives. With this rule, the incentive is to have the consultant do all his work as quickly as possible (ie – taking no time for training) and to have as little impact as possible on in-house staff time (as their time on the project is not valued). For RCx, a more appropriate message would be sent by encouraging the use of in-house labor in the process. This would encourage teamwork between the RCx consultant, paid largely under state funds, and in-house operating engineers, representing owner contribution.

Similarly, where public energy efficiency programs require matching funding, the costs of formal training should be accepted towards this owner contribution. This ruling, costing the state nothing out-of-pocket, would significantly support and leverage the training resources discussed above that are so necessary for the broad market transformation sought.

Encouraging Feedback and Learning-by-Doing With Program Design

Along with operator involvement, another aspect of learning theory applicable to RCx program design is prompt feedback on actions taken. For an operations-oriented program, it is important to take actions that can provide positive feedback and learning experience. Operators typically respond best to hands-on experience. Where more elaborate evaluation is to be undertaken, the pathway to implementation needs to be clear.

The RCx process as structured in the NYSERDA pilot prohibits any implementation work under Technical Assistance funding. Whatever is found in initial scoping must be subjected to further testing and evaluation under TA support. This is a carry-over of rules for a capital-improvements program, which specifically excluded shared funding of O&M measures. TA in this context is intended to establish economically attractive energy investment options that would qualify for implementation support through other NYSERDA programs., with the owner providing a matching share of capital. Since testing is allowed under this rule, the program works well for RCx consultant work where sophisticated functional testing is necessary. But when applied to more straightforward scoping findings, this rule inhibits actions that could result in early implementation, positive feedback, and learning-by-doing. For example, addition to a building automation system of a well-understood control function, would instead have to be studied and then included as a recommendation in a larger TA-RCx study report or else be undertaken by the owner without state support.

Thus the initial scoping study process can only result in findings for further study supported by state incentives; any immediate implementation opportunities do not qualify for TA support. This inhibits the kind of in-house creativity and engagement that is sought by retro-commissioning. Lost is the opportunity to guide it by supporting development of deeper working relationships between in-house operators and consulting engineering resources. Both communities lose. Such small rules can be pivotal points in the state's ability to stimulate new relationships that transform market practices.

Conclusion

Studies of commissioning benefits have shown substantial persistence of measures and benefits. Research findings are limited by the period of time for which commissioning data is available, generally not longer than 3-4 years. But because commissioning measures tend to have short projected paybacks, cost-effectiveness is demonstrated even over the short periods investigated. Moreover, the degradation of savings is generally consistent with what is found in savings results for a broad range of retrofit measures that involve hardware and capital investment.

There is of course a range of results in degradation of savings over time. Researchers examining these variations see a correlation between persistence and the level and quality of operator involvement in the commissioning process. This finding supports a logical model of commissioning effectiveness as rooted in operator behavior, learning, and continuing feedback about the facility's performance.

Yet recent designs for existing building commissioning programs have generally failed to include this model and its training implications in their formal design, practice or evaluation. The systematic development and inclusion of training objectives and capabilities is suggested as a key element of program development that will result in more reliable and consistent long-term outcomes.

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