Methodologies for Determining Persistence of Commissioning Benefits

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Abstract: Studies on the persistence of commissioning benefits to date have used a variety of methods to evaluate this persistence. This paper proposes a consistent framework for describing and evaluating the persistence of commissioning benefits. It begins by splitting commissioning benefits into two broad categories: 1) benefits that inherently persist; and 2) benefits that may not persist. The study of persistence then considers only the benefits that may not persist. These benefits are critical, since the top five reasons cited for performing commissioning in both new buildings and existing buildings are benefits that may not persist. These benefits are then further divided into benefits that may be quantified and benefits that are generally difficult to quantify. This paper proposes that benefits that may be quantified should generally be evaluated for persistence using approaches that are already widely accepted and used for other purposes, with adaptations where needed.

Specifically, it proposes that energy and water savings be evaluated using methods consistent with the International Performance Measurement and Verification Protocol (adapted with additional weather normalization), that comfort and indoor air quality improvements be evaluated using relevant standards, specifically ASHRAE Standard 55 and ASHRAE Standard 62, but goes further and proposes a methodology for economic quantification of these benefits as well. Finally, it is proposed that the persistence of measures whose benefit is difficult to quantify be evaluated simply by determining whether the measure is still in place or performing.

Commissioning Benefits

Many benefits attributed to commissioning have been reported in the literature. Some of them, by their nature are one time benefits that inherently persist over time. The building owner and/or occupants may realize other benefits over an extended period of time – even over the entire life of the building. But these other benefits may also degrade or dissipate over time.

The one time, or inherently persistent benefits normally reduce construction cost directly or indirectly. Table 1 lists a number of reported benefits of commissioning (Mills et al. 2005, Friedman et al. 2002, Liu et al., 2002) that appear to generally fall in the category of inherently persistent benefits. They have been grouped as design benefits, construction benefits, early occupancy benefits, and “other”, primarily based on when they occur in the design/construction process.

The benefit from design improvements inherently occurs once, but these benefits persist until the building is renovated or equipment fails and is replaced. Many more design benefits than those listed may result from commissioning. The benefits that speed up or make the construction process flow more smoothly will clearly provide a one time benefit. The benefits that make early occupancy a more seamless process will generally be one time benefits, though the items related to safety and liability may be viewed as on-going benefits. The role of commissioning in qualifying a building for a LEED rating or participation in a utility program may provide long term benefits, but are treated as inherently persisting. A thorough retro-commissioning process can be a significant enabling factor for a thorough building retrofit. All of these benefits except the last will be associated with commissioning of a new building, but will also often apply to a commissioning of a significant renovation or retrofit of a building.

Table 1. Inherently Persistent Benefits of Commissioning

Design Benefits

- Equipment right-sizing
- Improved equipment layout

Construction Benefits

- Improved project schedule
- Clarified delineation of responsibilities among team members
- Fewer change orders
- Less disagreement among contractors
- Reduced contractor call backs
- More vigilant contractor behavior (knowing that Cx will follow their work)
- Reduced testing and balancing (TAB) costs

Early Occupancy Benefits

- Smoother process and turnover
- Less disruption to occupancy and operations during turnover
- Fewer warranty claims
- Improve safety
- Reduce liability

Other

- Comply with LEED or other sustainability rating system
- Qualify for rebate, financing or other services
- Qualify for participation in utility program
- An enabling factor for comprehensive system overhaul

The benefits listed in Table 2 have also been reported as commissioning benefits (Mills et al. 2005, Friedman et al. 2002, Liu et al., 2002), but these are items related to the operation of the building that are thought to be more likely to change over time, particularly if they are the result of the implementation of practices that are not widely understood by the community of building operators. Hence these benefits are treated as commissioning benefits that may not persist.

Table 2. Commissioning Benefits That May Not Persist

Reduce energy consumption

Ensure proper system performance (energy and non-energy systems)

Ensure or improve indoor thermal environment /occupant comfort

Ensure adequate indoor air quality

Increase in-house staff skills, knowledge, awareness

Improve water utilization

Repair or accelerate repair of a problem

Avoid premature equipment failure

Reduce operations and maintenance costs

Increase occupant productivity

Improve documentation

Improve operational efficacy

Provide sustainable engineering solutions to operational problems

Mills et al. (2005) found that the only five benefits that were cited among the reasons that commissioning had been applied in over half of the individual projects they surveyed (see Figures 1 and 2) were all measures that may not persist. We have listed those benefits as the first five in Table 2. This emphasizes the critical importance of users being confident that these measures will persist.

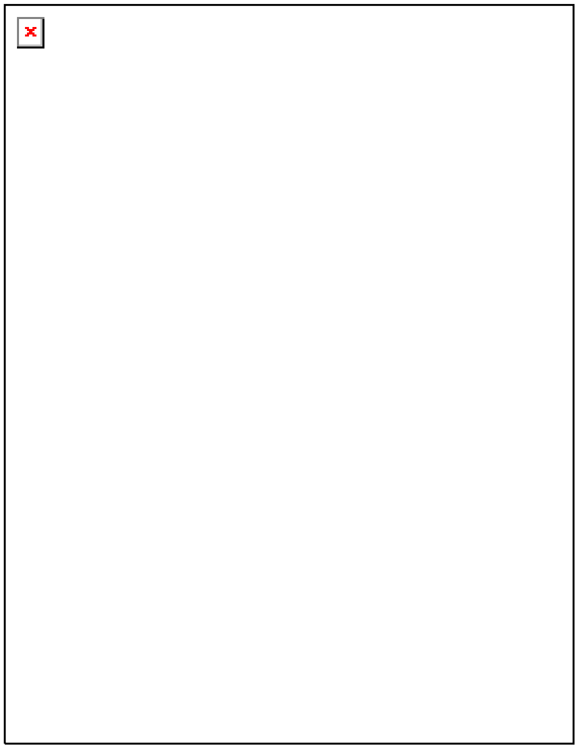

Figure 1. Reasons for New Construction Commissioning (Mills et al. 2004)

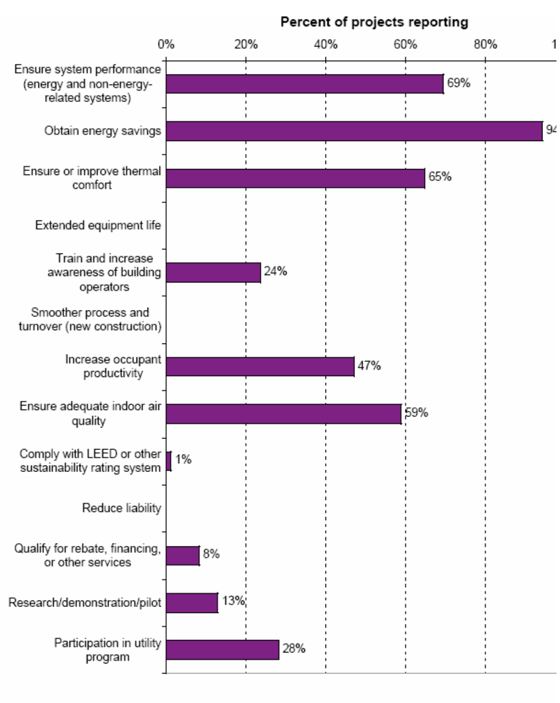

Figure 2. Reasons for Commissioning Existing Buildings (Mills, et al. 2004)

<u>Measures of Benefit Persistence</u>

Table 3 lists the benefits that may persist in separate categories: benefits for which persistence can be quantified in a reasonable manner if suitable baselines are available; and benefits that are difficult to quantify. The *International Performance Measurement and Verification Protocol* (IPMVP 2001) is widely used to determine savings in energy and water resulting from either retrofits or operational changes. It provides procedures that may also be applied to new buildings if the impact of commissioning measures implemented can be accurately treated in a simulation. Comfort has been widely studied, and measures of comfort such as dry bulb temperature and relative humidity can be measured and logged. Likewise, CO_2 and other measures of indoor air quality may be measured. It is assumed that new buildings will provide comfort and quality indoor air, so it will be difficult to document commissioning benefits to comfort or indoor air quality in new buildings. However, when commissioning is carried out in an existing building, these changes can be documented with appropriate measurements before and after commissioning.

These measurements are most likely to be made if a serious comfort and/or air quality problem provides a significant part of the motivation for commissioning the building. Typical maintenance costs are understood quite well, and likewise, equipment lifetimes and some key factors that reduce equipment lifetime are well known. Hence, it is possible to quantify the impact of commissioning on reducing premature equipment failure and maintenance costs.

The remaining items listed in Table 3 are much more difficult to document, beyond the documentation of specific commissioning measures that have been implemented and verification that these measures are still in place months or years later. Hence the only further treatment of these benefits within the proposed methodology will be through documentation of specific measures related to these benefits.

Table 3. Commissioning Benefits That May Not Persist

Quantifiable Benefits
Reduce energy consumption
Ensure or improve indoor thermal environment /occupant comfort
Ensure adequate indoor air quality
Improve water utilization
Avoid premature equipment failure
Reduce operations and maintenance costs
Benefits that are Difficult to Quantify
Ensure proper system performance (energy and non-energy systems)
Increase in-house staff skills, knowledge, awareness
Repair or accelerate repair of a problem
Increase occupant productivity
Improve documentation
Improve operational efficacy
Provide sustainable engineering solutions to operational problems

Given this context, and based on a review of the existing literature on persistence of commissioning benefits (Frank et al. 2005), the proposed methodology for determining persistence of commissioning benefits will specifically treat the persistence of the energy, water, comfort, indoor air quality, avoiding premature equipment failure, and reducing maintenance cost benefits of commissioning in a quantitative manner. It will treat all other benefits through examination of the persistence of specific commissioning measures that have been implemented.

Persistence of Energy Benefits from Commissioning

It is proposed that energy benefits of commissioning be determined using an appropriate methodology from the International Performance Measurement and Verification Protocol (IPMVP 2001). This protocol provides a general approach that compares measured energy use or demand before and after implementation of an energy savings program using the equation:

Energy Savings = Baseyear Energy Use – Post-Retrofit Energy Use ± Adjustments

The "Adjustments" term brings energy use in the two time periods to the same set of conditions by adjusting for differences in weather, occupancy, plant throughput, and equipment operations. These adjustments are made routinely for weather changes, or as needed for occupancy changes, scheduling changes, etc.

Four basic options are presented for determining energy savings within the IPMVP. These options are briefly described in Table 4. Within the context of this methodology, the only option that is considered appropriate for determining the energy savings from commissioning of a new building is Option D, Calibrated Simulation. This permits the calibration of a simulation to the measured consumption of the building following commissioning, followed by simulation of the changes made during commissioning. For existing buildings that are commissioned, energy savings from comprehensive commissioning projects may be evaluated using either Options C or D. If the savings from the commissioning process are too small to evaluate in one of these ways, or only one or two measures are expected to result in energy savings, then Option B may be appropriate. Option A will rarely be appropriate. The detailed procedures in the protocol are to be used.

Following determination of energy savings in multiple years using the selected procedure, savings from each year in which savings are determined will be further normalized to a common weather year to eliminate bias in the persistence determination from

Table 4. The Four IPMVP Energy Savings Options: Source: IPMVP 2001

M&V Option	How Savings are Calculated	Typical Applications
A. Partially Measured Retrofit Isolation Savings are determined by partial field measurement of the energy use of the system(s) to which an ECM was applied, separate from the energy use of the rest of the facility. Measurements may be either short term or continuous. Partial measurement means that some but not all parameter(s) may be stipulated, if the total impact of possible stipulation error(s) is not significant to the resultant savings. Careful review of ECM design and installation will ensure that stipulated values fairly represent the probable actual value. Stipulations should be sown in the M&V Plan along with analysis of the significance of the error they may introduce.	Engineering calculations using short term or continuous post-retrofit measurements and stipulations.	Lighting retrofit where power draw is measured periodically. Operating hours of the lights are assumed to be one half hour per day longer than store open hours.
B. Retrofit Isolation Savings are determined by field measurement of the energy use of the systems to which the ECM was applied, separate from the energy use of the rest of the facility. Short term or continuous measurements are taken throughout the post-retrofit period.	Engineering calculations using short term or continuous measurements.	Application of controls to vary the load on a constant speed pump using a variable speed drive. Electricity use is measured by a kWh meter installed on the electrical supply to the pump motor. In the base year this meter is in place for a week to verify constant loading. The meter is in place throughout the post-retrofit period to track variations in energy use.
C. Whole Facility Savings are determined by measuring energy use at the whole facility level. Short term or continuous measurements are taken throughout the post-retrofit period.	Analysis of whole facility utility meter or sub-meter data using techniques from simple comparison to regression analysis.	Multifaceted energy management program affecting many systems in a building. Energy use is measured by the gas and electric utility meters for a twelve month base year period and throughout the post-retrofit period.
D. Calibrated Simulation Savings are determined through simulation of the energy use of components or the whole facility. Simulation routines must be demonstrated to adequately model actual energy performance measured in the facility. This option usually requires considerable skill in calibrated simulation.	Energy use simulation, calibrated with hourly or monthly utility billing data and/or end use metering.	Multifaceted energy management program affecting many systems in a building but where no base year data are available. Post-retrofit period energy use is measured by the gas and electric utility meters. Base year energy use is determined by simulation using a model calibrated by the post-retrofit period utility data.

weather differences in the different years. Other adjustments may also be made when warranted by known conditions.

<u>Persistence of Water Savings Benefits from Commissioning</u>

The IPMVP methodologies for determining water savings are the same as those used to determine energy savings. In these cases, it becomes important to consider precipitation if the building water consumption includes water uses for exterior landscaping.

Persistence of Thermal Comfort and Indoor Air Quality Benefits

Thermal comfort may be evaluated in terms of whether the conditions fall within the comfort zone as defined by ASHRAE Standard 55 (ASHRAE 2004a). Likewise, indoor air quality may be evaluated in terms of its compliance with ASHRAE Standard 62 (ASHRAE 2004b). Persistence of commissioning benefits may then be evaluated relative to these standards. When an existing building is commissioned, the benefit may be evaluated in terms of specific improvements in comfort or indoor air quality provided sufficient baseline measurements of these conditions are made.

Cost Impact of Thermal Comfort and Indoor Air Quality Improvements

Sometimes, particularly in existing buildings, comfort and indoor air quality problems decrease the efficiency of the HVAC system. For example, too much air flow in a constant volume air handler can both increase energy use and keep the system from maintaining comfort at times. In such cases, the improved comfort also results in energy cost savings. In other cases, the improvement in thermal comfort or indoor air quality comes at the expense of increased energy consumption and cost. This occurs, for example when it is found that the outdoor air dampers have been completely closed and damper leakage is not providing adequate outside air to meet the ventilation standard. The commissioning engineer will set the outside air damper properly, but this will increase the energy consumption of the building. This increased energy consumption has typically been treated as an additional cost of the commissioning process, and basically treated as an un-quantified benefit. Hence the net effect in the perception of most owners is likely to be negative, unless the comfort problem was so severe that it dominated the reasons for initiating the commissioning project.

The proposed methodology will adjust the baseline energy consumption upward to account for the deficiency found in the building so no energy cost penalty accrues to the commissioning project. It will then evaluate the economic benefit of the improved comfort or air quality by evaluating the energy cost of the change. This cost will be added to an annualized measure of the cost ($/MMBtu-year) of installing and maintaining the HVAC system in the building. This energy cost will be treated as a conservative measure of the economic value of the change. Building owners are routinely willing to pay the energy cost of operating HVAC systems to provide comfort. They also routinely pay the original cost of the HVAC system as well as additional maintenance and replacement cost. Finally they routinely pay the cost of operating them inefficiently. Hence it is a conservative evaluation of the benefit of an improvement in comfort or indoor air quality to assign it a value equal to efficiently meeting the additional operating cost.

Persistence of Commissioning Measures

In some cases, appropriate metering is not installed or baseline information needed to determine energy savings is not available. In other cases, the measures of interest may not impact energy consumption, but may impact other benefits of commissioning as discussed in the section on “Measures of Benefit Persistence.” In these cases, persistence shall be determined by comparing a list of documented commissioning measures that were implemented during the commissioning process with the measures that are subsequently documented as being in place or operational during the time when persistence is being checked.

When used to evaluate measures that impact energy consumption, the most comprehensive systematic listing of measures that may be considered is probably that of Mills et al. (2005). They used a matrix that included the specific commissioning measures in the four categories listed in Table 5. These measures were then considered as being applied to deficiencies in the areas or systems shown in Table 6.

Table 5. Specific Commissioning Measures

Design, Installation, Retrofit, Replacement

- Design change
- Installation modifications
- Retrofit/equipment replacement
- Other

Operations and Control

- Implement advanced reset
- Start/stop (environmentally determined)
- Scheduling (occupancy determined)
- Modify setpoint(s)
- Equipment staging
- Modify sequence of operations
- Loop tuning
- Behavior modification/manual changes to operations
- Other

Maintenance

- Calibration
- Mechanical fix
- Heat transfer maintenance
- Filtration maintenance
- Other

Deficiency unmatched to specific measure

Table 6. Areas or Systems in which Measures

Correct Deficiencies

HVAC (combined heating and cooling)

Cooling plant

Heating plant

Air handling and distribution

Terminal units

Lighting

Envelope

Plug loads

Facility-wide (e.g. EMCS or utility related)

Other

Deficiency unmatched to specific measure

CONCLUSIONS

This paper proposes a consistent framework for describing and evaluating the persistence of commissioning benefits. It begins by splitting commissioning benefits into two broad categories: 1) benefits that inherently persist; and 2) benefits that may not persist. The study of persistence then considers only the benefits that may not persist. These benefits are critical, since the top five reasons cited for performing commissioning in both new buildings and existing buildings are benefits that may not persist. These benefits are then further divided into benefits that may be quantified and benefits that are generally difficult to quantify. This paper proposes that benefits that may be quantified should generally be evaluated for persistence using approaches that are already widely accepted and used for other purposes, with adaptations where needed.

Specifically, it proposes that energy and water savings be evaluated using methods consistent with the International Performance Measurement and Verification Protocol with additional weather normalization to improve year-by-year comparison. It proposes that comfort be evaluated in terms of compliance with ASHRAE Standard 55 and that indoor air quality improvements be evaluated using ASHRAE Standard 62. It goes further and proposes that these benefits be quantified in terms of the energy cost of providing the improved comfort and/or air quality. Finally, it is proposed that the persistence of measures whose benefit is difficult to quantify be evaluated simply by determining whether the measure is still in place and/or performing.

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