

# ASHRAE JOURNAL

THE MAGAZINE OF HVAC&R TECHNOLOGY AND APPLICATIONS OCTOBER 2012

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# Commissioning Design/Build Projects

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The commissioning (Cx) process is not one-size-fits-all. For example, in a design/build<sup>1</sup> project, design occurs during the construction phase, requiring changes to the traditional commissioning process. This article discusses these differences in commissioning for a design/build project vs. a design/bid/build project using examples from practice, including an example from a net zero energy school project.

## Commissioning Process

The commissioning process has evolved over the last three decades as the owners' quality process focuses on verifying and documenting that the final built project meets the owners' project requirements (OPR).<sup>2</sup> ASHRAE started developing guidance on commissioning in 1982, and published Guideline 0, *The Commissioning Process*, in 1989. Commissioning has proven to be a cost-effective enhancement that improves building performance, or at least performance of commissioned systems, with respect to energy, sustainability, and indoor environmental quality.<sup>3</sup>

## Guideline 0-2005 and Design/Build

The distinguishing characteristic of traditional design/bid/build, at least in theory, is that the design phase ends prior to the start of construction. The commissioning process in ASHRAE Guideline 0-2005 follows this sequential approach to the delivery process (Figure B.1 of Guideline 0-2005). The design phase and the commissioning activities conducted during design all occur prior to the construction phase<sup>2</sup> to ensure the best possible set of bid documents. This is followed by construction phase commissioning to ensure those documents are realized in the built project. However, this traditional approach does not

apply so clearly to design/build where design and construction overlap.

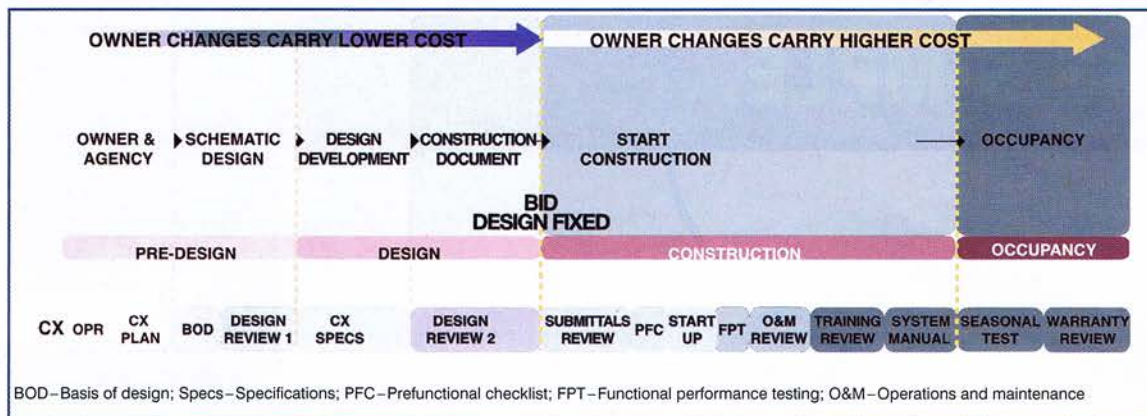
LEED and other systems such as the Collaborative for High Performance Schools (CHPS) view commissioning as so essential to sustainability that they mandate commissioning.<sup>4</sup> The bias toward design/bid/build in the traditional commissioning process is also reflected in such rating systems. For example, LEED credits are designated either "design" or "construction." LEED fundamental commissioning focuses on construction activities, while enhanced commissioning includes design activities.<sup>5</sup>

Since design/build delivery blurs the lines between design phase and construction phase, the Guideline 0-2005 Cx process can be more costly and less effective, diverting Cx resources from the substantive technical work that is so essential to an effective Cx approach.

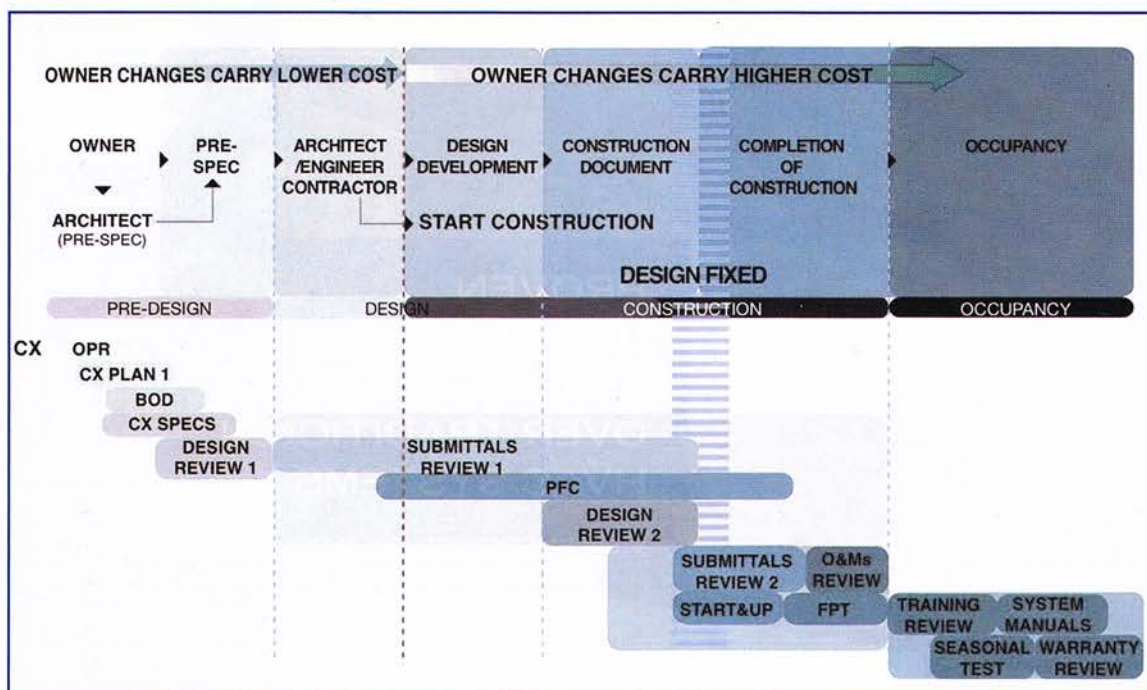
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**Figure 1:** Sequence of commissioning tasks on design/bid/build projects.



**Figure 2:** Sequence of commissioning tasks on design/build projects.

Ideally, the Cx process should be tailored to suit design/build, so that it is more effective and less costly to provide than the unmodified Guideline 0-2005 process.

### Commissioning Design/Bid/Build Projects

Figure 1 shows a simplified time line to illustrate the phases of a design/bid/build project, and the series of tasks that make up the commissioning process. With the design completed prior to the construction phase, the project design and construction tasks as well as the commissioning tasks are sequential with little overlap. Because of this, a simple linear flow chart can be used to represent the commissioning process and its sub-tasks. This particular example shows the LEED-required approach to design review. The back-check of the design documents is listed here as "Design Review 2."

### Commissioning Design/Build Projects

Figure 2 shows a similar time line to illustrate the simplified phases of a design/build project. Because of the overlap

between design and construction, the project phases as well as the commissioning tasks are reordered and overlap. Therefore, a series of tasks in a single line sequence, as used for the design/bid/build process, no longer suffices.

The commissioning tasks in Figure 2 are presented in Gantt chart format to clarify the extended time frames and the overlapping of commissioning tasks. "Pre-spec" in this figure is an abbreviated reference to the documents used by the owner to solicit design/build proposals, sometimes called bridging documents.

The commissioning process should reflect the realities of design/build in plans and schedules, and also requires non-trivial changes in the commissioning process. For example, the approach to commissioning design review may require substantial revision for design/build projects. Instead of all-encompassing reviews of complete sets of project documents, partial document packages may require phased review over an extended period of time to support a design/build project's progress.



To better calibrate the commissioning design review process to the design/build delivery method, it is useful to review the logic behind the approach to commissioning design review for design/bid/build projects. Then, an improved commissioning design review process can be developed that better suits design/build projects. Several other stages of the Cx process can be similarly evaluated and optimized to suit design/build projects.

### The Ability to Influence Project Outcomes

Figure 3 shows curves originally developed by the American Society of Civil Engineers that show that the ability to make changes to a project decreases with time, and the cost impacts increase. The curves are general and do not reflect sudden changes that occur with design completion.

Figure 3 is the basis for an expanded version with Cx-related information in Figure 4. Figure 3 shows, in generic terms, accepted industry wisdom: the ability to influence a project is greatest at the beginning of the project, before design or construction work has begun (the blue curve). It also shows that the cost to make changes to a project is lowest at the beginning, and increases over time, especially as construction is completed (red curve).

### Cost and Influence Curves

These generalized curves have been refined in Figure 4 to emphasize that the ability to influence a project drops abruptly when the design is fixed. On design/build projects, this does not occur in one step when the design phase ends. Instead, the first step change occurs at the time the owner issues the design/build request for proposals (RFP), since the bridging documents or pre-specs issued with the design/build RFP typically serve as the reference and basis for the design/build scope and cost throughout the project. The second step change occurs when the design is completed by the design/build entity and becomes fixed.

As a result, two steps down are shown in the "Ability to Change" curve: one at the time the pre-spec is issued and another at the time that the design is completed or fixed.

Note that the design is not fixed until later in the process, compared to design/bid/build projects. Theoretically, this should make it possible to have greater influence on the design later in the process. But the cost basis for the remainder of design and its construction were fixed at the moment the design/build contract was awarded. As a result, on many projects, the cost to change has already jumped, and the ability to influence has already dropped substantially, at the time of design/build contract award. As a result, these changes are shown in two steps.

Because of the overlap of the design phase with the construction phase, the commissioning process cannot be neatly executed on design/build projects in the terms widely used in industry guidance and green building rating systems. In terms of ASHRAE Guideline 0-2005, the first of the four statistically based quality design reviews (required at 35%, 50%, 95%,

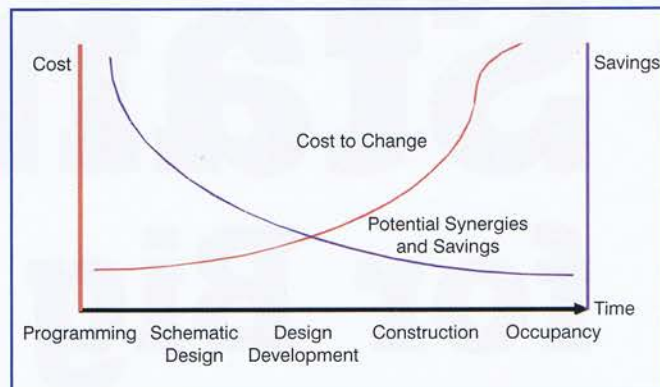


Figure 3: Potential to harvest savings from design synergies.<sup>6</sup>

and 100% design) may be most effective if it occurs prior to the completion of the bridging documents, instead of occurring at 35%.

LEED-enhanced commissioning requires design review, "...prior to the mid-construction documents phase and back-check [of] the ... subsequent design submission."<sup>5</sup> This is less stringent than ASHRAE Guideline 0-2005. Therefore, with LEED design reviews, the problem of diminished effectiveness of commissioning reviews may be even more acute. What does it mean to the commissioning effort if the first design review is not performed until 50% CDs, as required by LEED, if the bridging documents on which the design/build effort is bought were long ago completed and procurement of the design/build contract is complete? In many cases, a unique and significant opportunity to verify and document the quality of the project has been missed.

On design/build projects, design changes can occur more readily and with lower cost during early construction. This is a double-edged sword. Commissioning firms can leverage this extended ability to influence project outcomes to improve both the commissioning process and final project outcomes. On the other hand, the quality of a project is not embedded in a "locked down" set of documents prior to construction, increasing the risk that project teams may depart from strategies to meet owners' project requirements well into construction.

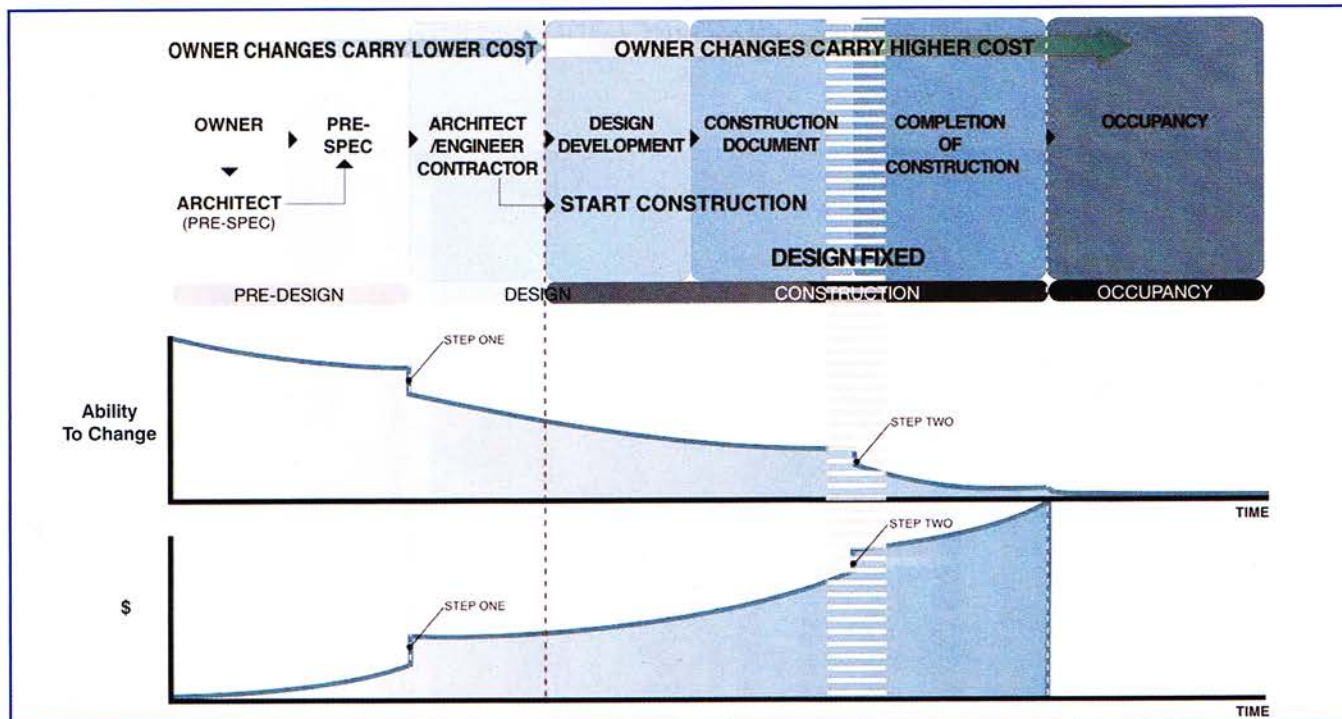
### Improving Commissioning: Real-World Examples

Modifications to the Cx process, such as the approaches in the discussion below and the real world changes in the sidebar, *Design/Build Net Zero Energy Schools Project*, must be thoughtfully anticipated in the commissioning proposal and fee estimating stages. In this sense, design/build projects may be more vulnerable to the risk of the Cx firm expending too much of their fee on early project stages, without enough fee left over to perform the later critical technical work, including hands-on functional performance testing, system tuning, and other subsequent first-year Cx tasks.

### OPRs and Basis of Design

On design/build projects there are always changes to the basis of design (BOD) during construction, since the design of





**Figure 4:** Ability and cost to change design/build projects.

the commissioned systems is still occurring. As with design/bid/build systems, each round of value engineering is likely to require changes to the basis of design. But with design/build projects, it is virtually certain that substantial updates to the basis of design and, in many cases, the owner's project requirements, will be required.

### Commissioning Specifications

On design/build projects, commissioning firms are presented with a unique opportunity to influence the participation of the design team in the commissioning process with bridging document content. In the authors' practice, commissioning specifications for design/bid/build projects are limited to performance and quality requirements for the general contractor or construction manager and the tier, trade, or subcontractors. Content regarding owner or designer participation in commissioning has, for several years, been provided to clients only in the commissioning plan, since discussing the architect's role in commissioning is wildly out of place in specifications for design/bid/build projects.

Design/build projects, however, are entirely different. The bridging documents can appropriately include detailed requirements that extend to the performance of the entire design/build team, including the designers.

On a recent design/build project targeting LEED Silver under NC-2009, the following language was issued as part of the bridging documents:

A. This renovation is a design/build project. The commissioning requirements after the award of the design/build contract for the design professionals of record for commissioned systems include:

1. Incorporate commissioning requirements into the final project specifications.
2. Respond to commissioning design review comments.
3. Update BOD to reflect final design.
4. Consider commissioning comments on submittals in review actions.
5. Participate in nine of the construction phase commissioning meetings. Representatives of the design team shall attend every other construction phase commissioning meeting.
6. Assist in resolution of issues identified through the commissioning process.
7. Include the commissioning authority on project correspondence related to commissioned systems including supplementary information and changes.
8. Incorporate commissioning review comments into final as-builts.
9. Review and comment on commissioning documentation.

In the authors' practice, we take advantage of this opportunity to impose requirements on the engineer of record. Architects and engineers may be surprised when they realize the situation: that the requirements for their participation in the commissioning process have been imposed on them contractually by the owner, by virtue of the commissioning sections developed for and included in the bridging documents. But commissioning authorities may be delighted to realize that they have the ability, for example, to require the engineer's attendance at construction phase commissioning meetings.



# Cx Process for Design/Build Net Zero Energy School

*For a real-life net zero school project, the key owner's project requirements included the goals of being CHPS compliant, Living Buildings Challenge certified, and net zero energy within surrounding site. This high performance building used a modified commissioning process to accommodate the design/build delivery method.*

Commissioning Authority (CxA) is first consultant hired by owner (prior to developing bridging documents or issuing design/build RFP)

CxA develops OPR prior to Design/Build team selection

CxA performs initial design review of Design/Build bridging documents prior to bid

CxA performs phased design review of Design/Build packages as they are issued throughout the project

Cx specifications are issued with bridging documents and include: Cx schedule, required to be incorporated into master project schedule

Formal Cx notifications protocol, while reserving the right to communicate informally with sub-consultants and sub-contractors when expeditious

Requirements for formal submittals from trade contractors for review by engineer of record

All related submittals required prior to review, i.e., controls product data will not be reviewed by CxA until controls engineering drawings are provided

Requirements for timely responses to Cx design issues by engineer of record

Requirements for CxA to receive reviewed design package

and approved submittals prior to delivery or start of installation of each system or component

Engineer of record required to attendance of at least six Cx meetings during construction

Design/build team required to review draft PFCs and FPTs prior to implementation

Requirements to perform & document start-up, TAB, & controls point to point checks prior to FPTs

Required response in the event of repeated failures of FPTs on major components

Required response in the event of numerous failures of FPTs on repetitive components such as VAV boxes

Requirements to provide As-Builts, O&Ms, final controls programming and setpoints, and other detailed information to CxA

Draft PFCs and FPTs before construction, and finalize based on approved submittals after construction start

Single Cx issues log includes all issues whether from design review, construction, FPTs, or other source

CxA provides monthly briefing to owner's project manager summarizing Cx status and noting Cx issues where owner's help to expedite Design/Build team response is requested

## Design Review

Planning commissioning design reviews so that they occur at the appropriate phase of design is complicated by the design/build approach, since design is occurring well into the construction phase. Since the bridging documents set the bar for the quality that the design/build team will have to deliver, commissioning review is very important. On a recent simple dormitory project, a small, fast track LEED-NC 2009 project with simple MEP systems, the second design review was coordinated with the design/build team to occur near the end of coordination when the MEP design was "locked down." This was effective because the design of the commissioned systems were all completed around the same time.

## Phased Design Review

On more complex design/build projects, the design does not typically become fixed early in the construction phase. To further complicate planning the commissioning process, different aspects of the design may be completed early on, while other aspects of design are still not fixed. This can delay the second commissioning design review and, as shown previously, also diminishes the extent to which the commissioning review can influence the design.

To address this complication on a recent college athletics center with natatorium, a large, complex project with extensive MEP and on-site renewable energy systems, the second

design review could not be performed until two months prior to completion of construction. The resulting discontinuity in the commissioning design reviews from the bridging documents to construction diminished the impact of the second design review, since the ability to influence the design had dropped so far by the time the review was performed.

Another approach is to offer a phased design review process, with necessary fee adjustments to cover the additional effort. This allows timely commissioning review of each aspect of the design as it is completed, before it is too late to influence that area of the design.

## Submittal Review

The commissioning authority will often have to perform submittal review in phases over an extended period of time on design/build projects. This is particularly true when different aspects of the design are completed early on, while other aspects of design are still in flux. In some cases, it may be appropriate to insist on waiting to perform commissioning review if related submittals have not yet been received. For example, controls product submittals are rarely reviewed prior to receipt of the controls engineering plans, since it is typically infeasible to review the product submittals without the controls plans in hand.

Design/build bridging documents should clearly require a formal submittal review process. On projects without this, de-



sign/build teams have avoided or delayed producing submittal documents since the design team is no longer a separate contractual entity from the contractor's team. Commissioning contributions to bridging documents can include language requiring a formal submittal process. This language can formally require an owner's submittal review process that incorporates the commissioning review comments. With the owner as the formal conduit for the commissioning comments, the contractual relationship between the owner and the design/build team can increase the influence of the commissioning authority.

### Pre-Functional Checklists

When submittals are phased over a longer period of time, this typically requires a phased approach to developing pre-functional checklists (PFCs). Instead of a short period of time during which all submittals are provided and reviewed by the design team and others, as is typical for design/bid/build, submittals for various work packages may be approved over a long period of time, as design work is completed in phases for different aspects or areas of the design/build project. Since the final submittals are not available in one discrete set, they are not available for a single effort to produce PFCs, requiring the Cx firm to produce batches of PFCs as submittals are approved by the architect or engineer of record.

When this occurs on design/build projects, the equipment delivery and installation will probably also be spread over a longer period of time, and contractors will also have to participate in a phased approach to PFC completion. Commissioning specifications that link the development of PFCs to the completion of approved submittals, and make it clear that PFCs are to be completed by contractors on a timely basis as the associated work is performed, can make PFC requirements clear to contractors. The authors recommend this approach to specifying PFC completion on all projects whether design/build or not, but we have found that this language can be helpful and even critical on design/build projects.

### Functional Performance Tests

In the authors' practice, the Cx authority leads, directs, and participates actively with the installing contractors in performing the functional performance tests (FPTs). This highly technical work is the heart of the technical Cx services provided, and it is the single most expensive part of the Cx process. Because of the potential to increase the effort and associated cost of the Cx process, phased completion of FPTs is a very sensitive subject among Cx authorities! The staggered completion of design elements that may occur on complex design/build projects need not translate into an undue impact on the *execution* of FPTs. However, if design of certain aspects of commissioned systems is completed late in a design/build project, then phased *development* of FPT procedures may be required instead of waiting for a final approved controls submittal showing all systems and sequences to develop all the FPT procedures.

On recent design/build projects, the same approach to avoiding phased FPT execution that is successful on design/bid/build projects has been equally effective. Under this approach, the commissioning schedule is provided in Gantt chart format, and shows the completion of installation work, TAB, controls point-to-point checks and sequence verification, factory and contractor start-ups, and other contractually required work as a prerequisite (or, in schedulers' parlance, a predecessor) to systems-level FPTs.

In practice, the authors will often accommodate requests to perform component-level FPTs prior to the completion of these prerequisite tasks, but will decline to perform partial system level FPTs. For this reason, we prefer project schedules to show three phases of testing: component, system, and inter-system. An example of a component level FPT would be verifying the safeties on a pump, whereas testing the control sequences of the hydronic system the pump serves, such as  $\Delta P$  control or lead/lag rollover, are considered system level tests and will not be started until all the testing prerequisites are complete.

On design/build projects, documenting these requirements clearly early on and "sticking to your guns" can be even more difficult, but is even more critical to ensure effective testing that is also cost-effective to provide. If bridging documents do not include these commissioning requirements, as may occur when commissioning is procured late, then the owner may be well-advised to put in place an addendum to the design/build contract with Cx specifications provided by the Cx firm, explicitly stating specific commissioning requirements for the project.

### Conclusion

The improvements discussed in this article, and illustrated in the case study, enhance the commissioning process for design/build projects, and help address potential risks unique to, or heightened by, the design/build delivery method. The resulting commissioning process is better suited to such projects. Not only can it improve commissioning outcomes, it can help control the costs of providing commissioning, as well as leading to enhanced building performance for owners.

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