PDHonline Course P155 (3 PDH)

A Project Lifecycle and the Construction Process - Seven Stages from Conception to Demolition

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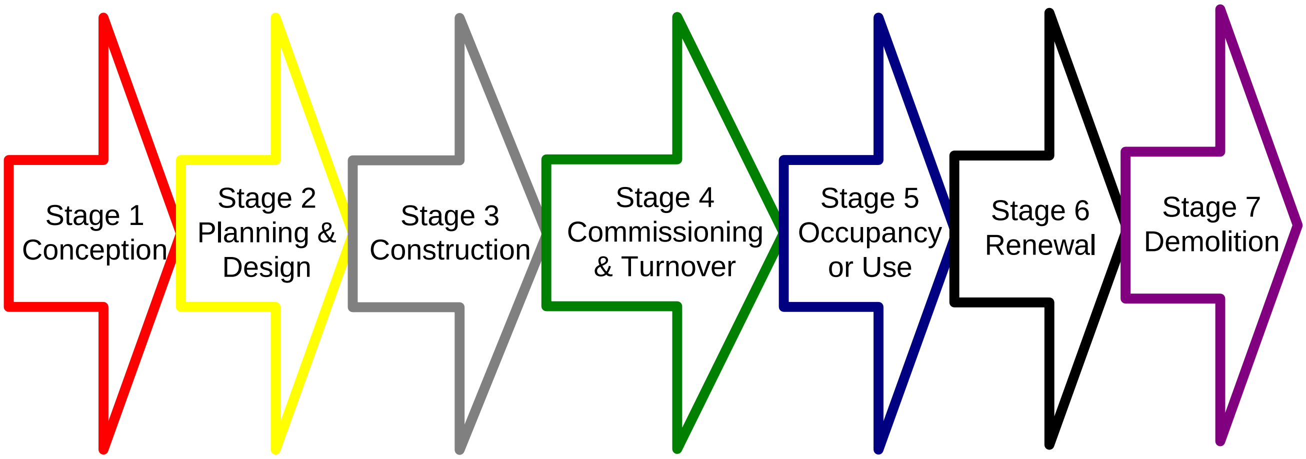
Course Content

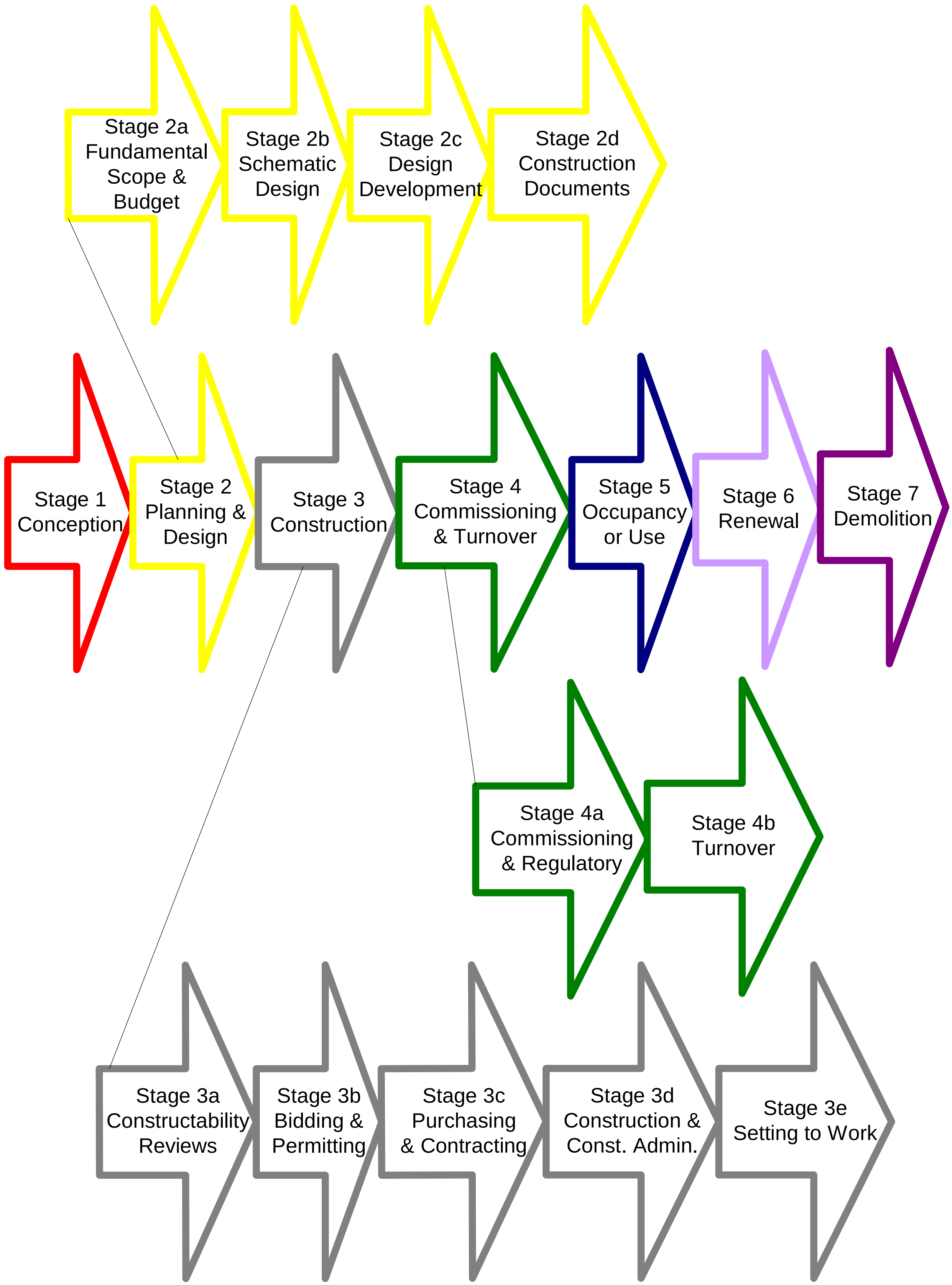


Introduction

We can look at a project as a living organism – it begins with a birth and ends with a death. According to the psychologist Erikson, people pass through eight developmental stages – with reluctance, you might have been required to study this in that required psychology elective. In each stage, there is a crisis of sorts that must be overcome before moving on to the next stage. As engineers, we might view this kind of thinking as a bit of nonsense – we will move on to a stage whether we want to or not with life dragging us along (although all of us know someone who is an adult but acts in an earlier stage.) Yet, we all must admit there are stages in ones life. (On an even lighter side, someone said that the stages of a man's life can be related to Santa; when a man is a child, he believes in Santa. When he becomes a dad, he becomes Santa. When he grows old, he looks like Santa.)

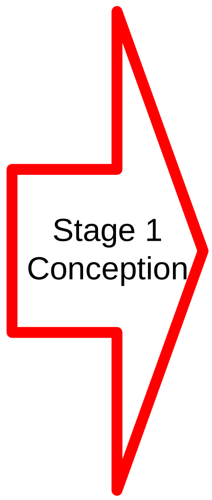
Similarly, there are seven stages of a project described in this course, with activities that must be completed (hopefully not a crisis) before moving on to the next; birth is Stage 1, or Conception.

The final stage, death or demolition, is Stage 7. Often, projects are attempted to be managed by circumventing a stage or substage, and problems result. Like life, we will go to the next stage automatically, but if something was missed or unresolved in the previous there will be problems. This course describes the fundamental elements of the stages, also including Stage 2 – Planning & Design, Stage 3 – Construction, Stage 4 – Commissioning & Turnover, Stage 5 – Occupancy or Use, and Stage 6 – Renewal. Substages for Stage 2, 3, and 4 are further delineated. These stages are tried and true (although sometimes described differently), and are essential in developing a successful project. These stages or steps in a project are useful in describing the process of developing and maintaining a project for your customers.



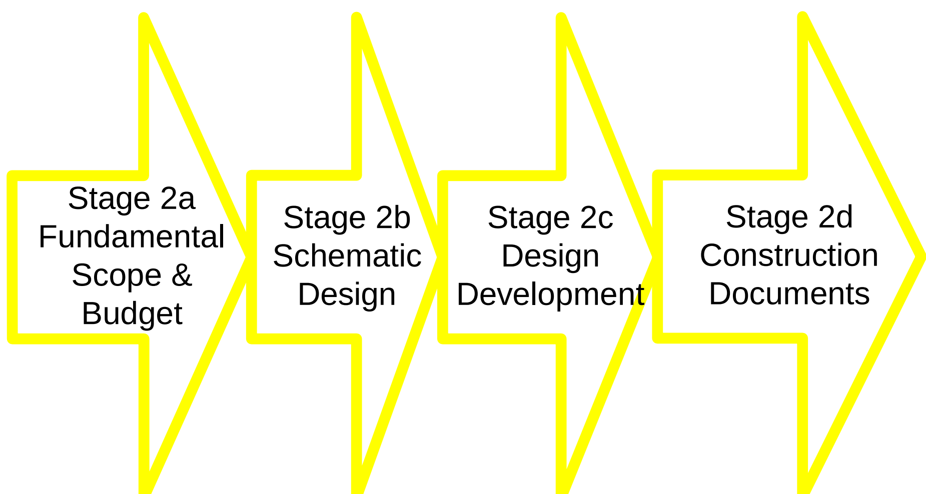
The Project Lifecycle

Stage 1: Conception



A project begins with the identification of a need or constraint. The need could be a result of a regulatory pressure, or business need. Most constraints are governed by forces out of our control. A regulatory driver could be environmental, legal, safety, et al. A business need could be the desire to become more efficient, introduce a new product, renovate facilities to attract customers or attract/retain employees, et al. Usually engineers do not initiate projects at this stage unless related to infrastructure – usually the project conception begins in the business arena. As well, at this stage budgets are often requested "at the last minute" and can result in problems later for the engineer. Owners are encouraged to proceed to Stage 2a before beginning to project or request budget values.

Stage 2: Planning and Design



The next stage is Planning and Design, which includes four subphases. For small projects, the initial subphases may be combined as appropriate.

Stage 2a: Fundamental Scope and Budget

The first subphase is Fundamental Scope and Budget assessment, which follows the Conception of the project and usually is the first phase with involvement by an engineer or architect (usually internal to the client and not outsourced if resources permit.) At this phase, the primary scope is defined with the primary goals. For example, the following are typical decisions made during this subphase.

1. Number of units to be produced
2. Approximate size of facilities needed
3. Major equipment identified
4. General approach to fit and finish

The above should be developed from interviews with affected parties. The following documents are generally provided to define the above, and represent only about 2 –5% design completion:

1. Basic scope writeup
2. General Arrangements (floor plans showing major equipment)

Following the scope development, an estimate is performed. The expected error accuracy for this low level of detail is usually 20-40%. Because of the low level of detail, estimates are usually based on benchmarks (recent similar projects), experience, and some squarefeet extrapolations. A generous contingency of 20-40% should be applied to cover uncertainties including scope, design issues, and estimating accuracies, as well as human error and hidden conditions (especially for renovations). Often, yearly capital budgets are assigned for this level of project scope development but create problems later. However, if a higher accuracy of estimate is needed, go to the next step before establishing the budget.

Once the estimate is completed, cost benefit and other financial considerations can be reviewed. There should be a pause before the next step is pursued so a business decision can be made. Should we go ahead with the project?

Stage 2b: Schematic Design

This stage is typically when outside architectural/engineering consultants should be brought in to assist (although small projects often are performed in-house via Owner's staff if available). Some larger and more sophisticated Owner's have resources to do this in house, however. This subphase builds on the previous, but develops more detail needed to arrive at a better budget. This often is the ideal level to develop yearly capital budgets. Design documents typically needed at this level represent 5-25% design completion depending on project complexity and typically include the following deliverables:

1. General Arrangement
2. Basic scope writeup
3. P&ID (Piping & Instrumentation Diagrams) and other diagrams
4. Detailed narratives of scope in a standard divisional format (such as CSI), with more detail on materials and fit/finish.
5. Narrative on major utility/infrastructure requirements
6. Draft of any required regulatory scoping documentation

Following development of the above, the cost estimate can be refined further, with a typical expected error of estimate 15-30% depending on project complexity. By this stage, the estimate can be developed with the same resources as Stage 2a, except assembly estimate techniques can also be applied, as well as limited unit take-off and vendor pricing information. However, before final funding requests can be made and we proceed to final design, the next substage should be considered to ensure a more accurate estimate. As before, there should be a pause for a business decision before proceeding. The next phase may cost 1-4% of the total project cost, and should not occur unless there is a business case for proceeding.

Stage 2c: Design Development (Preliminary Engineering)

In this stage, the design effort continues to develop the scope to the point a highly accurate estimate can be acquired. Some also call this stage preliminary engineering. For some small projects, the next step after conception begins here. At this stage, documents are similar to final construction drawings except specific details and specifications are lacking. The following are the typical design document deliverables by this phase building on and refining the previous.

1. General Arrangement
2. Basic scope writeup
3. P&ID (Piping & Instrumentation Diagrams) and other diagrams
4. Detailed narratives of scope in a standard divisional format (such as CSI), with more detail on materials and fit/finish.
5. Narrative on major utility/infrastructure requirements
6. Outline Specifications
7. Final draft of any required regulatory scoping documentation
8. Drawings and plans for all disciplines substantially complete without specific details
9. Typical general details
10. Major equipment schedules

The above deliverables represent approximately 20-50% of the design effort (depending on the project complexity), and can result in an error of estimate +/-10%. To arrive at this estimate accuracy, major design decisions/calculations must be complete, and qualified individuals are needed to perform the estimate. Often, A/E firms (Architectural/Engineering) are excellent at assigning scope, but poor at estimating. Conversely, construction firms are often excellent at estimating cost, but poor at assigning scope. Therefore, a good approach is to have both do an estimate independently, and meet for a budget reconciliation meeting.

Pause at this stage to again ensure the proper business decision to move forward; the next step will typically cost 6-14% of the total project cost (usually less costs incurred for Design Development.) Complete any "value engineering" or "design to budget" exercises if there are constraints on meeting the scope with an assigned budget. As we go forward, it will become more expensive to make changes, and valuable schedule will be absorbed.

Stage 2d: Construction Documents

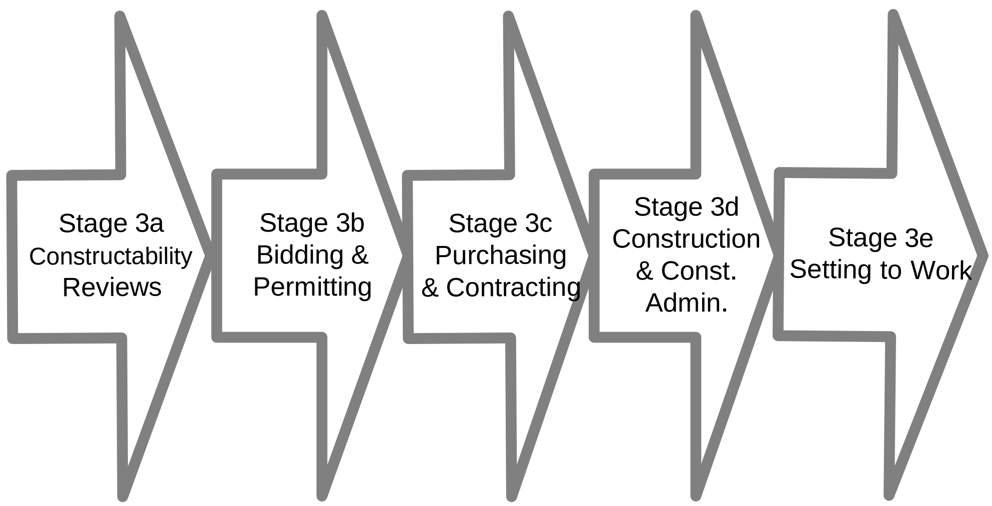
In this substage, drawings are finalized to enable permits to be acquired and bids received. Specific details are added to the drawings, they are crosschecked, and detailed specifications are written. For larger projects, a control estimate may be performed to ensure there hasn't been "scope creep" and to further refine the previous estimate. Estimates at 90% completion may be 5-10% accurate. Estimates at this stage include detailed unit take-offs and vendor estimates.

Delivery Methods: There are delivery methods as well to be considered, some of which include later phases. Methods may use one or combinations of the above. Some options are as follows:

- Design-Bid: In this approach, the design is completed and then competitively bid. This is an economical way to approach a project, but is the most lengthy to complete. Another disadvantage is not including a contractor early in the design decisions and estimating exercise.
- Design-Build: This approach has been heavily marketed of late. Under this arrangement, a single contract exists between the Owner and Design-Build firm. The advantage that is purported is that there is a single point of contact/responsibility, expedited schedule, and costs are low. (It is in the Instructor's opinion and experience that this method is not the lowest cost in many cases.) This approach is best suited for highly defined or highly specialized/propriety projects, or small plant-type projects, or for projects that have highly developed scope already. One disadvantage is that often the Design-Build firm has a stronger expertise in one area (design vs. construction.) Another disadvantage is that unless the scope is highly defined, there can be cost overruns or insufficient engineered solutions or lower quality equipment/materials. Also, there can be a conflict of interest between good engineering practice/ordinary care and financial goals of the constructor. Finally, there is a healthy tension between designers/constructors that is lost when under the same contract. If this approach is to be employed, consider a thorough preliminary engineering phase to define the expectations and scope. Also, consider robust design standards and standard details. Despite the heavy marketing for this approach, use it with caution, especially for larger more complex projects. What is good for a Design Build firm may not always be to the Owner's advantage.
- Design-CM (Construction Management): In this approach, a separate Construction Manager is brought on early during the design to participate, do construability reviews, early bidding/purchasing, and estimates. The General Conditions (costs to manage the project) and Fee (the CM's overhead and project) can be bid once the basic scope is understood (usually 8-15 % of direct construction costs.) The CM then bids the completed design to vendors and subcontractors (or phases.) Of late, many so-called "CM" firms have come about, but in

actuality are program managers. The best CM for the Owner is in effect a GC (General Contractor) that is capable of performing the above unless the Owner doesn't have internal oversight capability. Require a NTE cost after bid day; if earlier, excessive contingencies will be added or there will be a hostile change-order environment. Beware of a CM that will not agree to a NTE arrangement. Also beware of a CM that will not thoroughly parse out the contracts - the CM should not under most circumstances combine work under another GC (if done, this is a sign that the CM is really a program manager.) Another advantage to the CM approach is that long-term mutually beneficial relationships can be forged, and each project will not require a *learning curve*. Based on the experience of the Instructor, Design-CM is preferred for larger and multidiscipline projects that require GC-type oversight.

Stage 3: Construction



Construction has four substages as shown above.

Stage 3a: Constructability Reviews

The first substage occurs during the design. Designs should be reviewed for constructability, which includes considerations of safety, cost, methods/materials, and other construction-related constraints and value-engineering opportunities (meeting the needs of a user creatively while reducing cost). This may require bringing on a contractor early, which is a Construction Management approach (occasionally Design/Build as well.) Individuals with construction expertise should attend design review meetings and review drawings at various stages of review.

Stage 3b: Bidding and Permitting

The next substage is the bidding and permitting process. In this day of fast-track projects, permitting and bidding often occur simultaneously. However, it is recommended to resolve any site and zoning/public hearing issues early in the design effort (which may require early substantial design completion of building façade and site issues.) Many municipalities require a general building permit, and the specific trades (HVAC, Plumbing, Electrical, etc.) can usually be submitted after the successful subcontractors let individual subcontracts. (See your governing municipality for specific requirements.) The methods of contracting out the work are varied, and often fall in the following categories:

- Bid: This requires a project to be thoroughly scoped and designed prior to acquiring proposals from bidders. To minimize the likelihood of the "lowest bid" syndrome that results in unqualified successful bidders, consider prequalifying bidders before bidding. For subcontracts, this is the best approach in the Instructor's experience (if time permits) - this approach benefits from free market forces and over time should maintain lowest cost while retaining quality. Three bids seem to be the magic number that works best in acquiring the lowest market rate. Often, one will be significantly more competitive than the other two. Caution: If one bidder is substantially lower, carefully review scope with them. It serves no ones interest to have a hostile environment later.
- Negotiated: This approach is to negotiate with a single contractor for work to be performed. The disadvantage in this is that one may not be able to ensure a fair market rate is being offered unless the work is a near duplicate of previously bid work. Negotiated bidding often occurs for proprietary systems, where sole sourcing is necessary and for which there is no choice of another vendor. When you know a vendor will become proprietary after the first install, include in the initial bid guaranteed escalation rates tied to an economic indicator (such as CPI, Consumer Price Index), etc. to ensure you won't be cheated later. Also ask for price book discounts, etc., and require the vendor to bid to three subcontractors/suppliers for subsequent work. Require an "open book" approach for future work.

- Time and Material: In this method, work is performed at pre-agreed-to labor rates and mark-ups on materials. While this enables work to begin quickly, the work must be closely monitored and can be difficult to manage from a budget viewpoint. Try to get a "NTE" if possible (see below).
- Not-to-exceed (NTE): This approach is similar to the previous, except the contractor agrees to a maximum charge for the agreed-to scope. Keep in mind, however, scope changes are outside the NTE.

Stage 3c: Purchases and Contracting

At appropriate levels of design completion, it may be necessary to purchase long-lead equipment early depending on the schedule. This necessitates having clear roles and responsibilities defined in the construction documents. Upon bidding completion, purchase orders are written to successful vendors and contractors/subcontractors. Contracts are generally recommended for complex projects/equipment/systems, and/or at a particular cost threshold. Smaller purchases are probably not worth the effort to require a formal contract. Contract issues are covered by separate courses.

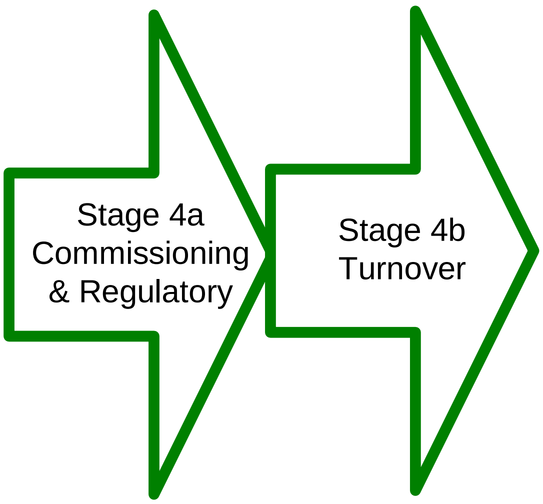
Stage 3d: Construction and CA

Once permits are acquired and bidders selected, the contractors mobilize to construct the projects. Ensure temporary protections are in place to protect adjacent areas and nonrelated employees. Often, temporary facilities (office trailers, "portajohns," etc.) are provided. Post signage for deliveries and Owner's employees as well. Have clear contractor procedures and rules issued and each individual worker trained. Projects should have frequent construction meetings for updates and issue resolution. Usually, payment requests are monthly and should have retainage (10% until near-project completion) to cover any construction problems. During Construction, continue to include the A/E at the meetings. As well, the A/E should provide certain CA (Construction Administration) support by reviewing and approving shop drawings and submittals, issuing change bulletins, and reviewing payment/change order requests from the contractor when needed. Be careful of "substitutions" by the contractor, as quality could significantly decline.

Stage 3e: Setting-to-work

At the beginning of or before Commissioning, equipment and systems must be set-to-work. (Arguably, this Stage may better fall under Stage 4.) Setting-to-work and other regulation and adjustments are needed prior to energizing the system or full startup. This could include factory representative start-up, calibration, and other considerations needed before fully operating the equipment and beginning other aspects of Commissioning.

Stage 4: Commissioning and Turnover



Stage 4a: Commissioning and Regulatory

See other courses, which thoroughly cover this stage. But to summarize, before an equipment, facility, or system is put into use, it must first be Commissioned. Commissioning is a "well planned, documented, and managed engineering approach to the start-up and turnover of facilities, systems, and equipment to the End-User that results in a safe and functional environment that meets established design requirements and stakeholder expectations." [i] That is, Commissioning verifies what was specified *was* installed, that it functions properly, and it was successfully turned over to the user *and* reasonably ensures the next step verification for regulated industries will be successful. Regulated industries, such as the Instructor's Pharmaceutical industry, may require an additional step before put into final use or sellable product is manufactured. For the Pharmaceutical industry, this is called "Validation" or "Qualification." Validation is "Establishing documented evidence which provides a high degree of assurance that a specific process will consistently produce a product meeting its pre-determined specifications and quality attributes"[ii] Qualification is a subset of Validation including IQ/OQ/PQ, and is "The documented verification that all aspects of a facility, utility or equipment that can affect product quality . . .

- . . . adhere to approved specifications" (Installation Qualification or IQ)
- . . . operate as intended throughout all anticipated ranges" (Operational Qualification or OQ)
- ". . . perform as intended meeting predetermined acceptance criteria"[iii] (i.e.: over time. Performance Qualification or PQ)

Stage 4b: Turnover

The project is not fully commissioned until Turnover is also completed. Training, Project Closeout (documentation), and Commissioning Documentation are parts of a successful project turnover as follows:

Training

Unless staff are properly trained, they will be unable to safely and efficiently operate and maintain the facility, equipment, or system. The commonsense questions to ask before determining training requirements are:

1. On which equipment/systems is training required?
2. Who needs to be trained?
3. What training do they need? (Not everyone needs the same training).
4. How must training be recorded?
5. What are the required qualifications of the trainer?

Project Closeout, Documentation

A project is not complete until all associated documentation is completed and turned over to appropriate individuals. This includes as-built drawings and specifications, Operations and Maintenance Manuals, etc. Documentation must be thorough and filed in a manner it is easy to retrieve and is preserved. Consider electronic formats, including CADD files for ease of future renovations.

Stage 5: Occupancy or Use

After the construction is complete and Commissioning/Regulatory issues are resolved, it is time to move in or begin operations. But the project lifecycle does not end here nor does it fall into a state of inactivity (although the assigned project team leadership move on to other opportunities). Now comes maintenance and preservation. A useful tool in managing this stage of the project lifecycle is to establish a Computerized Maintenance Management System (CMMS). This allows the assets to be monitored, and regularly scheduled preventive maintenance performed. Some regulated industries require documented maintenance on critical elements.

Stage 6: Renewal

Assets are usually renovated, or uses change over time. Be careful not to violate codes when changing use. Occupancy classifications can be violated, fire protection systems overstressed, and emergency egress (doors, travel paths, etc.) inhibited. As well, structural or HVAC overloading can occur. Be sure to include the appropriate professionals when planning a renovation or renewal.

Stage 7: Demolition

The final stage in a project lifecycle occurs when it is time to remove the asset or demolish the facility. Consider environmental considerations, such as hazardous materials/waste (examples include asbestos, lead paint, soil/subsurface contamination, etc.) There comes a point at which the facility, equipment or system becomes irrelevant, and other needs govern. Its time to pause and wax philosophical, taking all this in perspective. The Instructor remembers an illustration from a sermon, where the speaker[iv] took the opportunity to teach a lesson to his son. While taking trash to the dump, his son noticed a good bicycle in the pit. “Dad,” the boy said, “Why would someone throw such a good bike into the pit?” Seizing the teachable moment, his dad replied, “Son, everything eventually goes into the pit.” That really puts it into perspective – while we need to work hard and diligently at implementing a project and maintain it well, everything goes into the pit eventually. (There seem to be a few exceptions, such as the pyramids.) Enjoy the ride, don’t take it too seriously, because its all going in the pit . . .

COURSE SUMMARY

This course describes the fundamental elements of a project’s lifecycle stages, including Stage 1 – Conception, Stage 2 – Planning & Design, Stage 3 – Construction, Stage 4 – Commissioning & Turnover, Stage 5 – Occupancy or Use, Stage 6 – Renewal, and Stage 7 – Demolition. Understanding this rational approach to a project lifecycle is essential in planning, implementing, and maintaining a project.

References

[i]“Pharmaceutical Engineering Guides for New and Renovated Facilities – Volume 5 – Commissioning and Qualification”

[ii] FDA Guidelines on General Principles of Process Validation, May 1987

[iii] Reference: “Pharmaceutical Engineering Guides for New and Renovated Facilities – Volume 5 – Commissioning and Qualification,” Glossary

[iv] Speaker was Dr. Bob Vallier, on or about 2003