

“The Case for Front End Loading (FEL) and Constructability Reviews”

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Abstract:

The stakes for the Project Manager have never been higher. Many still doubt the efficacy of the tools and processes espoused by the rapidly-growing membership of the world's largest and fastest-growing project management professional organization and seek to tarnish its accomplishments by imputing that the profession is simply one of a long line of professional fads that is overly-burdened and preoccupied with descriptive phrases, jargon and/or "buzz words". Yet some highly-effective tools for accomplishing solid improvements in Total Investment Cost (TIC) and Return On Investment (ROI), which are the basic business-related reasons for performing projects in the first place, are not consistently known and/or employed by many project managers nor by the management or stakeholders that they represent.

This paper will attempt to tie the concepts of Front End Loading and Constructability Reviews into the Project Management Institute's PMBOK-oriented processes in order to provide the Project Manager with justification, rationale and some quantifiable metrics for selling improved project management processes that start at the "front end" (Concept and Development stages), where so much opportunity to achieve cost-effective results is often squandered.

Front End Loading:

In July of 2002, an article appeared in the trade magazine "*Hydrocarbon Engineering*" that asserted the following:

- As much as 80% of costs are committed during the Conceptual ("Initiation" & "Definition") phase(s) of a project,
- Poor management of the design phase affects every stage of the project lifecycle,
- 80% of design changes are caused by a lack of data or the wrong data,
- Design Engineers spend between 30% and 50% of their time looking for their "stuff!", and
- Systems that generate and manage data that are not integrated result in duplication and inconsistency.

An even more disheartening set of statistics appeared in 1998 (Standish Group's Chaos research on Information technology Projects):

- 24% of the monitored projects were rated as "Failures",
- 49% were rated as "Challenged" while only
- 27% were rated as "Successful".

At about the same time that these dismal statistics appeared, the Independent Project Analysis group, which benchmarks projects, both large and small, largely in the petrochemical and utility areas, was collecting and reporting for its 2002 report to membership some very compelling statistical evidence that showed that Front End Loading (FEL) contributed significantly to (1) lower total investment costs, (2) faster project cycle times and (3) enhancements in system/installation operability, all of which resulted in **enhanced safety** and a **larger Internal Rate of Return (IRR)**. And let us not forget that (almost) every project is undertaken to make the same product: Money!

IPA breaks down their version of FEL into three categories of components, illustrated in the following Table:

Site Factors	Engineering Definition	Project Execution Plan
Equipment layout Soils data Environmental requirements Health & Safety requirements	Engineering Tasks <ul style="list-style-type: none"> • Detailed scope • Feedstock/product properties • Process Flow Diagrams (PFDs) • Process & Instrumentation Diagrams (P&IDs) • One-line Electrical diagrams • Cost estimate 	Plans <ul style="list-style-type: none"> • Commissioning • Startup • Operation • Manpower • Quality Assurance
	Participation/buy-in of: <ul style="list-style-type: none"> • Operations • Maintenance • Business 	Contracting Strategy <ul style="list-style-type: none"> • Who • How
		Team participants & roles
		Integrated schedule <ul style="list-style-type: none"> • Critical path items • Identification of shutdowns for tie-ins • Overtime requirements

Table I – Components of Front End Loading (IPA- 2002)

IPA also cited other process enhancements as vital contributors to success (between 6% to 14% improvement on IRR, on average) enjoyed by the reporting projects, such as:

- Process simplification (Value Engineering)
- Constructability review process
- Customized standards and specifications
- Predictive maintenance
- Design-to-capacity

More evidence that insufficient credibility was being given to FEL appeared in an article in the trade magazine *“Engineering News Record”* on July 12, 2002, which cited a study of 600 projects with a core of 258 in transportation, ranging in value from \$1.5 to \$8.5 billion:

- Deliberate deception by project sponsors caused overruns averaging 28%
- Over 90% of the megaprojects done in 20 countries experienced cost overruns
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The ENR article further reported that:

- Cost benefit deceptions were largely in the concept phase (For economic gain or political leverage)
- Distortions were worse in developing countries but still bad in Western nations
- The study eliminated technical ignorance

ENR recommended more “transparency” in the cost forecasting process and the use of **independent appraisals** prior to project approval.

Recent research conducted by the Construction Industries Institute (CII) Small Projects Execution Research Team indicates that the front end planning effort for small projects is critical to success since small projects typically have no "slack" in either budget process nor in schedule.

1997 research (Note 1) based on a study of fifty-three local area petrochemical projects has concluded that there is a strong correlation between adequate planning preparation and resultant project success and has indicated the following recommendations:

- *“The pre-project planning team should be working with a written charter - a document, based on corporate sponsored guidance, that defines the pre-project planning team’s mission and responsibilities.*
- *The pre-project planning process should have a pre-project planning plan.*
- *The more corporate groups with varied interests providing input during the pre-project planning phase the better.*
- *During the pre-project planning process, control guidelines should be developed.*
- *During pre-project planning, an execution approach for engineering, procurement, construction, and start-up should be developed.*
- ***The recommended percent design complete before project authorization is from 10 percent to 25 percent depending on the complexity of the project.***
- *In summary, it is recommended that owners place emphasis on organizing pre-project planning efforts using a formal process.”*

Rating Front End Loading:

A system has long existed (developed in 1994) and been espoused by the CII which independently gauges the readiness of projects to move forward to and through the authorization process. This system is called the “**Project Definition Readiness Index**”. While originally developed and applied to petrochemical projects, the same logic can (and has been) successfully applied to other engineering areas (such as utilities) and the concept could even be extended to software projects. The CII has gone even further and developed a “Process Success Rating” (PSR) which they use to measure the degree of correlation between pre-project definition or “good front end project definition” (among other factors) and project success.

Basically, PDRI is an evaluation system that judges proposed projects on their merits and imposes quantifiable metrics to determine:

- Where does this project fit in our overall prioritization scheme?
- Is it really ready for approval (full funding authorization)?
- *Have we really done our homework?*

Note (1) Ivan Radovic, Dissertation for Master of Science in Engineering, “Validation Of Project Rating Indexes On Construction Industry Projects”, University of New Orleans, 1997

Here's the way a PDRI evaluation might be organized for your next project:

SECTION I BASIS OF PROJECT DECISION

This section consists of information necessary for understanding the project objectives. The completeness of this section determines the degree to which the project team will be able to achieve alignment in meeting the project's business objectives.

CATEGORIES:

- A: Manufacturing Objectives Criteria
- B: Business Objectives
- C: Basic Data Research & Development
- D: Project Scope
- E: Value Engineering

SECTION II FRONT END DEFINITION

This section consists of processes and technical information elements that should be evaluated to fully understand the scope of the project.

CATEGORIES:

- F: Site Information
- G: Process / Mechanical
- H: Equipment Scope
- I: Civil, Structural, & Architectural
- J: Infrastructure
- K: Instrument & Electrical

SECTION III EXECUTION APPROACH

This section consists of elements that should be evaluated to fully understand the requirements of the owner's execution strategy.

CATEGORIES:

- L: Procurement Strategy
- M: Deliverables
- N: Project Control
- P: Project Execution Plan

One of the basic tenets of FEL is that approximately 20% of the engineering should be accomplished during the "Concept" phase (or the "Initiation" and "Definition" phases). Use of the PDRI system will tell the Project Manager if he/she has done all he/she should do prior to authorization (full funding) of the project. The catch is that Management has got to be convinced that they will eventually save lots of scarce construction money by spending small sums of "investigatory and developmental engineering money" on some projects that may never come to fruition. And there's always a lot of wrangling over where to charge off "capital suspense dollars". Generally speaking, it ends up being part of the Project Management Office (PMO) overhead and becomes one of the many crosses that this organization has to bear.

Constructability Reviews:

Now that we've explained what FEL is and how its levels can be effectively measured using PDRI, let's look at another FEL component, Constructability Reviews.

One definition of Constructability Reviews taken from the American Association of State Highway and Transportation Offices (AASHTO) is:

*“A process that uses construction personnel with extensive construction knowledge **early in the design stages** of projects to ensure that the projects are buildable, while also being cost-effective, biddable and maintainable”*

Another definition from the already-cited Construction Industry Institute (CII):

“... optimum use of construction knowledge and experience in planning, design, procurement and field operations to achieve overall project objectives.

The reader should note the key common words/phrases used by both the two cited definitions:

- “construction knowledge”,
- “projects” and
- “design”

CII research has shown cost reductions of between 6% and 23% in Total Investment Cost (TIC) are possible by implementing Constructability concepts. So the bottom line to implementing Constructability is cost savings.

In practical terms, a Constructability Review is a multidisciplinary and independent review, performed from a construction (not design) viewpoint. It provides the perspective of a “fresh set of eyes” and is normally accomplished very early in the Design (end of “Initiation” or in “Definition” phases?). The scope of the review normally includes:

- Proposed Specifications
- Proposed Drawings
- Actual site conditions
- Construction schedule

A Constructability Review is an assessment of “the ability to construct”, it is an enhancement to “Front End Loading” (FEL) and, above all, **a “constructability review” is a risk reduction technique!**

A slightly different view, and the one preferred by this author, is that the planning/execution phases for a typical major industrial project involve:

- Conceptual engineering
- Detailed engineering
- Procurement
- Construction
- Start up.

Construction optimization analysis (or “**constructability reviews**”) should begin during the conceptual stage, at the same time as operability, reliability and maintainability considerations surface. It can then continue through the remaining phases. Constructability is, after all, a continuing and iterative approach to engineering optimization.

Planners (and Project Teams) must recognize that the payoff for optimization analysis is greatest in the earliest phases of a project, growing progressively less, but never ceasing, until the end of the project.

A Constructability Review can also be viewed as an “oversight” process and might contain the following components and considerations:

- Expandability requirements (Future?) and capabilities?
 - Plant capacity
 - Available footprint for expansion
 - Security enhancements

- When might they be required?
- How are they being accommodated (or not being comprehended) by this Project?
- Reliability concerns of the planners and operators. Consider concerns of:
 - Operations staff
 - Maintenance staff
 - Customer/client
 - Project cycle
 - Life cycle
 - Cost of repair/replacement
 - Other stakeholders?
- Maintainability concerns of the maintenance organization/contractor. Objective: To influence system design such that the end product can be maintained in a cost-effective operational condition with minimum downtime.
 - Timing: In order to provide maximum influence to a program, maintainability design principles must be implemented early in the Design phase.
 - Method: Ask the following questions (as a minimum) and check to ensure that the following are thoroughly evaluated:
 - Accessibility
 - Maintainability
 - Designed components
 - Subsystems
 - Where designed accessibility appears restricted, the subsystem must be noted along with the reason for the restriction. Issues concerning maintenance servicing, preventive maintenance, spare parts usage rates and repair times must also be treated during this analysis.
 - **Bottom line:** *Have the access and maintenance concerns of the operations and maintenance staffs and Customers/Clients been included into the design of this Project?*
- Operability concerns. The entire system and each sub-system has to be considered to determine applicable operating parameters (only a partial list):
 - Pressure
 - Volume
 - Flow rate
 - Temperature
 - Voltage
 - Amperage
 - Phase
 - Corrosion tolerance and vulnerability
 - Host facilities
 - Intervention needs and techniques
 - Operating strategies
 - Procedures
 - Utility reliability
 - Must be assured that the entire system and each sub-system can be built and operated successfully and economically. All operating and interaction modes including startup, steady state, shut-in, switching, interruption, and unexpected major system change (lightning strike, mechanical failure, etc.), emergency shutdown and loss of flow throughout the system life cycle must be considered.
 - Robustness must be “built in” to some degree to compensate for:
 - Operating strategies
 - Procedures
 - Depending upon the system service requirements.
 - That is, they must be developed with system unknowns and uncertainties in mind and must be readily adaptable to work with the system that is found to exist, ***even when that is different than assumed during planning and design.***

- Hazards (Is the facility, as conceived and/or designed, as safe to operate and maintain as we can build it?) The Hazard Identification review (HAZID) is followed by the Hazard and Operability (HAZOP) review
 - Formal process
 - Team-based
 - Systematic way to identify hazards to staff, facilities, and the environment
 - Normally involves review of P&ID
 - Usually led by a specialist
 - Results usually computerized
 - Output: identified risks and levels
 - May be applied to many types of plants and facilities, ranging from large continuous processes (such as petrochemical plants) to small batch ones such as autoclaves or machines for forming plastic.

The typical Constructability Review normally includes anything that will make the project easier, faster, safer and more cost effective to build, while maintaining quality, safety and access for employees, tools and equipment during construction, production and maintenance. Some examples might include:

- Staffing
- Financing
- Engineering
- Procurement
- Construction
- Safety
- Environmental compliance

Constructability reviews are normally employed to optimize the use of construction knowledge and experience and to achieve overall project objectives in planning, design, procurement and field operations. A common ***(and mistaken)*** view of constructability guidelines involves only determining more efficient methods of construction after mobilization of field forces, allowing construction personnel to review engineering documents periodically during the design phase, assigning construction personnel to the engineering office during design, and a modularization or pre-assembly program.

Reducing total construction time is an expected benefit of employing Constructability concepts by creating conditions that maximize potential for concurrent (rather than sequential) construction, minimize potential for rework and wasted time, reducing work-hour requirements by creating conditions that:

- promote better productivity or creating designs that demand less labor
- reducing cost of construction (and tools) by reducing requirements for such equipment and creating conditions that promote more efficient use of the equipment
- minimizing the need for high-cost, special purpose equipment
- reducing materials costs through more efficient design, use of less costly materials, and creation of conditions that minimize waste
- creating the safest work place possible, since safety and work efficiency go hand in hand
- promoting total quality management (TQM)

Effectively employed, it is a program that requires:

- proactive attention:
 - individuals with a knowledge of construction must jointly participate with the other interested parties (owner, engineer, operator, and maintainer)
 - brainstorm concepts and approaches **before** they are committed to a drawing (remember that “constructability” is a component of **planning**)
- Team effort
- Management commitment and support elements:
 - Clear communication of senior management commitment

- Single-point executive sponsorship
- Implementing programs for each project (not a generic one-time effort)
- Database compiling lessons learned and examples
- Orientation and training
- Active appraisal and feedback.

A “Constructability Review” Is ***not*** an opportunity to change Scope of the project, it is ***not*** a decrease in the Designer's responsibilities nor is it Construction and Design groups taking the opportunity to review Design's methodology. It should not be viewed as a method for determining construction methods after mobilization. It is more than periodic review of design drawings during design (Too late!) or an attempt to improve construction methods. It can not be regarded as purely “Construction's responsibility”it's a Project Team responsibility!!

A “constructability review” is ***not*** a Scope Review (It should ***not*** be a chance to get things restored or added that were not approved during project scoping!) It is not Value Engineering (They are different processes, although the two may be sometimes mistakenly associated)...there's lots of industry discussion here!!

Value Engineering, by way of contrast, is usually defined as an effort that consists of describing the goal in terms of a verb and a noun (Example: move materials), identifies all options possible, evaluates all options, eliminates those not practical, and makes a short list of options with the most potential. The remaining options are then evaluated in detail and the Team selects the best (most cost-effective) option. It makes optimum use of engineering experience, is cost-focused, re-active and is most typically accomplished in “one-shot” fashion.

Keep in mind the iterative and ongoing effort of the constructability concept, as just one big difference between the two methodologies. Other differences are that Constructability makes optimum use of Construction not Engineering) experience, investigates all aspects of planning and is always and continually pro-active

The basic purpose of a Constructability Review is to test our approach for the potential for errors, change orders, and claims. It effectively seeks out overlooked problems that can increase costs, impair our planned schedule, decrease quality and/or decrease our safety margins. It consistently assures better results from the bidding process by checking for:

- coordination among the various construction documents
- clarity
- consistency
- completeness
- ease of construction

Perhaps best of all, it enhances Team Building (the project Builder better understands the Owner's objectives and vice versa).

Constructability reviews normally and typically may involve:

- Multidisciplinary Project Team
- Extended Project Team
- Personnel with extensive field experience
 - Construction Engineers
 - Operations Coordinators
 - In-house construction assets
 - Contractors/Consultants
 - Major equipment vendors

Why not access the real experience and expertise of the construction community during the initiation and definition phases? Isn't this likely to produce a more constructable project?

Questions that might be asked during a Constructability review might be some of the following:

- Can the facility be physically constructed as laid out/designed?
- Can this facility be safely and economically constructed as designed and laid out?
- Are there any unusual construction elements scoped? (If so, they deserve special attention)
- Is there anything special required about the sequencing of the various construction elements?
- What non-standard provisions for construction must be made?
- Are the plans/specifications biddable (clarity, consistency, etc.)?

Many proponents of Constructability espouse the "Ten Commandments of the KISS Philosophy":

- Keep It Straight & Simple
- Keep It Same Size
- Keep It Shop Standard
- Keep It Square & Squatty
- Keep It Specification Simple
- Keep It Standard Size
- Keep It Support Simple
- Keep It Standards Simple
- Keep It Schedule Sacred
- Keep It Size Suitable

Here's why the Oregon Department of Transportation mandates Constructability Reviews for all major projects:

- Reduce costs and enhance quality
- Improve and shorten project schedules
- Improve public and construction safety
- Reduces addendums (to contracts)
- Reduce change/extra work orders
- Expand constructability knowledge in ODOT
- Reduce environmental permit violations and non-compliance
- Minimize public inconvenience and intrusion

There's always the question of when best to conduct Constructability Reviews. Here are some suggestions:

- Depends on complexity and size
- On a very small project, maybe never (combine with regular Project Team Meeting?)
- Usually after about 20% engineering complete (remember, the FEL processes means we normally perform about 20% of the "pre-engineering" during "Initiation" and "Definition" phases)
- Design reviews at 20%, 50% and 80% completion?
- At the latest, the initial Constructability Review should be very early in the "Design" phase, but more preferably late in the "Definition" phase **before the design is firmed up and drawings get put on paper.**

And how could we measure results? Remember, we always need quantifiable metrics to quell the nay-sayers:

- Better Plans and Specifications
- Less Contract Change Orders

- Enhanced Project Team cooperation and morale
- Money (\$\$\$)! CII research has shown cost reductions of between 6% and 23% are possible by implementing Constructability concepts

Conclusions and Recommendations:

This paper has attempted to indicate the overall desirability (improved safety, enhanced operability, etc.) and the specific financial benefits available from pre-investing time and resources in project pre-planning (Front End Loading) and in the use of risk reduction techniques such as constructability studies. It has been conclusively demonstrated from a review of available industry statistics that improvements in ROI and TIC of between 6% and 23% are possible and have historically been achieved as a direct result from employing either one or (even better) a combination of these methodologies.

We have also shown that it is possible (and, indeed, both practical and advisable), using established and creditable processes and systems, to employ available and industry-accepted methodologies (Project Definition Readiness Index) that measure (using easily quantifiable metrics) the relative readiness of projects to proceed through the quality "gate" to full authorization (funding).

Aren't these enhanced project results worth your time and effort?