Front-end Loading–A Path to a Successful Project

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Introduction

There has been considerable concern in the business community over capital project cost overruns in recent years. The industry findings indicate that poor scope definition at the project funding stage and loss of control of project scope rank as the major contributing factors to cost overruns and schedule delays. The construction industry points to a lack of scope definition as the most serious problem on construction projects. This paper describes how an organized approach to front-end loading (FEL) with well-defined scope can result in a successful project. The findings are based on industrial projects mostly in oil, gas, and petrochemical industries.

FEL plays an important role in defining a capital project. The construction industry research indicates a relationship between project success, preplanning efforts, and well-defined project scope developed during the FEL. The FEL phase covers basic and preliminary engineering done for the engineering, procurement, construction, and start-up/commissioning (EPCC) phases of the project prior to commencing the detailed engineering. The objective of the FEL phase is to provide the detailed design disciplines with a well-defined front-end engineering package to ensure that progress is smooth and expeditious with minimal changes and rework during the execution of the detailed engineering.

An owner has a greater ability to influence the outcome of a project during the early stages when expenditures are minimal than during later stages. The impact of the decisions made in the early stages has the greatest influence on the final cost of a project. Exhibit 1 shows cost influence versus project phases. The cost/project phase curve indicates that more than half of the opportunities to influence cost occur before the detailed engineering effort starts.

These relationships signify the necessity for early and aggressive decision-making and effective communication of project objectives and expected results to the project team. Construction Industry Institute (CII) research indicates that FEL and early project planning can reduce project cost by as much as 20 percent on average in comparison to the cost of poorly planned projects. In addition, the facility can be delivered in optimum time with minimum rework and delays while enhancing Net Present Value (NPV). The FEL offers the greatest opportunity for risk management and for superior project execution by mitigating risks and increasing the chance to meet project goals.

The quality gate check is employed to ensure that the project phase is completed before moving to the next phase. Premature start of the next phase of the project adds cost with an illusion of schedule gain. The quality gate check is the single most important criterion to ensure completion of each phase of the project. The project work process is outlined in Exhibit 2. To ensure quality of deliverables and completeness of scope, the FEL must be completed with quality gate concept before moving to the next phase, detailed engineering. The FEL, when executed properly, offers lower overall project cost while meeting quality and schedule goals.

Elements of a Successful Front-end Loading Phase

Project management leadership and the project team can be organized during the FEL phase to maximize benefits of early project planning and a well-defined project. Some important considerations during the FEL phase are outlined below:

- Well-defined business goals
- Clear Owner's project objectives
- Project execution strategy
- Scope definition
- Cost reduction practices
- Project execution plan
- Cost estimate
- FEL and EPCC schedule
- Project team organization
- Project benchmarking
- Plan for transition from FEL to EPCC phase
- Lessons learned from similar projects.

Business Goals and Owner's Project Objectives

The project development phase of the project will identify business opportunity followed by a conceptual study. The business plan will address the long strategic view of the business including product market research for supply/demand trends, opportunity for increased market

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Exhibit 1. Project Phases

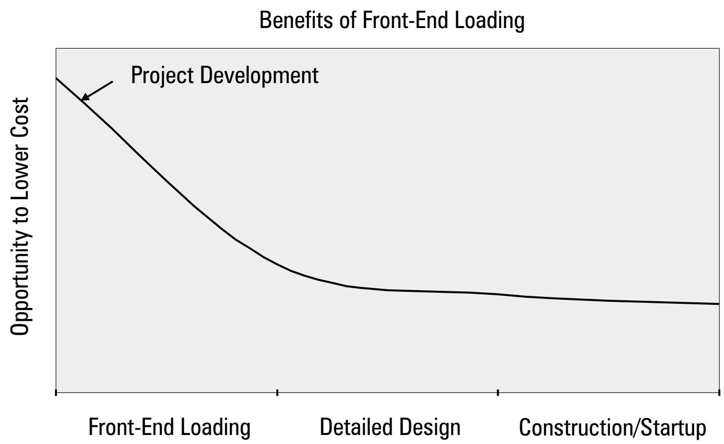
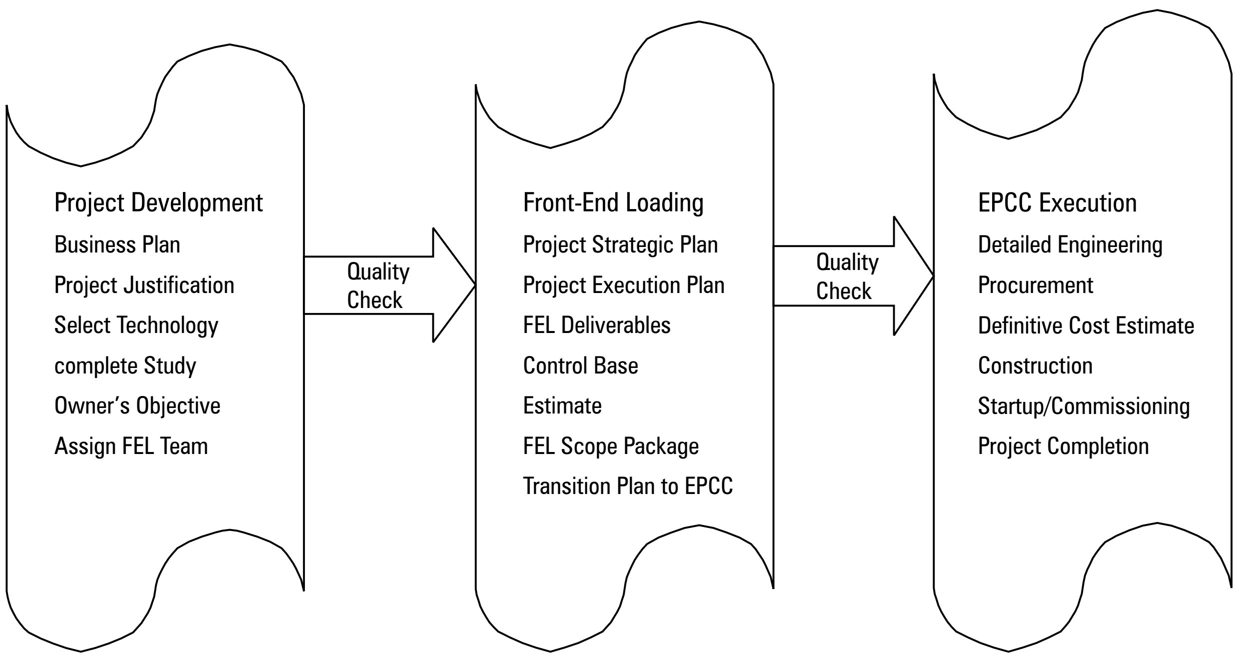


Exhibit 2. Project Work Process



share, plant capacity, technology, modification of the existing plant or a new facility, and project economics.

The FEL team will take a business plan as a starting point to develop the owner's project objective (OPO). OPOs are developed through constant communication with the business team. When the business unit is unclear on what it wants, the process can become repetitious. The team should develop a preliminary scope of the project including a very high-level cost and schedule estimate to reconfirm the viability of the project before the OPOs are finalized. This process will provide the business team opportunity to redefine the business plan or reconsider the project. The business could decide not to proceed at this point for various reasons such as project economics, technology issues, or other uncertainties. This step must be addressed before significant money and resources are spent. Once the business team decides to proceed with the project, OPOs are finalized.

Exhibit 3. Sample Owner's Project Objectives

Business Plan
The business team defines the need to build or modify a facility and location and the relationship to other projects.

Project Justification
The business team develops a conceptual scope, cost estimate, project economics including life cycle analysis, facility life, return on capital (ROC), and net present value.

Marketing Plan
Market analysis, demand and supply projections, product pricing trends.

Project Cost and Schedule Goals
Owner provides cost and schedule expectations.

Plant Capacity
Determine optimum plant capacity, design and operating capacity, and breakeven capacity.

Future Expansion Plans
Identify future expansion plans and pre-investment criteria.

Raw Materials
Identify feed characteristics, feed mix requirement, flexibility in use of the alternate feed materials.

Product Specifications
Specify product quality, specifications, and product mix.

Risk Areas
Identify risk associated with technology, design, project execution, and operation.

Process Technology and Licensing Plan
Identify technology preference, licensing requirements, its impact on product pricing and feed specifications. Specify sparing philosophy.

Sample OPOs for a process plant facility are shown in Exhibit 3.

Project Execution Strategies

A project strategy, critical for a successful project, dovetails with the business plan. By having clear project strategies, the project team can recognize project opportunities as well as barriers. Although strategic issues may vary depending on the type of project, key considerations for most industrial projects are:

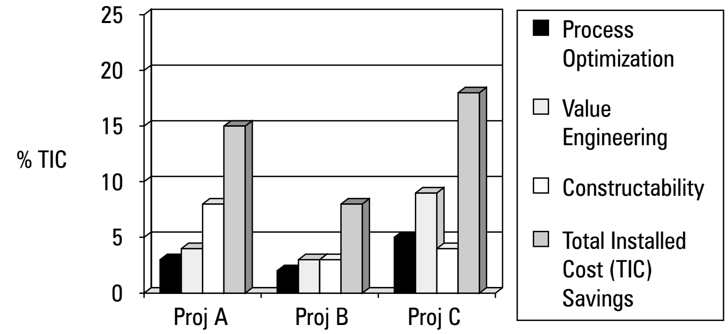
- Project funding strategy—Project funding will cover owner equity, equity partners, bank loans and guarantees, and cash flow projections.
- Project contracting strategy—The choice of the type of contract, fixed price versus cost reimbursable, should be heavily influenced by 1) the extent to which work is defined, 2) the risk allocation between owner and contractor, 3) the availability of owner resources and expertise on the project, 4) need to accommodate fast-track design and construction, and 5) market condition.
- Technology basis—Identify technology basis, design requirements, process limitations, and technology risk.
- Project strategic interfaces—Define roles and responsibility of all stakeholders including owner, joint venture partner, contractor, and licensor. Identify interfaces with other projects and existing facilities.
- Project execution strategy—Fast track versus normal project execution.

Scope Definition

The project scope definition covers plans, methods, specifications, and detailed drawings. The facility scope documents describe the project requirement and become a key communication tool for the project team. The following is a sample process plant FEL deliverables matrix that covers the project scope definition:

- Owner's project objectives
- Project execution strategy
- Construction, supplier, and traffic surveys
- Project execution plan
- Project cost estimate

Exhibit 4. Sample Cost Reduction Metics



- EPCC schedule
- Process description
- Heat and material balances
- Process studies, alternate design
- Process flow diagrams
- Piping and instrument diagrams
- Plot plan
- Scope of work for electrical, civil/structural, and piping
- Equipment specifications
- Scope of work for instrumentation including specifications and control philosophy
- Material specifications
- Environmental and safety plan.

The cause for poor scope definition can be explained as follows:

- Owner does not have expertise and resources to provide complete scope definition.
- If the initial conceptual study and estimate looks favorable, Owner may see no reason to spend additional funds for scope definition through front-end loading.
- Driven by the perception that the shorter the time spent on preliminary engineering, the faster the project can be completed at less cost.
- Market conditions make project duration shorter allowing owner no time for front-end loading.

Scope Definition versus Scope Changes

As noted, loss of scope controls ranks second in terms of impact on cost overruns. A poorly defined scope or a lack of FEL effort does not provide a clear baseline against which changes can be evaluated as being either inside or outside of the scope.

Ways to Control Scope

- Freeze design—the freezing of design is the most effective way to control scope growth.
- Owner and the project team commitment to change control changes control program is far more effective when there is commitment from owner and the project team.
- Formal change justification—all changes must be justified and reviewed by the project team; establishes hurdles so only essential or critical changes get implemented.

Cost Reduction Practices

Front-end loading offers the greatest opportunity to optimize project cost and schedule. There are a number of tools and work processes that can reduce the total installed cost (TIC) and shorten the project schedule. The following areas can enhance the value of most industrial projects. A sample cost reduction metrics is shown in Exhibit 4.

Process Optimization

Process optimization develops process alternatives to determine the lowest TIC while meeting process requirements. It involves evaluation of alternate design to arrive at the optimum solution for operating parameters, feed and product specifications, control philosophy, equipment specification, and material selection.

Value Engineering (VE)

This is an organized approach to identify the best functional balance among initial cost, reliability, and performance of a product or project. The VE goal is to achieve the lowest possible cost without sacrificing function, performance, or ability of a facility to carry out its specific duty.

Net Present Value (NPV)

Net present value is the sum over a number of years of cash flow attributed to an investment discounted at a given interest rate for the time value of money. The NPV allows the calculation of the rate of return on capital investment on an after tax basis. The understanding of cost of capital, tax rates, plant life, depreciation, and operating and maintenance expenses will help determine optimum NPV.

Risk Management

This approach is recommended by the Construction Industry Institute (CII) as a method to reduce TIC when applied to a capital project. The purpose of risk management is both to actively predict problems that might negatively impact the project goals and to manage the problems if they do occur. Risk analysis is a process to identify and quantify risks (i.e., risk events, risk probability, and amount at stake). The risk management account is set up on the project to allow for the risk items, which need to be implemented at a later date. This approach minimizes cost and schedule overruns while allowing the project team to take appropriate risks. The risk management account should not be confused with the project contingency, which is required for estimating variations. In addition, the Monte Carlo®-based project cost and schedule risk analysis may be employed where conditions of uncertainty exist regarding financing, design development, technology, work content, weather, equipment reliability, contractor performance, resource requirements, transportation, logistics, and other factors. This approach reduces the likelihood of costly schedule overruns while allowing effective contingency planning.

Reliability Analysis

The reliability analysis effectively predicts and manages the performance and lifecycle costs of complex systems. The plant's design is analyzed before construction to ensure that it will achieve the following owner's project objectives:

- The plant's annual projected availability and output capacity
- The plant and unit outages and their expected duration
- The impact of design with and without an online spare
- Recommendations for improving plant reliability and availability.

Designing for Constructability

This is defined by CII as "the optimum use of construction knowledge and experience in planning, design, procurement, construction and field operations to achieve overall project objectives." Constructability offers the opportunity to reduce project cost and improve the project schedule. A philosophy of simplicity in equipment layout, structural design, and specifications, along with the standard and duplicate design, can significantly reduce the project cost and schedule.

Multi-Project Leveraged Procurement

This may offer significant cost savings because forty to sixty percent of the TIC on industrial projects, particularly in chemical, refining, and gas processing industries, results from material, equipment, and subcontracts.

Standard Plant Design

Standard plant design with duplication of grassroots process units will offer lower TIC, compared to custom-designed plants.

Modular Design

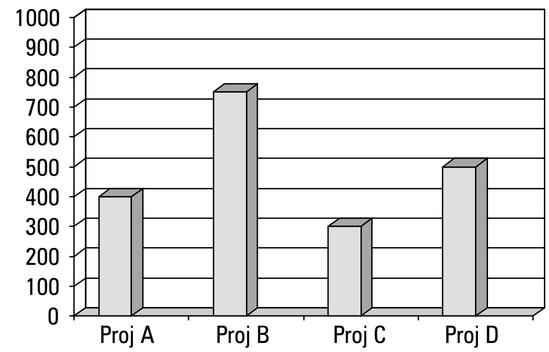
Modular design or skid-mounted process units with maximum shop fabrication offer cost and schedule advantages for remote plant location or areas with high field labor cost.

Project Execution Plan

For a successful project execution, it is important to prepare a detailed project execution plan (PEP). The plan should describe in detail who is to do what, when, and how including all major decisions affecting the project execution. PEP is a key document in providing details on engineering, procurement, construction, and startup and commissioning plans for the project. The components of the PEP will vary depending on the type of project and location. A typical format for a process plant facility should contain the following information as a minimum:

- Project objective
- Strategies and tactics
- Project organization
- Project work process
- Facility description
- Environmental plan
- Project management plan
- Project controls plan—estimate, schedule, code of accounts, and reporting
- Automation—hardware, software requirements
- Project administration plan
- Process engineering plan
- Design engineering plan
- Procurement plan
- Construction plan, and work breakdown structure
- Design and construction safety
- Community relations plan
- Startup and commissioning plan
- Quality assurance plan
- Division of responsibility matrix
- Project completion, closeout, and historical report
- Lessons learned.

Exhibit 5. Project Definition Rating Index



A low PDRI score represents a project definition package that is well defined.

Cost Estimate

Scope definition versus cost estimate—During the course of the project, a number of estimates are developed. Although there is no standard estimating terminology for various estimates, the following will provide a general guideline. The project development phase typically will include either an order of magnitude estimate or a factored estimate for project justification. The front-end loading effort will be concluded with a control base estimate for the formal project funding authorization.

Type of Estimate	Basis % Engineering	Estimate Quality
Order of Magnitude	< 5%	+/– 50%
Factored Estimate	5–10%	+/– 30%
Control Base Estimate	20–30%	+/– 15%
Definitive Estimate	30–40%	+/– 10%

Project Schedule

The planning efforts carried out during the FEL phase of the project increase the chances of meeting project schedule goals. The back-to-front scheduling technique will allow the project team to develop a fully integrated engineering, procurement, construction, and startup/commissioning schedule. The critical paths are identified early and given the right priority. Cost and schedule tradeoffs are identified to allow determination of a minimum cost schedule. Schedule compression concepts can be effectively implemented during the FEL phase for a fast-track project execution.

Project Team Organization

A project team organized during the FEL is very dependent on the size and complexity of the project. Divisions of responsibility for various groups within the project team help facilitate better control of the work process. The team members must be united and dedicated in making the project a success. A formal team-building session at the beginning of each phase of the project is highly recommended for effective project execution.

Key personnel are typically assigned during the FEL phase to develop the project strategic plans and to make major decisions on the project execution plan. A project-staffing plan for the detailed engineering and construction phase is developed as part of the front-end loading. The staffing plan must address required skills, timing, and assignment duration. In addition, the resource plan must be aligned to the project cost and schedule.

Benchmarking the Front-end Loading

There are a number of variations in how project benchmarking is accomplished. Benchmarking can be confusing because it includes a number of different activities built around a simple idea: We can gain a competitive advantage by the careful study of how others do business. At its best, benchmarking is a continuous discovery process that opens the organization to new and even radical ideas. However, benchmarking is not a one-shot bullet that will improve project performance.

The benchmarking criteria for front-end loading, such as FEL index developed by the Independent Project Analysis, Inc. (IPA) or project definition rating index (PDRI) developed by CII, must be identified at the beginning of the

FEL phase. PDRI is a relatively simple tool used to identify and describe each critical element in a scope definition package. It determines the completeness of scope definition, specifically on industrial construction projects before project funding. PDRI allows the project team to quantify, rate, and assess the level of scope definition on capital projects prior to authorization for detailed design and construction. A sample PDRI metrics is shown in Exhibit 5.

Project success criteria should be established during the FEL phase to focus the project team on meeting or exceeding owner's project objectives. The project team may determine the success criteria based on the project performance goals for cost, schedule, safety, and quality. The project team must also decide how the performance goals will be measured and reported. There is a relationship between a successful project and well-planned front-end loading, project management leadership, team building, and a project team reward for superior performance. Project team rewards may include individual and team recognition, financial rewards, owner/contractor sharing of cost savings, and contracting strategy with incentives.

Transition Plan from FEL to EPCC Phase

A written transition plan will help smooth the transition from the FEL phase to the EPCC phase of the project. This is especially important when a different team executes the detailed engineering phase of the project. A transition plan will provide project overview, scope of work, FEL deliverables matrix, FEL package, and a list of follow-up items and critical issues. A meeting with the detailed engineering team and participation of key personnel involved in the front-end loading phase are required for a flawless transition.

Lessons Learned from Similar Projects

Front-end loading is the ideal time for evaluating past project performance and improvement opportunities for a new project. The project problem areas and the root causes vary significantly from project to project due to a number of factors involved in executing a project. The performance problems, based on the lessons learned, are unlikely to repeat when addressed in the early phase of the project.

Conclusion

Front-end loading offers a significant opportunity for project preplanning and optimization and is a foundation for a successful project. The project execution requires a phased approach and discipline to follow the project work process. A quality check before moving to the next phase prevents a premature start of the next phase of the project. Well-defined scope of work developed during the FEL phase ensures that the project is completed within cost, schedule, and performance targets while offering the lowest total installed cost. Operating companies and EPC contractors place more emphasis in recent years on the project work process and better-organized phased project execution. As projects get more complex, global, and fast track, the front-end planning efforts become even more important for a successful project.

Nomenclature

- CII — Construction Industry Institute
- CPM — Critical Path Method
- DOR — Division of Responsibility Matrix
- EPCC — Engineering, Procurement, Construction, Startup, and Commissioning
- FEL — Front-end Loading
- IPA — Independent Project Analysis, Inc.
- NPV — Net Present Value
- O&M — Operations and Maintenance
- OPO — Owner's Project Objectives
- P&ID — Piping and Instrument Diagrams
- PDRI — Project Definition Rating Index
- PEP — Project Execution Plan
- PFD — Process Flow Diagram
- PMI — Project Management Institute
- ROC — Return on Capital
- TIC — Total Installed Cost
- VE — Value Engineering

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3-1 Constructability – A Primer

5-1 Impact of Various Construction Contract Types and Clauses on Project Performance

6-2 Scope Definition and Control

6-7 Concepts and Methods of Schedule Compression

37-1 Team Building: Improving Project Performance

39-1 Pre-project Planning- Beginning a Project the Right Way

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