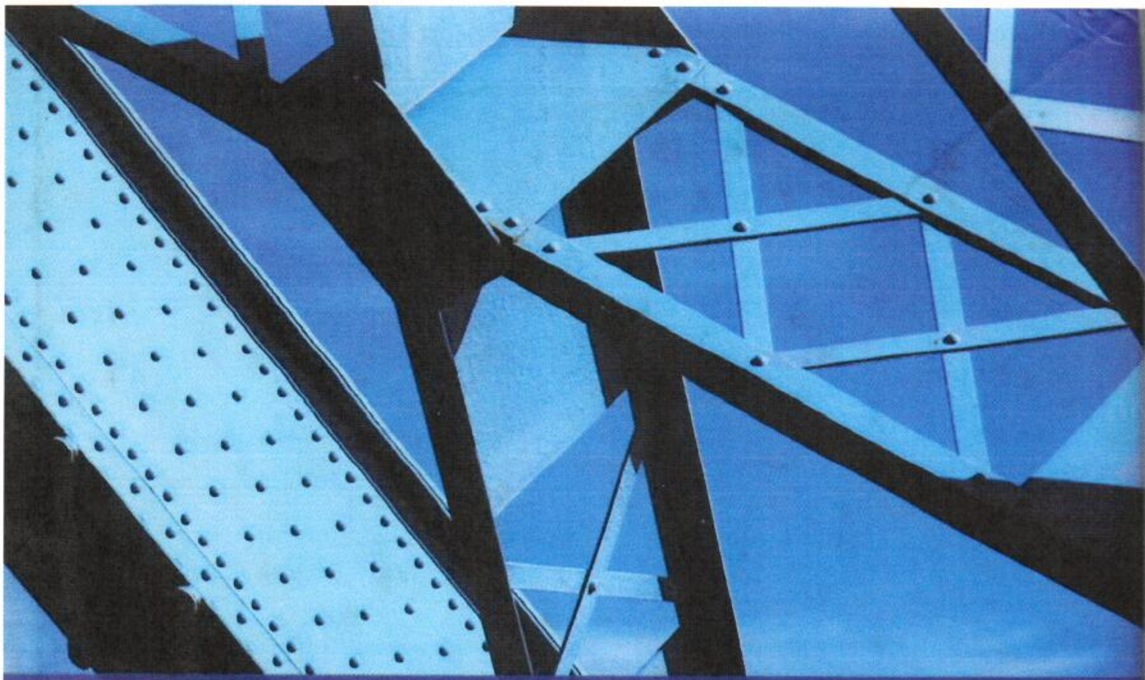
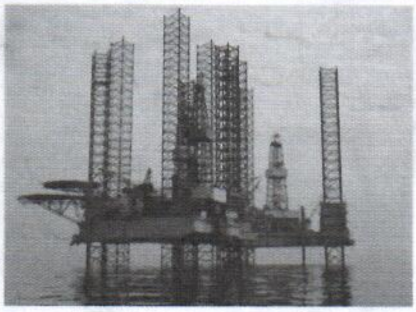
Text	**Edition**	**ISBN**	**Chapter and pages**
Merrow, E.W. (2011). *Industrial Megaprojects: Concepts, strategies and practices for success.* New Jersey: John Wiley and Sons.	1st	978-0-470-93882-9	Chapter 10: pp199 – 227



Edward W. Merrow


industrial **mega**projects

Concepts, Strategies, and Practices for Success

CHAPTER 10

PROJECT DEFINITION

GETTING THE FRONT END RIGHT

For want of a nail the shoe was lost.
For want of a shoe the horse was lost.
For want of a horse the rider was lost.
For want of a rider the battle was lost.
For want of a battle the kingdom was lost.
And all for the want of a horseshoe nail.

Because megaprojects are fragile, even little things matter. Let me offer an example of a seemingly trivial oversight in project preparation that brought down what could otherwise have been a great project.

The project was a greenfield chemicals joint venture megaproject executed in a nonremote, project-friendly area. The shaping process developed without any problems, and the scope was fully defined at closure. The project team did an excellent job defining the project. Our evaluation of its front-end work gave the team an almost perfect mark. Their undoing was the "almost." A single item was not completed before the project was tendered for EPC lump-sum bids: a HAZOP* evaluation of the design. The HAZOP, of course, not only finds potential hazards in the design but also tends to find any errors and omissions in the piping and instrumentation diagrams. The team elected not to do HAZOPs because it decided to put the task in the requirements for the winning contractor. I believe that when the team

*HAZOP stands for hazards and operability study. It is a rigorous examination of the design, especially studying what happens when the plant is started up, shut down, or experiences an upset such as sudden loss of power.

made the decision, they already had a good idea of who the winning contractor would be and they knew it to be a technically strong organization. It was considered a minor shortcut by the team, but they were pressed to meet their sanction date and HAZOP is one of the very last tasks in front-end loading phase 3 (FEL-3). So instead of a perfect 4.00 score on their FEL index, they received a 4.25.

Several months into execution, the team asked its contractor to show it the results of the HAZOP. The contractor responded that it didn't think the sponsors *really* meant for them to do the HAZOP, so it hadn't done it. The owner team demurred, saying that the complex would handle huge hydrocarbon inventories and the HAZOP was not optional. So the contractor stopped work, performed the HAZOP, and found a significant number of errors that had to be corrected.

Because design had been progressing rapidly for several months with both the contractor and a licensor participating, the changes were very disruptive to engineering, and engineering fell seriously behind. The engineering contractor had bid the project using the most highly respected international construction contractor in the region as its subcontractor. When informed that construction would have to begin nearly a year later than planned, the construction contractor voided its agreement with the engineering contractor, as it was permitted to do by its agreement. The construction firm had other projects to which it was committed that now conflicted with our project.

As a result, the lead contractor was forced to look for alternatives and finally had to settle for a number of smaller construction firms, several of which turned out to be hopelessly incompetent. Construction hours spiraled out of control, which ended up overrunning the contractor's bid estimate by more than 25 million field hours! The whole project fell still further behind, and when the project was finally delivered, the result was a shoddily constructed, marginally operable complex. All this despite the fact that the contract was a "lump-sum turnkey" with penalties and was awarded to one of the world's premier engineering contractors. The plant took a year and half to start up and in my opinion will never operate satisfactorily. "All for the want of a horseshoe nail."

For a number of reasons, the sort of debacle just described would not happen on a smaller project simply because the HAZOP was postponed. Because the engineering effort would be smaller, it would probably be possible to catch up. The market for competent construction firms would not be as constrained for a smaller project. And in the case of a smaller project, the HAZOP, which caused the problem to begin with, probably would have been executed by the team because it would not have been that time-consuming. Because megaprojects are fragile, they are terribly sensitive to seemingly small mistakes.

The definition of a project, from the formation of the core team until full-funds authorization is achieved, is what we call the FEL process. After 30 years of showing the data, badgering, cajoling, and whining to the industry about the criticality of FEL, I believe there is now virtual consensus among project professionals within the community of industries we serve that FEL is the single most important predictive indicator of project success. There are very few project professionals in the process industries who do not agree with the basic principle that definition and planning drive success, and those who don't should probably be in some other line of work. In more than 300 megaprojects, only a few had project directors that considered FEL not very important. All were inexperienced project directors, which is unusual for megaprojects, and all were disastrous failures.

The basics of what later became the IPA FEL index were published in 1981.[1] Of course, the formalization of the process did not start there. Exxon Research and Engineering had a work process as early as the 1960s that in structure is very much like the stage-gated process that is now standard within the oil, chemicals, pharmaceutical, and minerals industries. I have encountered a number of "inventors" of the process over the years, and I have never doubted that the process was invented in parallel any number of times. It is indeed such an obvious process that parallel invention would be expected.

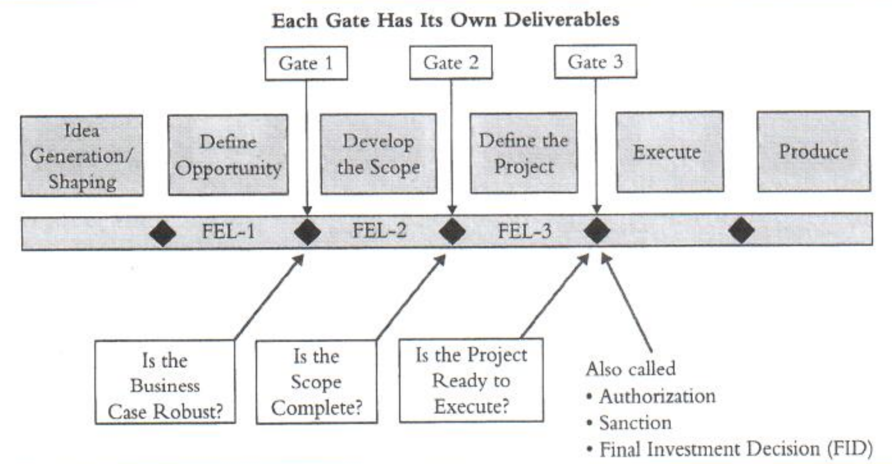
We have succeeded so well in getting agreement that defining a project thoroughly is a good thing that we are starting to see a backlash and complaints that we have "too much of a good thing."[2] Of course, one can do too much FEL; it is perfectly obvious. This is why IPA has always spoken in terms of "best practical" FEL, not "best possible." As soon as the investment in planning gets large enough to create a forward-going economics trap, you are doing too much. For megaprojects with difficult shaping situations, one also has to be aware of the problem of FEL getting in front of the shaping negotiations and distorting negotiating positions due to sunk costs. Yes, I know that sunk costs are sunk, which is to say they should be forgotten. However, sunk costs are often still too real psychologically to be dismissed. Unfortunately, we are nowhere near the point of having too much definition for industrial megaprojects. Indeed, quite the opposite is true.

What Is Front-End Loading?

FEL is the core work process of project teams prior to authorization. The work process is typically divided into phases or stages with a pause for an assessment and decision about whether to proceed. The gate assessments should examine both the economic/business and technical aspects of the project at that point. Those decision points are generally called gates. A basic rendition of the FEL process is shown in Figure 10.1. The number of gates in a system is not terribly important, although I believe that three is the minimum for a coherent process. There needs to be at least one gate at which the business case can be assessed, a gate when the scope is closed and the implications of the scope can be evaluated, and finally, a gate that triggers the full commitment of funds. But I know one (very good) project system that has an astounding 32 gates, although only a few are actually used as key decision points.

One of the most important misunderstandings within industrial firms is the purpose of the gates in the work process. Many business professionals assume that because the engineering and project management organization is the steward for the stage-gated process, the process is structured to meet an engineering purpose. In fact, however, the gates serve not an engineering purpose but a business purpose. That business purpose is to allow points in the development process to make decisions to stop, recycle, or proceed. The work process without the gates is a combined business-engineering process that starts out very heavily business focused and acquires its technical and engineering focus along the way. The engineers would gladly forego any gates and follow a seamless process all the way through, but that would be a disaster for the businesses.

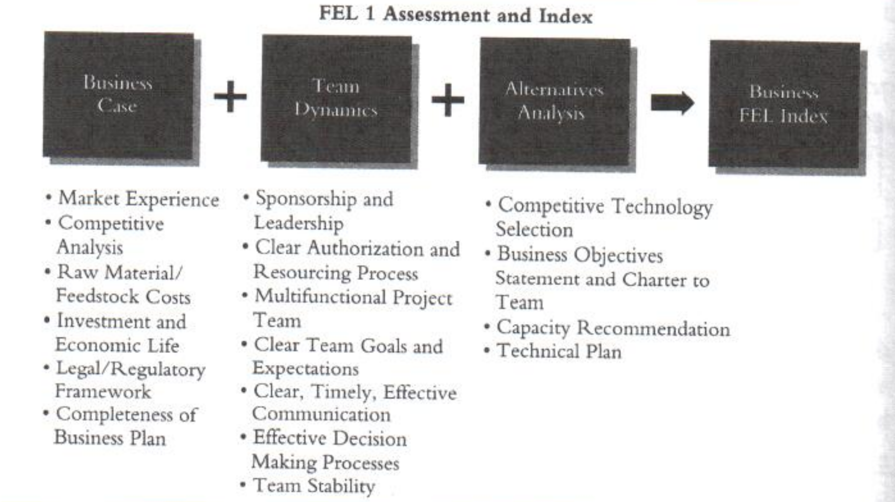
Figure 10.1
In Staged Process Each Gate Addresses Different Issues



It is very important to the health of the business's capital program that those decision points in terms of the development of the projects be the same for every capital project brought to a gate. Without commonality of FEL for all projects at each decision point, effective governance of the capital portfolio is not possible. The loss of governing control occurs because projects at different levels of FEL provide very different levels of reliability for cost, schedule, and production attainment. As we will see, this general observation about all projects is especially applicable to megaprojects because they are extremely sensitive to FEL status.

In the three-phase format shown in Figure 10.1, the first gate is designed to produce an inspection and evaluation of the health of the business case for the capital project. The way IPA assesses FEL-1 quality is shown in Figure 10.2. Each of the bulleted items in each major category is the subject of a number of questions. The scores from each item are aggregated to score for the main area (e.g., "Business Case" and then the main areas are added on a weighted basis to create the FEL index for Gate 1). That index is a very good predictor of the ratio of the actual net present value (NPV) achieved after 30 months

Figure 10.2
FEL-1 Is about the Business Case



to NPV promised at full-funds authorization. For megaprojects, the opportunity shaping process should subsume all of the items in Figure 10.2 and many more. In an effective megaproject development, there will be a lively interchange of information between those attempting to shape the project and those responsible for developing the technical scope of the project. The information needs to flow both ways. For example, the technical team needs access to the site of the project very early. The shaping team has to ensure that access is available. At the same time, the shaping team will be anxious to understand the likely cost and schedule of the project, but unfortunately, at Gate 1, the cost estimates and schedule forecasts don't mean much.

Cost estimates made at this point are little better than educated guesses because the physical scope that will be required to create a real project has not yet been defined. But guesses or not, there will be at least one cost "estimate" for the project. The problem with early cost forecasts is not just that they are usually too low. It is that they are too low by a completely unknowable amount. The cost number that was thrown out might be 80 percent of the eventual project cost, or it might be 30 percent. That means bias cannot be removed from the early numbers simply by applying a factor. For example, doubling the early numbers would kill some very good projects while doing little or nothing about the truly terrible ones.

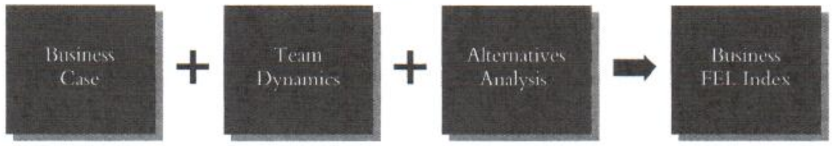
The best approach at this juncture in a project is to take a set of projects that are broadly similar and ask whether this one has characteristics that would make it tend to be lower or higher than those projects on a capital cost per unit output basis. If, for example, your project is petroleum production, ask how much capital per barrel are we spending on projects with similar sized reservoirs? Is this project in deeper or shallower water? Does it have easier or harder logistics? Is the resource owner easier or harder to work with? The same sorts of questions can and should be asked for minerals and chemicals projects. Nonetheless, the cost numbers at this early stage are not really estimates in the usual sense; they are at best indicators of cost. The same general rubric applies to schedules as well. At this point they are indicative only—and usually too short.

The corporate governance problem is created when cost and schedule numbers from a project that is still early in gestation are compared with those from a project that has been fully and carefully developed. The latter will lose because of the inherent low bias in the cost and schedule forecasts for poorly defined projects. Having the poorly defined project win out distorts behavior and encourages misrepresentation of projects by rewarding the poorly defined projects with money. If you create a situation in which liars win, sooner or later, that's all you will have.

It is unfortunate that Gate 1, the business gate, is by far the weakest in most organizations. Too many projects pass through the gate without much assessment. This in turn creates too many projects in FEL-2, which consumes the most creative technical people in the organization. Often, they are doing work that has no possibility of becoming a real project. Because Gate 1 is weak, many bad business ideas start scope development. Some of them inevitably become real projects. Unlike Gates 2 and 3, there is nothing approaching an industry standard in terms of deliverables for Gate 1. Businesses have been unwilling to subject themselves to the sort of strict standards that would make Gate 1 meaningful.

Figure 10.2
FEL-1 Is about the Business Case

FEL 1 Assessment and Index



- Market Experience
- Competitive Analysis
- Raw Material/ Feedstock Costs
- Investment and Economic Life
- Legal/Regulatory Framework
- Completeness of Business Plan

- Sponsorship and Leadership
- Clear Authorization and Resourcing Process
- Multifunctional Project Team
- Clear Team Goals and Expectations
- Clear, Timely, Effective Communication
- Effective Decision Making Processes
- Team Stability

- Competitive Technology Selection
- Business Objectives Statement and Charter to Team
- Capacity Recommendation
- Technical Plan

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Megaprojects with very weak business cases are much more likely to be single-owner sponsor ventures or to have a dominant lead sponsor and a small, passive cosponsor. Joint venture partners seem to have the effect of checking irrational enthusiasm. However, when the business case for a megaproject is weak, there are some telltale characteristics. First, the projects tend to enter FEL-2 (scope development) with a large number of possible options. This is highly problematic because prior research has shown that entering FEL-2 with more than two or three scope options results in FEL-2 not being complete, even when it is declared done.[3] Second, the projects with weak business cases are likely to come under intense pressure to cut costs during FEL-3, which leads to project failure. And third, weak business cases are associated with aggressive schedules because a more aggressive schedule will make cash flow appear to be better.

Assessing FEL-2

FEL-2 develops and articulates the scope of a project to a point where we can be confident that all elements of scope are accounted for. FEL-2 is the most important phase in the development of any project, including megaprojects. Early in FEL-2, the basic technology approach to the project must be selected if it was not done earlier. As we discuss later, the scope development must be informed by and be sensitive to the project context profile that has been developed by the country advance team (see Chapter 4). For example, finding out during FEL-3 (FEED) that your environmental impacts mitigation strategy will not suit the country requirements is a recipe for disaster.

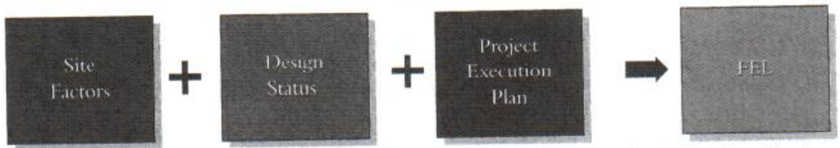
How IPA assesses FEL-2 is shown in Figure 10.3. The lists on the figure are tailored to process facilities, but analogous data are required for other types of projects.*

Scope development in FEL-2 must be comprehensive. Every part of the scope—on-plot, utilities, off-plot, infrastructure, waste treatment facilities, community development, everything—must be accounted for. The heat and mass balances must be closed, the process flow

*There are separate FEL indices for petroleum production projects, mines and minerals, pipelines, and pharmaceutical facilities projects. Modifications are made to the diagrams shown for power projects.

Figure 10.3
FEL-2 Is about Scope Development

FEL-2 Assessment and Index



- Site Determined
- Equipment Block Layout Identified
- Preliminary Soils and Hydrology Report
- Environmental Permitting Requirements and Strategy Identified
- Health and Safety Requirements and Strategy Identified
- Labor Survey Completed if Needed
- Local Content Providers Reviewed

- Basic Process Data
  - Feedstock/Product Properties
  - H&MBs
- Engineering Tasks
  - Written Scopes
  - Single Set of Complete PFDs
  - Sized Major Eqp. List
  - Utility, Infrastructure and Off-Site Requirements
  - Analysis of Existing Eqp.
  - Full Factored Cost Estimate
- Clear Business Objectives
- Participation and Buy-In of:
  - Operations
  - Maintenance/Turnaround
  - Business

- Execution Strategies (Not Plans)
  - Design
  - Procurement
  - Construction (Mod or Stick)
  - Turnover Sequences
  - Contracting
  - Team Participants and Roles
- Integrated CPM Schedule
  - FEL-3
  - Engineering
  - Procurement
  - Construction
- FEL-3 Plans (Not Strategies)
  - Contracting
  - Long-Lead Procurement
  - Resource Requirements
- Clear Project Objectives

diagrams must be complete, and every last piece of major equipment must be accounted for. The equipment list will then be priced and become the basis for the development of a *reliable* capital cost estimate for the entire project. Any piece of scope that is not found and included now will have two deleterious effects on the project: (1) it will increase the estimated cost (and possibly extend the schedule) when the scope omission is realized, which may cause serious stakeholder problems, and (2) it will cause a change to the project at a time when change is disruptive.

If FEL-2 is complete, then the cost estimate will be centered around the actual cost of the project in real (constant currency) terms.[4] Barshop and Giguere (2006) finds that the most important single measure of FEL-2 closure is whether the process flow diagrams

(PFDs) are complete. When the PFDs are complete, projects tend to experience no cost growth during FEL-3. When the PFDs are not complete, or when alternative scopes are still under consideration, significant cost growth occurs, and the probability of project failure increases significantly.

At the end of FEL-2, we should have closure of the shaping process, closure of the project scope, and reliable cost and schedule forecasts. By "reliable," I mean that they are centered around what the eventual actual values are most likely to be and the distribution around the most likely value is known and real, not the figment of somebody's imagination. But the forecasts are not yet highly precise, which is to say the distributions around both cost and schedule will typically be on the order of −15/+25 on a single standard error. At this point, the stakeholder-investors will have to make a decision about whether to do the project. It is unlikely that any more information will be forthcoming. The last option on the project is about to expire.

Some will object at this point that the final decision has not yet been made. Full-funds authorization will not come until after the FEL-3/FEED/feasibility phase is complete. Surely, we get one last chance to decide on the project, so this end of FEL-2 decision is less important! That interpretation of the FEL process is, I believe, profoundly incorrect. FEL-3 is necessary and important, but it culminates not in a decision about whether we *will* do the project but rather a decision about whether we are *ready* to do the project. The decision about whether the project should be done has to be made at the end of FEL-2. FEL-3 is far too expensive to be canceling projects after completing it. FEL-3 activities only become important to the decision about whether to do the project if FEL-2 activities were incomplete or otherwise defective. FEL-3 should not be important to the go/no-go decision.

Occasionally other circumstances will lead to project cancellation when FEL-3 is under way or even complete, but they are peculiar. For example, a megaproject was killed after FEL-3 when one of the major investors suffered a reversal of fortune in its general business and no longer had enough money to proceed. The project will go forward at some point, but another partner will have to be found. We know of a few projects that were canceled because an announcement by a competitor changed the market opportunity dramatically. Sometimes, megaprojects are canceled because the market for the product turns down sharply during FEL-3. However, unless something structural has changed in the market, a downturn should not cause cancellation unless the sponsors no longer have the cash flow or ability to borrow to sustain the project. Market timing should be irrelevant for megaprojects. By the time the project is up and producing, the market may well have changed again anyway.

ASSESSING FEL-3

FEL-3 is all about preparation to execute the project. FEL-3 is about filling in all of the details. All the items that were rated as "preliminary" at the end of FEL-2 need to become "definitive" at the end of FEL-3, meaning complete and final. The framework for the FEL-3 assessment is shown in Figure 10.4.

We characterize FEL as having three big blocks of work. The first is getting the project established and adjusted in its site. Examples of the kinds of issues that need to be tackled are shown in the figure. For onshore projects, the labor supply is particularly critical. For offshore petroleum projects, this is just as important and, in some respects, more difficult. Offshore project teams must understand the site in terms of ocean floor and the metocean conditions.* When moving into new ocean territory, fully understanding the metocean conditions can be difficult because there may be no records that cover the location adequately. For example, when BP pioneered the move into the area west of Shetland off of the UK coast, it encountered some of the most difficult ocean conditions ever seen. As a result, one of its vessels there, the Schiehallion, has been battered to the brink of destruction and is being replaced far sooner than ever envisioned.†

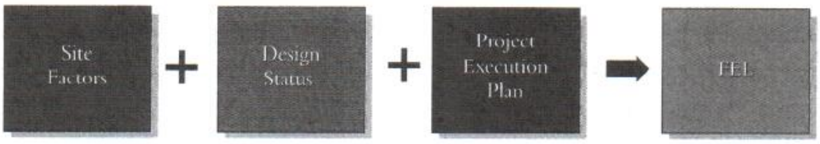
When local content is an issue, understanding the capabilities of the local materials and service providers is an essential part of the site factors work. It needs to be addressed early enough so that the information can be included in any invitations to tender.

*Metocean = meteorological and oceanographic.

†The Schiehallion's sister ship, Foinaven, was saved from a similar fate because it was a converted ice breaker and therefore rugged enough for the conditions.

Figure 10.4
FEL-3 Is about Readiness

FEL-3 Authorization Gate Front-End Loading Index



- Labor
  - Availability
  - Cost
  - Productivity
- Local Materials Availability
- Plot Plans and Arrangements
- Soils Data
- Environmental Requirements
- Health and Safety Requirements

- Engineering Tasks
  - Detailed Scopes
  - Feedstock/Product Properties
  - Heat and Mass Balances
  - License Packages
  - Piping and Instrument Diagrams
  - Electric Single-Line Diagrams
  - Major Equipment Specs
  - Take-off based estimate
- Full Agreement/ Buy-In of:
  - Operations
  - Maintenance
  - Business
  - Other Stakeholders

- Contracting Strategy
- Project Environment:
  - Community relations
  - Regulatory liaison
  - Local content providers
- Project Organization/Resources
- Team Participants and Roles
- Interface management and communication plan
- Critical Path Items
  - Identification of Shutdowns for Tie-Ins
  - Overtime requirements
- Plans
  - Commissioning
  - Startup
  - Operation
  - Manpower
  - Quality assurance
- Cost/Schedule Controls

Provided that the FEL-2 work was brought to closure, the design tasks for FEL-3 are relatively straightforward but require a great deal of work. The goal is to bring all aspects of the design up to a level from which rapid production design can commence. There are some subtleties in this process that deserve mention. Some parts of what would normally be considered "detailed" design, which is normally a postsanction process, may be required to support the ordering of long-lead time equipment that is on the critical path schedule. This has to be done without letting the contractor(s) "run away" with the project during FEL-3.

If the sponsorship of the project is a joint venture with more than a single lead sponsor being active in guiding the project, great care has to be taken not to confuse the FEED contractors during this period. Unless the joint venture team is so well blended that it is truly seamless—that does happen, but very occasionally—then any disagreements between partners about how to proceed with FEL-3 are likely to manifest in conflicting instructions to the contractors. Those conflicting instructions can result in making a hash of FEL-3. Let me give you an egregious example. This was a 50/50 joint venture with both partners actively involved in the management of the front end. One of the partners was very anxious for the project to proceed into FEED, believing (probably correctly) that if they could get FEED going, it would force the other partner to commit earlier than the partner wanted. So with scope development (FEL-2) about half done, the deputy director of the project simply hired the FEED contractor without consultation or permission of the director! That is extreme, but the lesson is important: If your contractors are given two orders—"go" and "don't go"—they heard "go."

The "best practical" rating for engineering design is what we call an advanced study design. We are frequently asked how this translates into the more conventional measure of "percent design complete." I resist giving a simple answer because the two measures are related but hardly the same. Design complete is generally calculated as the portion of expected engineering cost that has been spent. That measure suffers a number of problems. It is a percentage of what may be a completely fictitious denominator, as engineering costs tend to overrun more than any other single line item. Of even greater concern is that the design may be advanced too far in some areas and barely begun in others, and the "design complete" number will still sound perfectly reasonable.

The better way to measure is to ask what engineering tasks are complete. Three tasks, when taken together, constitute the acid test of whether the design is ready for sanction:

1. The piping and instrumentation diagrams (P&IDs) are complete, reviewed, and approved.
2. The major equipment specifications are completed and the long-lead time items are ordered.
3. The cost estimate was developed with take-offs of all material quantities from the P&IDs.

If all three conditions are met, the design is very likely advanced study. If "no" or the more common "well, sort of," the design is limited study and the project is not yet ready for sanction. Of the successful projects, 80 percent had achieved advanced study versus 40 percent of the failed projects ($P > |\chi^2| < .0001$).

Engineering is an area in which one can do too much prior to authorization. Our "best practical" rating of advanced study is substantially short of the best possible "full design specification." An interesting aside here is that none of the successful projects achieved a full design specification prior to authorization, but three of the failed projects did. These were projects in which the engineering effort continued despite major shaping problems. The sponsors were overcommitted to the projects and continued when they should have quit.

The third big element of FEL-3 at authorization is completion of the project execution planning. The development of the execution plan should start with the project itself at the start of FEL-2. By the time sanctioning of the project is near, the execution plan should be quite detailed. Many aspects of the execution plan must be decided no later than the start of FEL-3. For example, the decision whether the construction strategy will be modules or stick-built should be made as early as possible because it affects how the design will be developed in FEL-3.

It is tempting to postpone some aspects of execution planning on the theory that the needs are far enough in the future that there is plenty of time. This usually turns out to be a mistake. For example, it is tempting to delay the first draft of the commissioning and startup plans until sometime during execution, especially on long projects. The fault in that logic is that the turnover sequences for megaprojects are often complex. The turnover sequence defines the order in which various units should be commissioned, started up, and turned over to operations. Most of the turnover sequences are required, not discretionary. After they are finally worked out, you may realize that you cannot achieve the desired sequence because you failed to order a few pieces of long-lead time equipment way back in FEL-3.

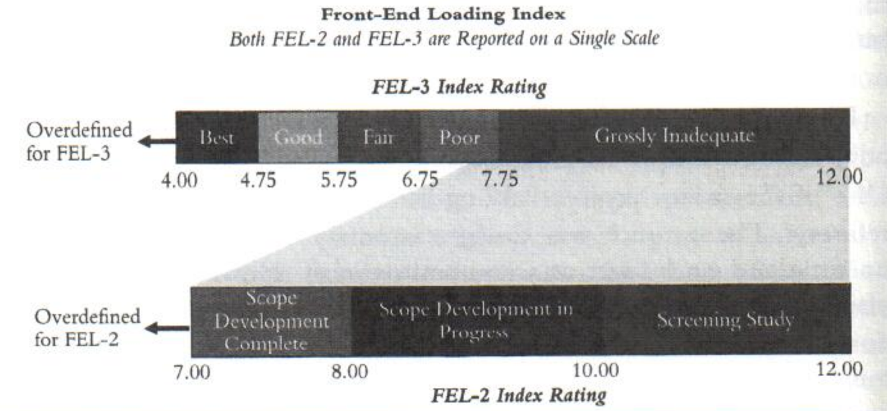
The local content providers need to have been identified and qualified well before any bid packages go out to prime contractors so that the local content risk can be reduced in the eyes of the potential bidders. The outlines of the contracting strategy should have started back in FEL-2 because how and who is contracted to assist with FEL-3 will depend on how you intend to contract the execution. As discussed in the next chapter, if the execution strategy is going to be lump-sum, hiring one of the desired lump-sum bidders to do the FEED work is not a good idea.

Especially for ventures in new geographies for the lead sponsor, the building of the operating organization must be planned during FEL. One of the sadder projects among our megaprojects was a grassroots refinery. The project was doing extremely well, being completed on time and on budget at a competitive cost. However, because the plant-manager-to-be did not believe the refinery could possibly be done on time, there was absolutely no operating organization to commission, start up, and operate the refinery when it reached mechanical completion. It took nine months to cobble an organization together to run a couple of billion dollars worth of investment that had been sitting on the ground rusting.

The most difficult single aspect of execution planning is the development of a high-quality schedule. Developing a good schedule is difficult not only because it simply takes a lot of work but also because too many companies no longer have the depth of scheduling expertise required or the data needed to properly resource load the schedule. Resource loading of the engineering and construction provides deep insight into whether the schedule you would like to meet is achievable by mere humans. We return to the importance of schedule later in this chapter.

The relationship of the measurement schemes for FEL-2 and FEL-3 are shown in Figure 10.5. The numbers shown are the points in the index where we break from one category to another. Both FEL-2 and FEL-3 are measured on the same scale but with quite different expectations for how much work has been accomplished by the time the gate at the end of the phase is reached. Note that in both cases, it is possible to overdefine. Too much definition means that the project is no longer synchronized with other critical activities. For FEL-2, it means that we have moved into FEED (feasibility for minerals) before achieving shaping closure. Recall that shaping closure should be coincident with passing through the gate at the end of scope development. Overdefinition for FEL-3 means that we have moved into execution

Figure 10.5
Single Scale Defines FEL



of the project without passing through the sanction gate, which means we never stopped to check whether we were ready to execute the project.

Best practical FEL-2 is when the scope development is complete and all elements are accounted for, all site elements are preliminary, and the pieces of the execution plan that will be needed for FEL-3, including the construction strategy and the basic contracting strategy, have been settled. If the project were authorized at that point, the FEL would be rated as "poor" with respect to sanction, although "best practical" with respect to Gate 2. In general, the costs to the end of FEL-2 are no more than about 0.5 to 1.5 percent of eventual total cost. If recycle has been necessary, or if the shaping process has slowed progress, the costs will be toward the high end of that range. If all has gone smoothly, the low end of the range will usually suffice. In any case, remember that none of the money spent in FEL-2 for either shaping or project development is project investment; it is information acquisition money.

To go from the end of FEL-2 to a ready-to-sanction project is considerably more expensive: another 2 percent to as much as 4 percent of eventual total capital cost may be required to complete FEL-3.

FEL-3 for a megaproject will always involve the mobilization of contractors to do the details of the site and engineering definition and to assist in the execution planning. FEL-3 costs are and should be considered project capital investment.

WHY IS COMPLETE FRONT-END LOADING SO IMPORTANT?

Once we launch the execution of a project, our goal is to maintain whatever business value has been created in the opportunity shaping and scope development processes. That means we have to deliver on whatever promises have been made in the authorization package that was reviewed and approved by top management, often including the main board of directors. Maintaining value means that the project will be on or close to its sanctioned budget and schedule and will produce as promised after startup. So let's review the importance of FEL to achieving those goals.

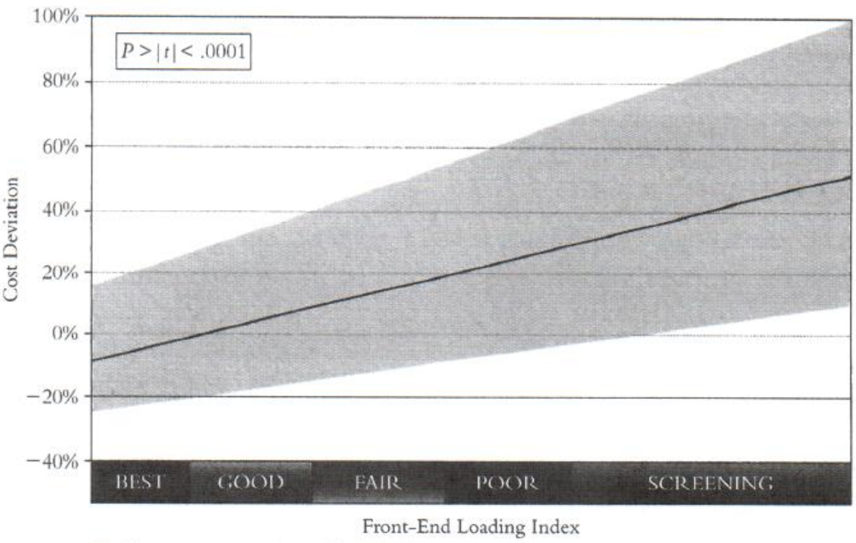
FEL and Cost Performance

Figure 10.6 plots the relationship between the level of FEL that had been achieved when the project was given the go-ahead for execution and how much growth in capital cost was seen, in real terms, to the end of the project.* The shading around the median trend line represents a standard deviation above and below the mean. Consider this chart in the context of risk assessment. If your FEL work is best practical, you will, on average, underrun by a few percent. The distribution around that slight underrun is about −15 percent and +25 percent.

In this case, the reality is even better than the numbers appear. A handful of projects were rated as best practical FEL but experienced huge (>70 percent) cost overruns for peculiar reasons. Two of the anomalous projects were overdefined, and shaping problems caused major disruptions after authorization. In one case, an inexperienced project director ceremonially dropped all the project definition work

*Cost overruns are measured as the ratio of the actual total capital cost in inflation-adjusted, constant currency terms to the cost estimated (contingencies included) at full-funds authorization measured on the same adjusted basis.

Figure 10.6
FEL Drives Cost Predictability



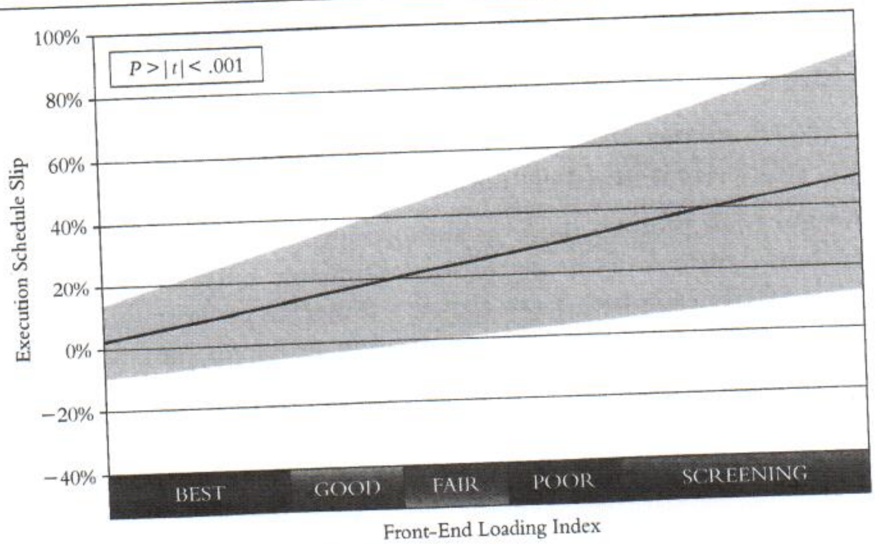
Shading represents +/− standard deviation

in the waste bin after authorization, saying that the project would be done "my way!" And in a couple of cases, well front-end loaded projects were directed to undertake major cost cutting after authorization, which made a shambles of the front-end work. When the outliers are discarded, the distribution around the slight underrun for best practically front-end loaded projects is about 10 percent. In other words, if the FEL is best, megaprojects are not particularly risky from a cost perspective!

By sharp contrast, if the FEL is "poor" at sanction, one is about equally likely to come in on budget or have a 60 percent (real) overrun. Now that is risky! If an outside observer—bankers, please take note—is trying to understand the cost risk for a megaproject, the very first measure should be the quality of FEL. If the FEL is poor, the project is a bad bet to back. If the FEL is "best practical," the project is odds-on to be fine with respect to cost.

The same basic relationship between FEL and cost growth is found in all projects and is equally strong statistically. However, the slope of the relationship for megaprojects is more than twice as steep as it is for

Figure 10.7
FEL Drives Schedule Predictability



Shading represents +/− standard deviation

projects of less than $500 million (based on the 2003 U.S. dollar). In other words, the same principles apply to all projects, but those principles are much more important for megaprojects.

FEL and Schedule Performance

Let's turn now to the risk of slipping our execution schedule* in Figure 10.7.

The pattern for schedule slippage is very similar to that for cost growth. The best practically front-end loaded projects usually achieved their schedules. When projects were rated "poor," they slipped by about 30 percent, which for the average project in our database means that first production would occur 13 months later than promised and 13 months later than the economic forecast for the project. Even more important from a risk perspective, the poorly

*Execution schedule is defined as the point of full-funds authorization to mechanical completion (in principle ready-to-operate) of all required kits. For petroleum production projects, the period ends at first production.

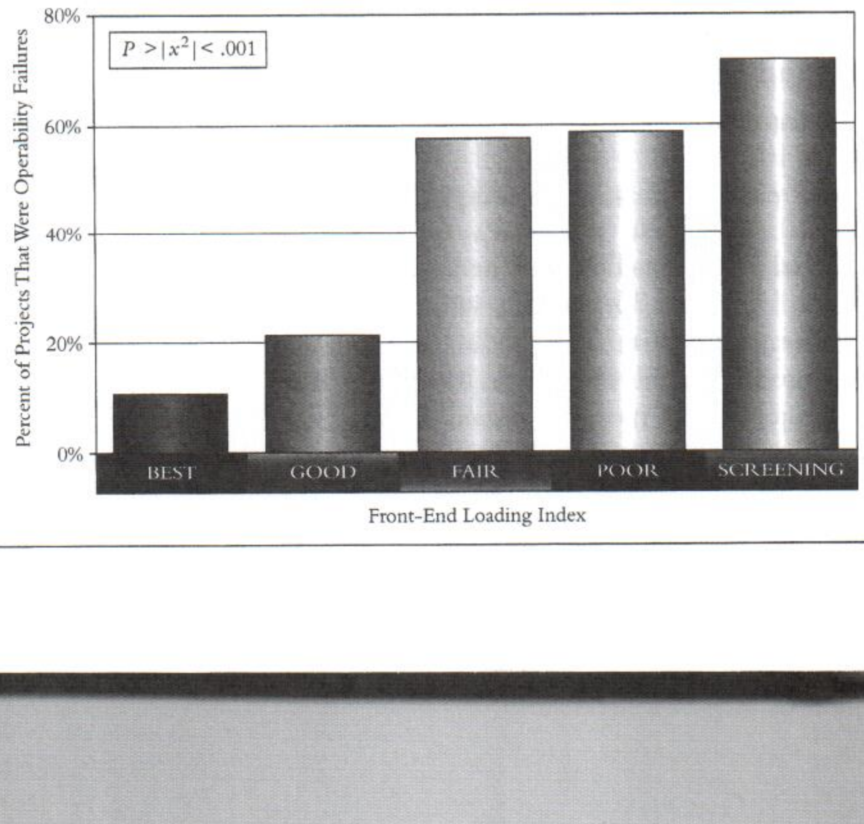
front-end loaded project is equally likely to be 26 months late to completion. Put in stark project management terms, if a project is "poor" on the FEL index at sanction, the only honest answer to the question, "When will this thing be done?" is a very unsatisfactory "I have no idea."

FEL and Production Performance

The third big promise made at authorization, and the promise upon which all cash flow from the project ultimately hinges, is operability. As described in Chapter 3, we classify a project as an operability failure if it has severe and continuing production problems into the second year after startup. The projects so classified averaged about 40 percent of planned production in months 7 through 12 after startup. The amounts spent to attempt to recover operability will never be known.

Figure 10.8 shows the relationship between the incidence of operability failure and FEL. When the level of FEL was "good" or better, the number of operability failures is under control. As soon as the

Figure 10.8
FEL Reduces Operability Problems



FEL index moves into the "fair" range, operability collapses. Projects that did not achieve at least "good" FEL were odds-on to fall short of meeting expectations. There were a number of underlying causes of the operability disasters. Some projects were so schedule driven that corners were cut in both Basic Data development and FEL. In some cases, the poor FEL triggered numerous changes during execution, and those changes caused quality to suffer. In some cases, poor FEL resulted in failing to fully understand the environmental permitting requirements, which in turn led to the facilities being shut down by the authorities for being out of compliance.

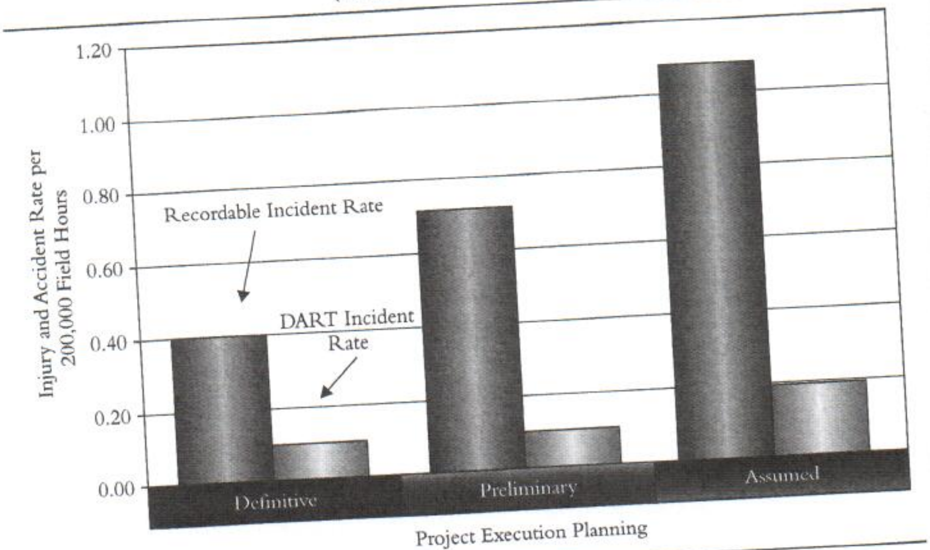
The failure of a project to produce at or close to the rates that were promised at sanction is debilitating to the economics of the project. If product prices remain constant, the early years' production are the most valuable the project will ever have. When a sponsor's assets consist largely of the project being developed, the failure of the project to be completed on time and then to produce at the expected rates often means bankruptcy or a "fire sale" of the company assets. The bondholders and banks must be paid.

FEL and Safety Performance

For projects generally, project execution planning is a major contributor to better construction safety. When I restrict my sample to countries that have strong reporting standards, I find the same relationship for megaprojects. Figure 10.9 shows how safety problems increase as execution planning degrades. The median recordable incident rate increases in a linear fashion as execution planning moves away from a "definitive" rating. The more serious accident rate, involving days away from work, restrictions on work that can be performed, and injuries forcing a job transfer (the so-called DART rate), does not show an increase until execution planning degrades to "assumed." It then doubles. Both relationships are statistically significant.*

*Because safety statistics have a sharp skew that is difficult to transform, I use a number of techniques to check my results, including Poisson regression, glm, and robust regression. All showed statistically significant results for both types of injuries. Although the statistical results are strong, I would not overinterpret the nonlinear result for the DART rate. Because the DART rate is more volatile than the recordable rate, the loss of observations is a potential problem.

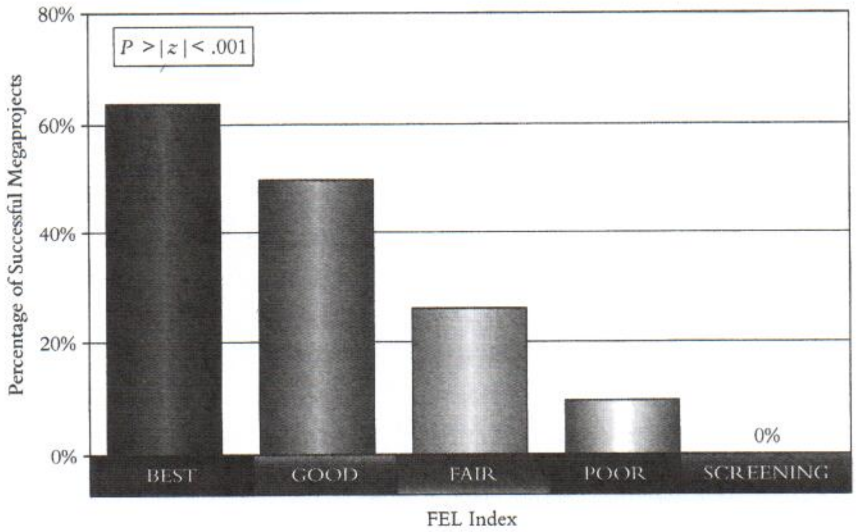
Figure 10.9
Execution Planning Improves Safety
(Truncated Sample)



That better execution planning drives better safety should surprise no one. Better planned sites are more orderly sites. Better execution planning is associated with less aggressive schedules and much less schedule slippage. When schedules begin to slip, safety begins to suffer. Projects with poor execution planning averaged almost a 30 percent slip in their execution schedules and almost twice as many recordable injuries than projects with "definitive" or "preliminary" execution planning. The DART injury rate correlates with execution schedule slip for countries with reliable reporting so strongly that nearly a third of the variation in serious injuries is explained by slip in the project schedule ($P > |t| < .0001$).

So, again, why is FEL so important? It is important because it is a prime driver of almost every project outcome that we care about: cost, schedule, operability, and safety. Figure 10.10 summarizes the relationship between the FEL index and successful projects. Almost two-thirds of the projects that achieved "best" FEL delivered what was promised at authorization. Among those projects that failed with best practical FEL, only a couple simply had bad luck. For example,

Figure 10.10
FEL Increases Likelihood of Success



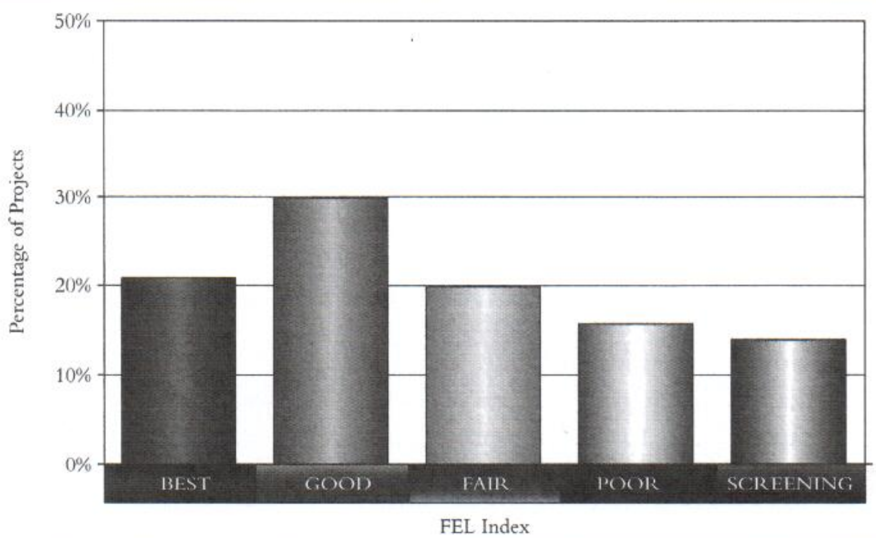
one of them failed because a third-party (government) project did not get done anywhere close to schedule. Two suffered repeated failure of major equipment despite conventional technology and well-established equipment fabricators. A few well-defined failures were highly innovative projects that overran badly but ultimately worked and proved the technologies, which may make money on future projects. A few others failed because they "gave away the store" to their lump-sum contractors. They were so anxious to get the projects done and on a lump-sum basis that they were willing to pay 50 percent and higher-risk premiums.

As soon as the FEL index moves down to "fair," the success rate falls below one project in four, and at the worst level of FEL, success disappears altogether. Every relationship we have reviewed in this chapter holds for smaller projects as well. But in every case, the relationship is more dramatic and severe for the megaprojects than it is for their smaller cousins. This brings us once again to the peculiar bimodal character of megaproject results.

How Well Are Megaprojects Front-End Loaded?

Megaprojects are the most important projects in any industrial company's portfolio. When they succeed, the company is strengthened for the long term. When they fail, massive amounts of shareholder wealth can be made to evaporate in a single project. Almost every project professional agrees that better, more thorough FEL means better project results. Logic, therefore, would suggest that almost all megaprojects would achieve "best practical" FEL before the investors' money is committed. As Figure 10.11 shows, however, that is not the case. In fact, only one megaproject in five achieves best practical FEL, and as explained previously, that number is actually somewhat exaggerated by those that undid their FEL work early in execution. Half of the megaprojects achieve "fair" FEL or worse. Fifteen percent of the megaprojects have a level of FEL that is the equivalent of a screening study, which is characteristic of projects just entering scope development rather than projects at full-funds authorization.

Figure 10.11
How Well Are Megaprojects Defined at Authorization?



There are no statistically reliable differences in the level of FEL by industrial sector. Liquefied natural gas (LNG) is a little better than average, but not systematically so. Pipeline megaprojects are a little worse than average, but not systematically so. The real question is, Why isn't FEL much better than it is for all industrial sectors?

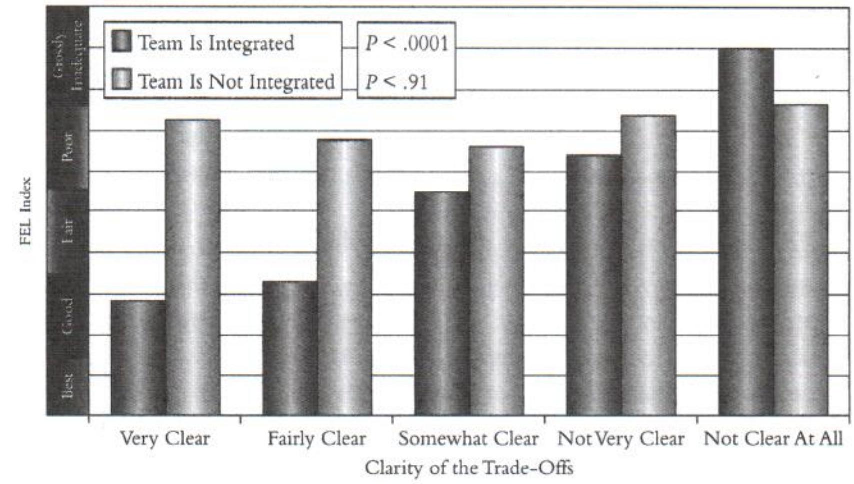
WHY ISN'T FEL BETTER?

The FEL story pulls together much of what we have discussed in the previous chapters of this book. Although failing to do excellent FEL is a primary proximate cause of megaproject failures, it is a symptom of a set of deeper problems. The relatively poor FEL for megaprojects is an extension of projects generally. When looking at our overall database of more than 14,000 projects, there is a systematic and undeniable relationship between larger size and poorer preparation. If we restrict our sample to only major projects that exceed $100 million (based on the 2003 U.S. dollar), the result does not change.* Megaprojects are merely at the far end of the cost spectrum and are, therefore, the most poorly prepared of projects on average.

What this means is that the more important a project is to the health of the modern industrial firm, the less likely we are to do the things absolutely necessary to make the project succeed. This perverse state of affairs starts with a lack of the people needed to do the work, which is due to the massive downsizing of owner engineering organizations that started in the mid 1980s. IPA asks megaproject directors at the end of FEL whether they had adequate numbers of staff to get their work done. A total of 61 percent answered yes, and 39 percent answered no. When they answered no, the FEL index was much poorer ($P > |\chi^2| < .0001$). But that is only the start of the problem. When the staffing was deemed adequate, 82 percent of the FEL teams were integrated. When the staffing was not described as adequate, only 25 percent of the teams were integrated. To some extent, these two

*The statistical results here are overwhelmingly strong. When I regress the FEL index against the natural log of estimated cost (in constant 2003 U.S. dollars), the t-ratio around the coefficient is greater than 11, meaning that one would need to go 11 standard deviations to the left of the coefficient before the relationship disappears. The probability that the relationship could be generated randomly is tiny indeed.

Figure 10.12
Team Integration Is the Critical Enabler



issues are tapping the same thing, but they are also tapping different realities as well. When the teams were not integrated, gaping holes were left in the FEL, whether or not there were enough people in total to get the work done. When the teams were integrated and the staffing was considered adequate, the average FEL was solidly in the "good" range. When neither condition was met, FEL was "poor."

But that is not the whole story. In Chapter 8, I discussed how having clear objectives and understanding the trade-offs among key outcomes was necessary to building strong teams. In Figure 10.12, we show that improving FEL depends not only on knowledge of the trade-offs, which subsumes having clear objectives, but also on team integration. When a team is integrated, understanding objectives and trade-offs drives much improved FEL. But when the team is not integrated, nothing helps. The team may perfectly understand what it is supposed to do, but if it is not adequately staffed or is missing one or more of the functions on the team at the right time, the FEL effort fails anyway.

Late arrival of Basic Data also degrades FEL, and this effect is not washed out when we control for team integration and staffing adequacy. Part of the reason for this is that Basic Data problems are associated with the FEL duration actually being *shorter* than it would otherwise be. That result, in turn, is an artifact of Basic Data problems being greatly exacerbated by pressure to drive the FEL schedule. This almost always happens because the entire project is being driven to be completed at a breakneck schedule. When corners are cut in Basic Data development, corners are likely to be cut in FEL and every other measure of project quality as well.

Sometimes problems encountered in the shaping process create problems in achieving good FEL. In a joint venture, which is the norm for megaprojects, partners may have very different ideas of what constitutes acceptable FEL. As the joint ventures are being formed early in the shaping phase, the businesses of the two (or more) partners may be discussing front-end work with little or no input from the project organizations. Because FEL issues are typically of low salience for business professionals, fundamental disagreements about how much FEL should be done or how long it should take may exist but not surface. When they do surface, as they must eventually, it is far too late to realize that you have the wrong partner.

Often the formal joint venture agreements are very slow to materialize. Usually, prior to formal agreement on the joint venture, there is a certain amount of confusion about who is willing to pay for what. We often encounter cases in which one partner is paying all of the FEL costs because the joint venture agreement has not been signed. As the FEL continues without a signed joint venture agreement, the business folks in the lead owner can start getting very anxious about the amount of money that is at risk and start slowing spending.

Some partners use FEL as an integral part of their shaping negotiating strategy. This may appear clever, but it really isn't. They want the other partner to spend as much "out of pocket" as possible because it bolsters their position. This is not materially different than demanding an upfront cash payment, which is another negotiating ploy but one very easily recognized as such. Encouraging the other partner to go as far out on the limb in funding FEL as possible works because the two partners now have an asymmetrical loss situation in the event that the project does not go forward. The reason this strategy is not clever is because it encourages too little FEL to be done. The resulting losses associated with project failure make everyone losers.

My very strong recommendation when in joint venture situations is to confront the FEL funding issue immediately when starting negotiations on the venture. Make the willingness of the other partner to fund FEL a simple matter of goodwill. If they are unwilling to fund their share, you must understand you are at an immediate disadvantage if you go forward in the shaping phase.

Sometimes insufficient FEL is done simply because the lead sponsor is excessively frugal (cheap) and doesn't want to spend the 2.5 to 5 percent required to get first-class definition of the project. We hear things like, "Why should it cost so much money? I once front-end loaded a big project on a napkin over a beer." If you are the project director, now would be a good time to post your resume.

More common, however, is that business management is driving the overall schedule for the project to first production. This is a problem we have already discussed in other chapters at some length, but one point needs to be revisited in this context: If as the project director, you respond to overall schedule pressure by shortcutting work on the front end, you are making a bad situation much worse. Poor FEL drives execution schedule slippages, startup time, and poor operability. Most important, poorly front-end loaded projects end up being slower overall.

Finally, there is the belief in some quarters, even among some project professionals, that the amount of FEL required will be less for certain contracting strategies. In particular, there is a belief that if the project will be executed on an EPC lump-sum basis, the execution planning is not really needed or is not needed to the degree it is for other contract forms. Not only is the belief without empirical foundation, it is precisely wrong. FEL has more effect in restraining cost growth and schedule slippages in lump-sum projects than it does in other contract forms. The reason is not hard to fathom. FEL reduces changes during execution. Owner changes during execution are major sources of profit for lump-sum contractors. You will get hit, quite appropriately, with the costs of the changes and the cost of the schedule delay that the changes cause. Then at the end of the day, the project operability will suffer because changes degrade quality.

FRONT-END LOADING AND THE PROJECT CONTEXT

In the discussion of shaping in Chapter 4, I said that the first step in a healthy shaping process was to explore the attributes of the project context. That information is needed both by the business leadership, who is trying to make a difficult decision about whether to go forward into the shaping process, and by the project team, who will need to mould its FEL activities to meet the challenges that the project context provides. The failure to fully explore the project context early in the evolution of the project puts the project team at a disadvantage. Before they can proceed, they will have to find sources of information about the context or risk getting things terribly wrong.

Three areas of the context are particularly important for the project team to understand very early:

1. Challenges of the physical location
2. Availability and quality of the construction labor
3. Permitting difficulties

I discuss each of these areas in turn.

THE LOCATION: DEALING WITH REMOTENESS

We classify our projects into three groups: very remote, semiremote, and nonremote. Very remote locations are more than 200 km from any major population center (greater than 50,000). The actual projects in our database that are classified as very remote average 400 km to the nearest population center.* Examples of very remote sites are around much of the Caspian Sea, the North Slope of Alaska, Central Africa, interior North Africa, much of Papua New Guinea, some parts of Australia, and so on.

Semiremote projects are closer to a major population center, but that center is far too small to provide labor or large amounts of

*We are not entirely rigid about these definitions. For example, if the site is less than 200 km from a population center but is separated by 100 km of dense jungle without access, we would classify it as very remote.