CHAPTER 5

Project development

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SUMMARY

The business objectives of a metallurgical project determine targets and constraints, such as the range of products, production capacities, in-service dates, and capital and operating cost parameters. Permitting is usually left to the project team, as are decisions regarding site location, technology, and construction approach.

Success requires an orderly methodology, represented in this book by front end loading (FEL) phases:

- FEL1 examines several alternative approaches;
- FEL2 ranks and eliminates less economically or technically attractive options; and
- FEL3 develops the preferred option to the point of major permit completion, with defined scope, schedule, and cost to submit for approval to proceed with implementation in FEL4.

Working through FEL1, FEL2, and FEL3, the project definition improves, estimates become more accurate, and project risks are reduced. The project design basis at the end of FEL3 is the control document for project implementation in FEL4.

5.1 INTRODUCTION

Chapter 3: The business case: defining the project discussed business case development, before project initiation. *Chapter 5* outlines the steps to convert the business case into a project definition that is ready for a full capital spending commitment. The focus is on the content and deliverables of FEL1 through FEL3, described in *Chapter 1: Introduction*. Project implementation (FEL4) is discussed in *Chapter 11: Project implementation*. The inherent risks of plant design and construction can only be mitigated through comprehensive project definition and development (see *Chapter 2: A risk-based approach to plant design*).

Capital and operating costs are central to the business case for metallurgical projects, regardless of their size and whether they are greenfield or brownfield projects. The accuracy of cost inputs must be developed to a level that is acceptable to the project owner, to minimize the risk of misallocating capital or building a facility that does not meet the business case objectives. Although detailed financial modelling might have been performed during business plan development, the conclusions could only be as good as the accuracy of the capital and operating cost inputs. The phased approach is focused on improving the accuracy of these estimates.

Metallurgical projects are typically capital intensive and complex to design, build, commission, and operate. They often have a customized flow sheet to suit the metallurgy specific to the materials being processed, and might require custom designs and equipment. It is rarely possible to procure a standard design for the processing plant.

A common mistake is to overlook local social acceptance or environmental and government permitting during the early project phases. This can result in major schedule setbacks and higher costs (further discussed in *Chapter 8: Sustainability in plant design*). It is paramount to identify the necessary permits and understand the timing and scope of submissions and approvals early in project development.

A rigorous methodology is needed to manage these complex projects effectively. The following approach is based on definition (by phase) of scope, depth of investigation, engineering methodologies, and deliverables, within the framework of the risk mitigation requirements of the owner.

5.2 FRONT END LOADING: THE FOUNDATION OF PROJECT DEVELOPMENT

The structured FEL approach is key to successful project implementation through to project closeout at facility commissioning and handover to the operators. This approach recognizes that the potential to influence the outcome favourably is greatest in the early phases, FEL1 through FEL3. The project development phases make it possible to accurately assess the feasibility of translating the business case into physical plant. Once plant design options are identified, the most viable is selected, then refined to enable an informed decision on whether to proceed to detailing, equipment procurement, and construction.

The important principle is that risk decreases and certainty increases in each phase (refer to Figure 1-2):

- In FEL1, test the broad business concept, and generate options for implementing the requirements of the business case.
- In FEL2, evaluate and prioritize options, select the preferred option, and more rigorously test project viability. Place emphasis on examining factors that drive implementation strategies and early permitting requirements.
- In FEL3, further define and confirm the feasibility of the preferred option. Define the optimized project in terms of cost, schedule, scope, and other elements required by the owner, such as major permits,

procurement, construction, and commissioning strategies. Place emphasis on planning execution, and aligning the project schedule, estimates, and other baseline data with the implementation plan.

- In FEL4, make the capital investment, finalize the plant design, and implement the project, in line with scope, schedule, cost, quality, safety, and other performance parameters.

Rigorous sequential completion of FEL1, FEL2, and FEL3 improves the likelihood of success during FEL4, and is crucial to the success of plant operations. It is essential that a project does not progress to the next phase until gate review criteria have been satisfied (Figure 1-3). This gate review process is further described in Section 5.4. Unsatisfied criteria could indicate or hide a flaw that would prevent successful realization of the project.

In essence, the FEL process involves the progressive and phased increase in project spending from concept to implementation. The result is decreasing risk and uncertainty, and increasing scope clarification over the project timeline (Figure 5-1). Rather than committing large sums at the outset to an uncertain investment, each incremental investment decision is made only when supported by the level of risk and certainty. By methodically addressing the major variables that influence project definition, the FEL phases serve to identify, analyze, and evaluate the project, and determine the single definition that best meets the

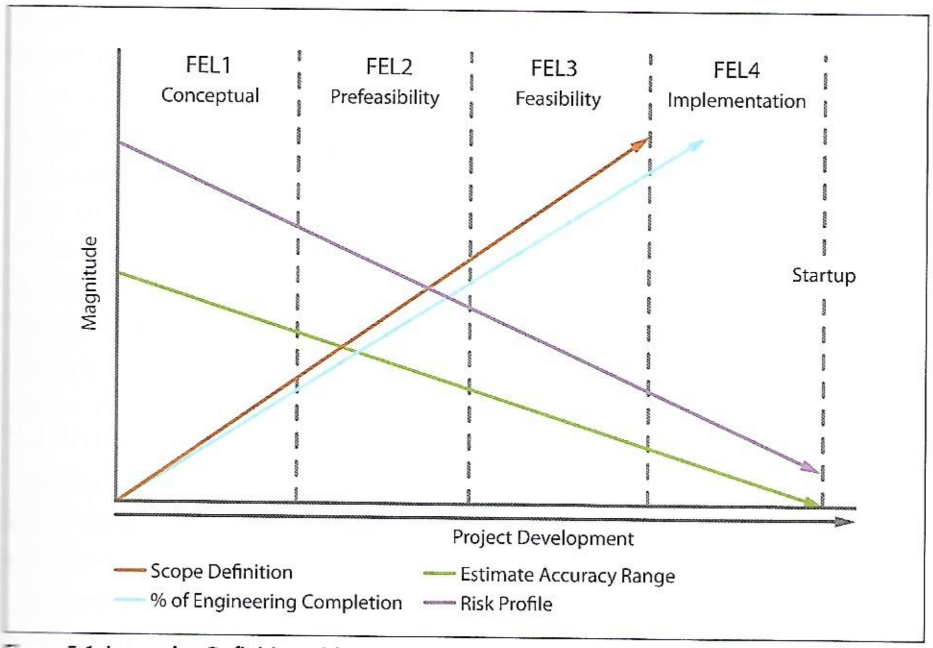

Figure 5-1. Increasing Definition with Engineering Progress Resulting in Decreasing Risk and Estimate Uncertainty Through the Front End Loading Phases

owner's business requirements. For each phase, a framework of key questions is presented below; their implications are explored in the following sections.

Key questions to be addressed at the end of each phase are in two major groups:

1. Have we defined the right plant to meet owner expectations?
   - Has the scope been fully defined, and have out-of-scope elements been listed?
   - Has the plant configuration been defined?
   - Have implementation requirements for the project been defined?
   - Have business objectives been met?
2. Have we done the right work for the FEL phase of the project?
   - Does the work in the phase align with the expected accuracy range estimate?
   - Does the work in the phase cover all elements required to define the complete project?

Typical FEL phase activities are shown in Figure 5-2, and expanded in tabular form for the design engineering functions in *Appendix 1: Key design activities, FEL1 through FEL3*.

Completion of FEL3 yields a sound definition of the plant. For many owners, this marks the point where approval of capital funding is sought for detailed engineering, procurement, and plant construction. Approval is conditional on project risks having been identified and mitigated. The resulting scope definition and cost estimates are used to confirm that the business case objectives can still be met and that the technical, social, and environmental issues have been addressed. Project definition during FEL3 also establishes realistic baseline data, against which implementation in FEL4 will be monitored and controlled.

After completion of FEL4, the objective of startup and operations is to begin ramp-up to nameplate capacity as quickly as possible, and start delivering a return on the capital investment. Commissioning an industrial plant is usually done by "system," defined as a group of equipment that works together to perform specific functions. Systems are generally commissioned in a prioritized order; for this reason the entire project plan is anchored in the start-up strategy.

Project planning must begin as early as possible in project development. The basic contracting, procurement, and construction strategies need to be understood in FEL2, and preliminary systems identification tasks commence in FEL3. Planning for commissioning, including any temporary facilities required, sets the framework for the engineering and procurement plan, and system dependencies determine the overall priorities for the project plan.

FEL1 Conceptual Study	FEL2 Prefeasibility Study	FEL3 Feasibility Study	FEL4 Implementation
Test business concept	Reconfirm business concept	Upgrade project design basis	Finalize project plan
Establish project design basis	Reconfirm project design basis	Develop facility engineering	Generate specifications
Establish key production parameters	Develop options	Develop risk mitigation plan	Complete procurement process
Establish alternative approaches	Develop costs for options	Develop implementation plan	Complete detailed design
Execute concept designs	Select preferred option	Develop procurement plan	Complete project revisions
Evaluate costs	Define implementation drivers	Develop construction strategy	Complete construction
Develop FEL2 plan & cost	Initiate environmental baseline studies	Complete test work	Conduct tests & commission
Conduct gate review	Develop FEL3 plan & cost	Complete major permitting	Perform acceptance tests
Approve options for FEL2	Conduct gate review	Prepare detailed cost estimate & schedule	Generate closeout report
	Approve preferred option	Conduct gate review	Close project
		Approve fully defined project	Conduct postproject review
			Archive

Figure 5-2. Typical Front End Loading Phase Activities During FEL1 Through FEL3, as well as Project Implementation (FEL4)

Table 5-1 summarizes the level of development of the general project information and engineering deliverables in column 1, corresponding to the end of each FEL phase.

5.3 THE PROJECT DESIGN BASIS DOCUMENT

The project design basis (PDB) document summarizes fundamental design parameters and decisions. It is initiated in FEL1 and evolves through FEL2, FEL3, and FEL4. Success of the FEL approach hinges on the PDB.

At the beginning of a project—particularly one with engineering and procurement of components at several locations around the globe—a primary task is to develop the design standards and criteria during FEL1 through FEL4. The design standards (normally set by national standards organizations) documented in the PDB apply to the entire plant. Design criteria (developed for the project) must incorporate requirements of the owner, as well as any governing body with jurisdiction over the project. They must also match owner expectations of quality and cost. Misunderstood design standards and criteria have been a root cause of failure for many projects.

Table 5-1. Estimate Input Checklist, Including Engineering Deliverables (modified from AACE International, 2012)

Inputs	Business Plan
General Project Information	
Project definition deliverables maturity level	0–2%
Project scope description	General
Plant production/facility capacity	Assumed
Plant location	General
Soils and hydrology	None
Metallurgical test work	General
Integrated project plan	None
Project master schedule	Assumed
Plant layout	General
Escalation strategy	None
Work breakdown structure	None
Project code of accounts	None
Contracting strategy	Assumed
Major equipment	Assumed
Nonprocess facilities (e.g., infrastructure, ports, pipelines, power supply)	Assumed
Engineering Deliverables	
Block flow diagrams	Started
Plot plans	-
Process flow diagrams	-
Utility flow diagrams	-
Piping and instrument diagrams	-
Heat and material balances	-
Process equipment list	-
Utility equipment list	-
Electrical one-line drawings	-
Specifications and datasheets	-
General equipment arrangement drawings	-
Spare parts listings	-
Mechanical drawings	-
Electrical drawings	-
Instrumentation and control system drawings	-
Civil, structural, and architectural drawings	-

The decreasing order of precedence in cases of conflict is usually:

- government and statutory regulations at the project site;
- prime contract and applicable agreements;
- local or international industry codes and standards required by the owner or good practice;
- project design criteria documents; and
- owner's expectations.

FEL1	FEL2	FEL3	FEL4
1–15%	10–40%	30–75%	65–100%
Preliminary	Defined	Defined	Defined
Preliminary	Defined	Defined	Defined
Approximate	Preliminary	Specific	Specific
None	Preliminary	Defined	Defined
Started	Preliminary	Defined	Defined
Started	Preliminary	Defined	Defined
Preliminary	Defined	Defined	Defined
Preliminary	Preliminary	Defined	Defined
Preliminary	Defined	Defined	Defined
Started	Preliminary	Defined	Defined
Preliminary	Preliminary	Defined	Defined
Assumed	Preliminary	Defined	Defined
Preliminary	Defined	Defined	Defined
Started	Preliminary	Defined	Defined
Preliminary	Preliminary/Complete	Complete	Complete
Started/Preliminary	Preliminary	Complete	Complete
Preliminary	Preliminary/Complete	Complete	Complete
Started/Preliminary	Preliminary/Complete	Complete	Complete
Started/Preliminary	Preliminary	Complete	Complete
Started/Preliminary	Preliminary	Complete	Complete
Started/Preliminary	Preliminary	Complete	Complete
Started/Preliminary	Preliminary	Complete	Complete
Started/Preliminary	Preliminary	Complete	Complete
Started/Preliminary	Preliminary	Preliminary/Complete	Complete
Started/Preliminary	Preliminary	Complete	Complete
-	Started	Preliminary	Complete
-	Started/Preliminary	Preliminary/Complete	Complete
-	Started/Preliminary	Preliminary/Complete	Complete
-	Started/Preliminary	Preliminary/Complete	Complete
-	Started/Preliminary	Preliminary/Complete	Complete

A capital project usually originates as an owner's idea to address a market need, strategic imperative, or other requirement. This idea is generated through cyclic strategic planning in the owner's business process. The strategic plans are typically reviewed and updated over time. As the project passes from one phase to another, it is essential to confirm validity of the incoming PDB against the current corporate plan. The outcomes of a prior FEL phase might drive substantial changes to the PDB content for successive phases. It is good practice to maintain the PDB as a living document, updated with design basis changes or development information as it becomes available. The PDB allows all parties to work with the same current information.

The PDB should be a complete, clear, and unambiguous statement of the owner's requirements in measurable terms, and is the source document central to setting the project context and the required technical outcomes. A well-prepared and maintained PDB greatly reduces the likelihood that the project team will make incorrect assumptions. Each time a decision is made that affects any element of the PDB, that decision is recorded along with supporting documentation. This procedure ensures that project changes are identified and justified as they occur, and that the reasons for the decision are understood by later readers of the PDB.

The final version of the PDB underpins safety analysis and the hazard and operability study (*Chapter 9: Design for safety*), and at the completion of design in FEL4, the manuals for commissioning and startup (*Chapter 11*). As a record of decision rationales, the PDB is also an invaluable resource for future expansions or plant changes.

A typical PDB addresses the following high-level elements:

- measurement units and symbols;
- governing codes, standards, and regulations;
- site data and meteorology;
- safety and environmental criteria;
- sustainable development objectives;
- process and production targets; and
- design criteria for
  - civil, structural, and architectural elements,
  - mechanical, piping, and electrical systems,
  - process control and instrumentation, and
  - computer systems and communication.

To mitigate risk, it is essential that data sources are documented, so that assumptions can be identified, tracked, and tested. Typical project data coding might use the following descriptions:

A. Criteria provided by the owner
B. Standard industry practice
C. Recommendations by engineering group
D. Vendor-originated criteria
E. Criteria from process calculations
F. Engineering handbook data
G. Assumed data
H. Criteria from technology supplier
I. Metallurgical test results

The designer requires well-defined performance parameters. For instance, in addition to the mean flow rates for materials handling systems, it is essential to establish the handling requirements profile, typically including:

- annual tonnage rate (t/y);
- daily mean tonnage rate (t/d);
- daily peak tonnage rate (t/d);
- instantaneous peak tonnage rate (t/h); and possibly
- arriving shipment size ranges (t) and frequencies.

Time availability is key to establishing equipment and plant parameters. The net time available for operation depends on

- type of process (e.g., continuous or batch),
- operating philosophy,
- approach to routine and annual maintenance,
- equipment reliability,
- level of system redundancy, and
- scheduled labour work shifts.

Categories of time allocation typically include:

- scheduled downtime such as statutory holidays, annual maintenance shutdown, and routine maintenance shutdowns (e.g., weekly or biweekly); and
- unscheduled delays and downtime.

Two examples below illustrate the type of information found in a PDB, and why the document is so important.

Example 1: Nominal Capacity of an Electric Arc Furnace

In the initial plant design phase, the electric arc furnace (EAF) capacity and material flows are usually defined in terms of annual capacity (e.g., t/y) or mean flow rates. These parameters serve well in the conceptual stage, but using them for plant design can be very misleading. As for operating time, the estimated use of available time is uncertain in early project stages.

The breakdown of the hours typically available in a year for an electric steelmaking shop is shown in Figure 5-3. Note that the distribution will vary among operations and/or within a given plant from year to year. For instance, during a period of high market demand for a product, the company might elect to defer the annual shutdown. In reality, only a limited number of hours can be considered discretionary, and 100% time use is not possible. Not recognizing non-production time, in particular the reality of unscheduled delays, would result in an inadequately sized EAF.

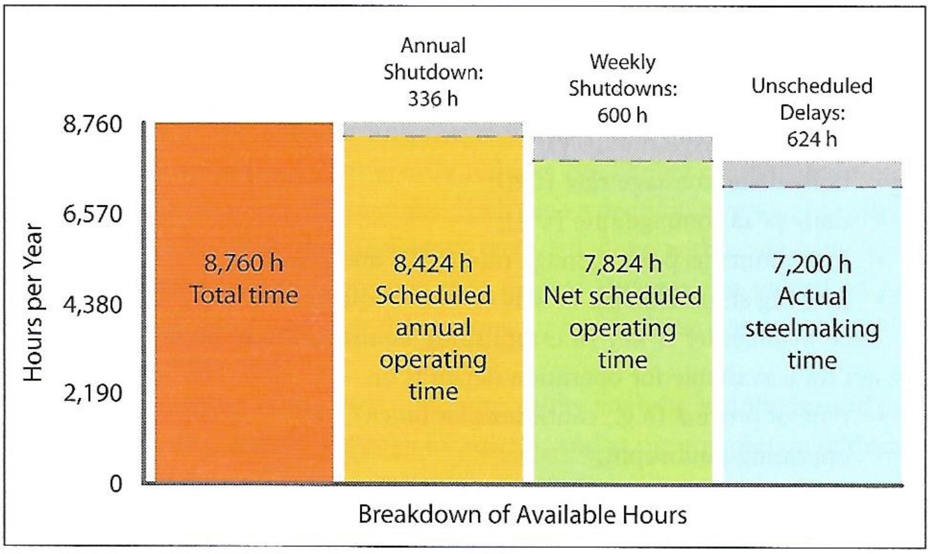

Figure 5-3. Annual Available Hours for Conventional Electric Arc Furnace

Example 2: Nominal Capacity of a Material Conveying System

Another example of why proper definitions are so important is the design capacity development of the main conveyor feeding a direct reduction shaft furnace (Table 5-2). At first glance, a conveyor capacity of 160 t/h appears to be

Table 5-2. Feed Conveyor Capacity of a Direct Reduction Shaft Furnace

Design Consideration to Convey 1,400,000 t/y	Available Hours per Year	Required Conveyor Capacity (t/h)
Annual feed, pellets + iron ore	8,760	160
Subtract annual shutdown (336 h)	8,424	166
Nothing planned for statutory holidays (0 h)	8,424	166
Subtract scheduled maintenance (138 h)	8,286	169
Subtract unscheduled delays (286 h)	8,000	175
Correct for conveyor load factor: 80%	6,400	219
Correct for time use of conveyor system: 95%	6,080	231

sufficient to deliver 1,400,000 t/y of feed. However, when all time and equipment factors are considered, the required conveyor capacity increases by 44% (231/160 t/h). Had the capacity been established based on the mean annual rate, the conveyor would have been significantly undersized, creating a serious plant bottleneck by starving the shaft furnace. The analysis typically summarized in a PDB shows that in reality the requirement is for 231 t/h.

Design Basis for "Fit-for-Purpose" Contracts

The term "fit-for-purpose," meaning roughly "good enough for the job," can be introduced into a project—usually by the owner—ostensibly to reduce capital expenditures to the bare minimum required for startup. This terminology can have a different meaning under the designer's services contract than the owner might intend. The fit-for-purpose requirement can be driven by several factors:

- constrained capital availability;
- a marginal business case that requires low capital expenditures (relative to appropriate benchmarks); or
- a high-value but short-lived (e.g., 5–10 years) feed material source, such as a small, high-grade orebody.

Design contracts are not usually for fit-for-purpose services, which are actually very demanding and normally reserved for aerospace and nuclear facilities where design failure cannot be tolerated. They are not the cheapest way to get "up and running" as is often assumed. To avoid conflict, the owner's intent must be made clear and contractual arrangements must be aligned.

However, responses to requests for the fit-for-purpose approach can take several directions. The design team must be very careful in their response, because if cost cutting is the intent:

- eliminating installed spares can have serious down-time and production consequences;
- removing design allowances for future expansion can have serious future cost consequences;
- reducing plant floor area and footprint can have maintenance access and safety consequences;
- bypassing appropriate painting or protective coatings can cause corrosion-driven failures and production problems; and
- using inappropriate materials where corrosive liquids are present (e.g., 200-series stainless steel rather than 300 series) to save money can be operationally disastrous.

From this small set of real examples, it is evident that the design team must always adhere to the following principles:

- follow the relevant standards;
- do not compromise safety; and
- ensure the owner understands the business case impacts of any changes in operating costs or production capability.

Pressure on the design team to minimize capital costs is both normal and appropriate. Often there is a pause at the end of FEL3 for "value engineering," where efforts are made to reduce costs while maintaining production objectives. However, the design objectives and legal obligations of the design engineers must be reconciled with owner expectations to establish an agreed design basis.

5.4 PROGRESS THROUGH FEL PHASES

The decision to proceed from one FEL phase to the next is made on the conditions that:

- after completing a phase the business case is still valid;
- the cost of the next phase is clearly established; and
- the level of risk or uncertainty associated with the next phase is understood and acceptable to the owner.

After the decision to proceed, a project team is assembled to execute the FEL study within the scope, time, cost, and quality constraints defined in the PDB. Gate reviews at the end of FEL1, FEL2, and FEL3 assess compliance with the owner's requirements for a given phase. In consultation with the gate review leader, the study team defines the gate review criteria to assess the quality of deliverables from the completed phase. Gate reviews are an essential means to:

- review project outcomes to date;
- confirm alignment of project outcomes with project objectives;
- re-assess project viability;
- grant authorization for the project to be released to the next phase; and
- meet the requirement that all large investment projects be reviewed for viability at regular, predetermined intervals before being permitted to continue.

The following sections expand upon the objectives and key activities of each FEL phase. The example in Figure 5-4 illustrates the logical flow of the phases, from initial identification of six options, through the successive elimination of five options at various points in the project evolution, to testing the feasibility of the selected option, in this case option 2.

FEL1 – Conceptual Study

The objective of FEL1 is to define a range of viable options for definition and development that meet the owner's business needs. Some options (e.g.,

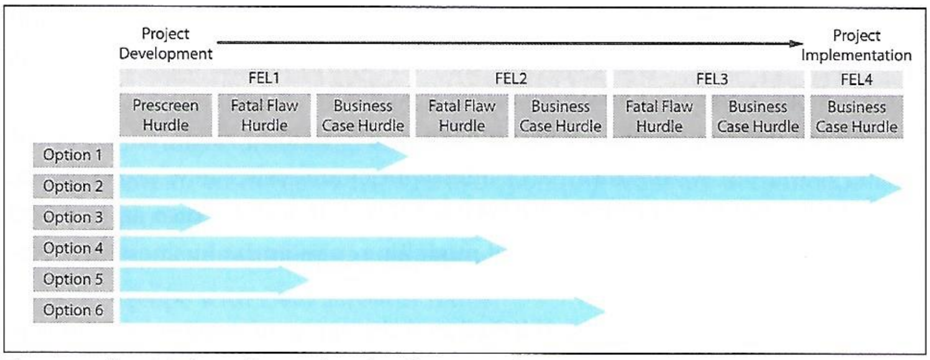

Figure 5-4. Front End Loading Option Identification and Analysis

option 3 in Figure 5-4) might fail a prescreen hurdle, a fatal-flaw hurdle, or a business case hurdle. A hurdle is a group of specific criteria for passing a gate.

FEL1 tasks primarily evaluate options, eliminate some options, then develop those that continue to meet the business case. One of the options that survive the business case hurdle is typically designated the base case for comparison purposes. In the scenario of Figure 5-4, options 1, 3, and 5 fail to survive various hurdles and are discarded, and three progress to FEL2 (one is the base case).

Many major projects span several years and are subject to staff turnover in the owner, engineering, and contractor teams. Therefore, it is critical during FEL1 and FEL2 to document in the PDB the analysis and rationale for eliminating options. To avoid costly rework, it is also prudent to document conditions under which options rejected now could become viable in the future.

Tools and methodologies applicable to FEL1 often rely on qualitative and quantitative decision-making. Early and judicious elimination of options allows budget reallocation (with owner consent) to be applied to improving the remaining options.

FEL2 – Prefeasibility Study

The objective of FEL2 is to select a single preferred option for FEL3 investigation, by option ranking and elimination supported by clear justification. This involves:

- evaluating options passing the FEL1 gate review;
- improving the level of understanding of the project and its implementation; and
- eliminating options that contain fatal flaws or fail to meet the owner's business needs.

Eliminated options should be reported in the phase deliverables, to signify a rigorous and transparent process. As in FEL1, elimination of options allows the rest of FEL2 to focus on improving definition for the remaining options and reducing the overall risk profile. In Figure 5-4, only one of the three options entering FEL2 (option 2) is carried forward to FEL3.

Decision-making in FEL2 is more quantitative than in FEL1, underpinned by field work, test work, third-party information, and other new project data. Data and models from FEL1 should be used to trend performance as new and better information develops. Financial modelling to re-assess business case viability begins in FEL2.

Once the site location is established and the range of required facilities is identified, work can begin on constructability, labour availability, and, when applicable, potential modularization studies. Permitting and local communication activities can also begin.

Designers of brownfield projects on an existing site, whether major upgrades or new system installations, face the additional challenge of assembling dependable site information. Drawings from the original project—seldom updated for field changes during construction, post-start-up modifications, and new systems additions—might not accurately reflect the current physical situation. Further, piping and electrical systems are prone to periodic undocumented changes and are the most labour-intensive to document. Field measurement and verification of critical dimensions, structural system integrity, and location of buried services are the only real remedy.

FEL3 – Feasibility Study

The FEL3 phase defines the plant and how it will be built. It focuses solely on project definition to substantiate an investment decision to build, and provides a robust baseline for managing and monitoring project implementation through FEL4. The schedule will be developed from the commissioning and start-up requirements, which can now be finalized.

FEL3 deliverables include:

- the complete project definition;
- the implementation plan; and
- control baselines for cost estimates, schedules, and scope.

Unlike FEL1 and FEL2, in which several concepts are established and examined, FEL3 tests the feasibility of a single option. This involves refining all design elements of the project, including equipment selection, procurement and contract packaging strategies, and construction methodologies, to develop the baseline definition. The emphasis is on project implementation planning, to generate sufficient information to justify continuation of the project (including financing), and to define baselines against which the project will be managed and controlled in FEL4.

It is expected that at the end of FEL3:

- field data collection and test work are complete;
- significant permits are in place (unexpected permit requirements can cause major delays and costs);
- all inputs from the owner's future operating team are accommodated;
- major constructability reviews are complete; and
- a single definition exists for the project in the updated PDB, covering
  - scope with clear physical limits,
  - facilities and services to be provided by third parties,
  - implementation method (including modularization, see Sections 11.5 and 11.9),
  - schedule, and
  - financial objectives within the project team's control.

During FEL3, a periodic review of the business case should be conducted to incorporate new data as they become available. The financial model is refined to keep in step. If adverse trends in the business case emerge, they must be analyzed at the earliest possible stage, so that alternative strategies can be developed. Such changes require strict application of change control protocols before implementation. However, there is often a cost-cutting pause for value engineering in the project as costs come into focus. Great care must be taken not to jeopardize safety, operability, or maintainability during these necessary and worthwhile initiatives.

Two other sets of activities might be necessary during FEL3 depending on the plant, location, or supplier market situation: two-stage procurement and prework development.

Two-stage procurement

Layouts around major equipment cannot be fixed until certified vendor drawings for the equipment are supplied, because calculations for nearby structures and foundations depend on that information. As fixed layouts are critical to good cost estimates, vendor drawings for major equipment are obtained as early as possible in FEL3. This is done by formally bidding the major equipment and specifically requesting a breakout price for the certified information (layouts, loads, utility requirements, etc). The vendor information can then be built into the design and cost estimate. Only when the project is released for FEL4 is the corresponding equipment ordered.

Prework development

During the FEL3 phase, before full project approval, ports, rail systems, power supplies, and camps might be needed, particularly at remote sites where infrastructure is limited or unavailable. For brownfield projects, demolitions and relocations might be required. Significant schedule savings might be achieved by starting this work early. However, spending capital prematurely presents a significant risk to the owner. In addition, complex licensing and permitting in many jurisdictions make it increasingly difficult to gain corporate approval for this approach.

Development of such prework is a calculated risk, based on the strength of the business case during FEL3 and acquiescence of the local permitting authorities. Hence, the need to develop infrastructure must be integrated into the schedule, with due consideration for the timing of overall project approval.

The decision to proceed to FEL4

By the end of FEL3, the project has been defined with great confidence. To manage and mitigate risks to this point, several key sets of activities and inputs were developed during FEL1, FEL2, and FEL3 (elaborated in subsequent chapters):

- new process or custom equipment development (*Chapter 6: Managing technology risk* and *Chapter 7: Custom designed equipment*);
- site selection and plant layout (*Chapter 4: Site selection* and *Chapter 10: Plant layout and logistics*); and
- sustainability, permitting, and safety (*Chapters 8* and *9*).

Sufficient information is available at the end of FEL3 that cost estimates qualify as Estimate Class 2 in the AACE International (2012) system. By their definition, the accuracy is –5 to –10% on the low side and +5 to +15% on the high side, after including an appropriate contingency (discussed in *Chapter 2*).

The major capital investment decision to start FEL4 is made only if the levels of risk and certainty of the outcome align with the owner's level of risk tolerance and investment criteria. This is the pivotal "go/no-go" decision for construction of the plant and delivery of the business case.

As engineering progresses in FEL4, design reviews should confirm that the design approaches, assumptions, quantities, and costs remain consistent with FEL3 baselines. Reviews facilitate early identification of issues and allow for mitigation with minimal risk.

It is important to note that a decision not to progress to the next phase of a project can be a good decision, provided it is based on sound analysis and an updated business case. Many unsuccessful projects have resulted from strong management pushing a weak business case.

FEL4 – Implementation

The objective of FEL4 is to build the plant to the definition and baselines defined in FEL3. The task of the project team is to manage the delivery of the roject according to the strategies documented in the implementation plan eveloped in FEL3. The project team monitors progress and changes against the aseline data developed in FEL3.

While it is appropriate in FEL4 to "aggressively resist change," change can nd will occur as new information and circumstances present themselves. The roject team and managers must proactively assess change requests with the wner and ensure the PDB remains current with the evolving, approved scope f the project.

.5 THE PROJECT WORK BREAKDOWN STRUCTURE

To determine that the "right project" is being studied, it is essential to define he complete project scope. A complex plant might contain multiple facilities over multiple locations (Figure 5-5). Complete scope definition implies that all project elements required for the plant to operate and produce a saleable product are uniquely identified. The scope must include potential bottlenecks, often outside the owner's operations and control, such as power supplies, construction labour capacity, and transportation links. This will ensure that complete project viability is evaluated.

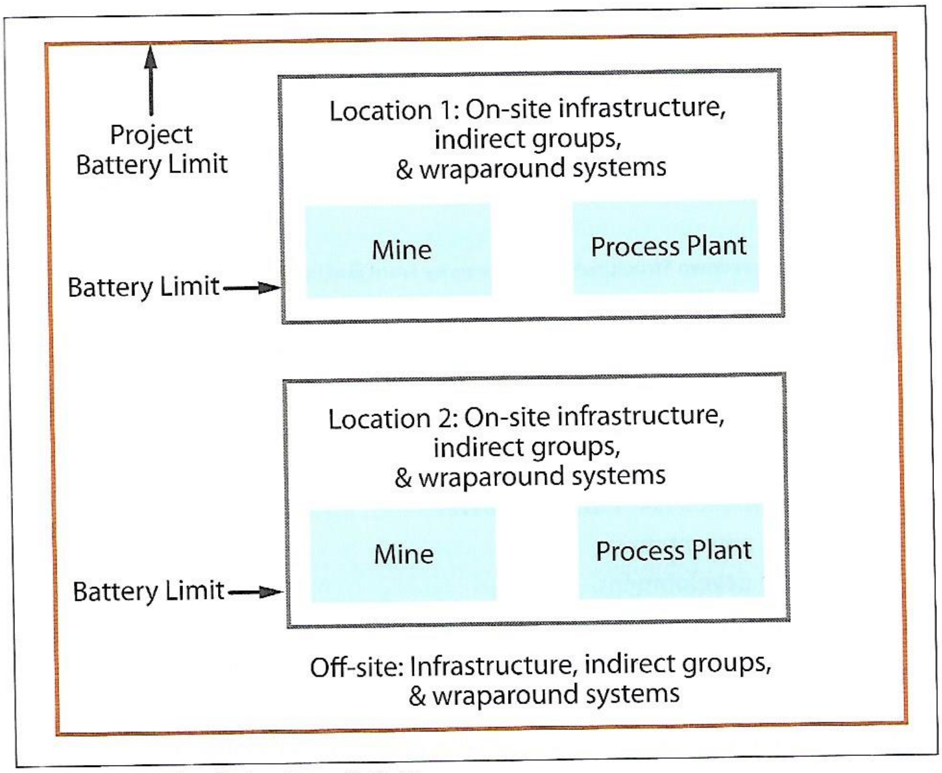

Figure 5-5. Complete Project Scope Definition

To rigorously define the physical asset, allocate costs, and prepare meaningful schedules, it is common to break the total plant down into areas, facilities, subfacilities, and systems. The work breakdown structure (WBS) defines this breakdown. The levels of definition required by each project phase are shown in Figure 5-6. Development of the WBS should encompass the complete (on-site and off-site) project scope to a set of battery limits defined within the PDB.

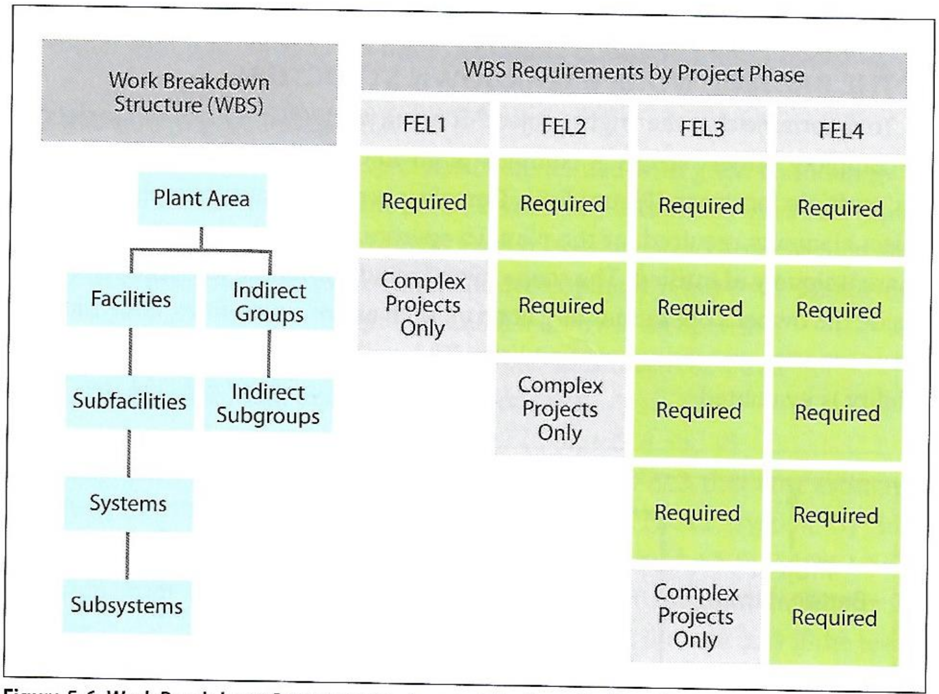

Figure 5-6. Work Breakdown Structure Requirements by Front End Loading Phase

The WBS should be refined at the beginning of each phase. However, it is important that the WBS reflects the construction strategy and packaging, so that progress in the field can be directly linked to the cost-estimate elements. Ideally the WBS developed in early phases is carried through to later phases and expanded as required. The WBS also drives

- estimate presentation,
- schedule development,
- equipment tagging (identifying or labelling every piece of equipment),
- line numbering (identifying or labelling every piece of cable, pipe, etc.), and
- drawing numbering (identifying or labelling every drawing).

The WBS should represent all elements of the plant. On-site and off-site elements include:

- processing facilities;
- infrastructure;
- wraparounds (i.e., other supporting physical elements of the total project); and
- indirect elements (e.g., temporary facilities and construction facilities).

Depending on corporate practices, the WBS can also tie in project activities and physical elements. These could include engineering, construction management, project management, operator training, vendor support during commissioning, and other service costs associated with the project. The WBS can also be structured to form a basis for the asset register of the constructed facility.

5.6 CONCLUSIONS

The current chapter described a framework for orderly project development in well-defined phases. The endpoint of FEL3 is documentation that can support a decision to proceed to implementing a permitted and fully defined facility.

However, the framework must accommodate—as appropriate—new processes, custom equipment development, safety constraints, sustainability criteria, and personnel turnover, as well as changes in regulations and markets. Therefore, the framework must be robust and flexible, so that the management processes can keep the PDB document up to date, project teams are fully informed, and the project can proceed to FEL4 with confidence.

5.7 ACKNOWLEDGMENTS

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5.8 REFERENCES

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