



Construction
Industry
Institute

Planning for Startup

includes
**Startup
Planning
Model**

- Requirements Definition & Technology Transfer
- Conceptual Development & Feasibility
- Front-End Engineering
- Detailed Design
- Procurement
- Construction
- Checkout & Commissioning
- Initial Operations

**Implementation
Resource**

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Planning for Startup

Prepared by

Construction Industry Institute

Planning for Startup Research Team

Implementation Resource 121-2

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Contents

<i><u>Chapter</u></i>	<i><u>Page</u></i>
Introduction	1
Phase 1: Requirements Definition and Technology Transfer	15
Phase 2: Conceptual Development and Feasibility	21
Phase 3: Front-End Engineering	31
Phase 4: Detailed Design	81
Phase 5: Procurement	121
Phase 6: Construction	125
Phase 7: Checkout and Commissioning	133
Phase 8: Initial Operations	143
Implementation Case Study	147
Appendix A: Glossary of Terms	153
Appendix B: References	157

Introduction

The importance of startup planning is evident given the challenging characteristics of today's industrial business environment:

- pressures to increase profits by reducing costs
- reduction in owner project staff and increases in outsourcing of services
- demand for shorter project cycle times
- lack of planning capabilities and supportive tools.

These business challenges demand increases in organizational efficiency and management effectiveness. As a result, planning and training tools are in high demand.

Definition of Startup

Plant startup is defined as the transitional phase between plant construction completion and commercial operations, including all of the activities that bridge these two phases. Critical steps within the startup phase include system turnover, check-out of systems, commissioning of systems, introduction of feedstocks, and performance testing.

Project Success, Startup Success, and Planning for Startup

Project management and the perception of project success must be aligned with a new paradigm: *mechanical completion is not the project objective; successful commercial operations is*. Successful commercial operation requires a successful startup. The message is evident — *if you want a successful project, you must plan for a successful startup*.

Further analysis of startups indicates that there is a reasonably strong correlation between startup success and extent of startup planning. The message is again clear: *effective startup planning requires that the right issues be addressed by the right people at the right time*.

The Startup Planning Model

Startup is a critical phase in the plant life-cycle and must be given adequate attention. The purpose of the Startup Planning Model (pages 5–8) is to help industry plan startups in a more thorough, effective, and efficient manner. The model is not intended to be a project management primer; rather, the activities in the Startup Planning Model should be supplemented with effective, basic project management practices.

The Planning for Startup Model is a sequence of 45 planning activities organized according to eight typical project phases (see Table 1.1). The model is presented in a flow chart that illustrates the interrelationships between the startup planning activities. Each planning activity is detailed in a one-page *activity profile* that presents nine fields of descriptive information.

Table 1.1. Startup Planning Model Phases and Activities

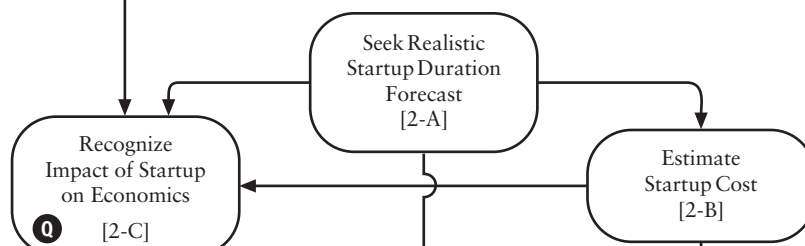
Project Phase	No. of Startup Planning Activities
Requirements Definition and Technology Transfer	1
Conceptual Development and Feasibility	3
Front-End Engineering	10
Detailed Design	15
Procurement	3
Construction	7
Checkout & Commissioning	3
Initial Operations	3

The 45 planning activities are complemented with 26 tools, each appropriately itemized on the activity profiles under the heading “Tools Needed/Provided.” These tools are intended to facilitate the implementation of the particular startup planning activity.

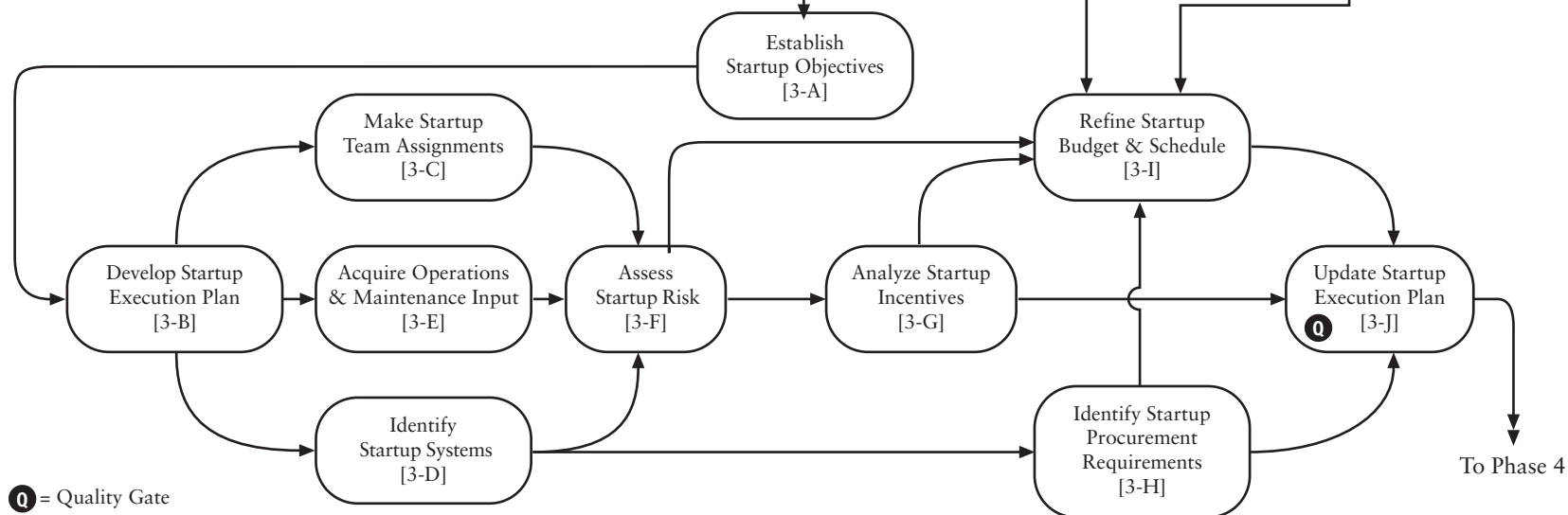
Phase 1 - Requirements Definition & Technology Transfer

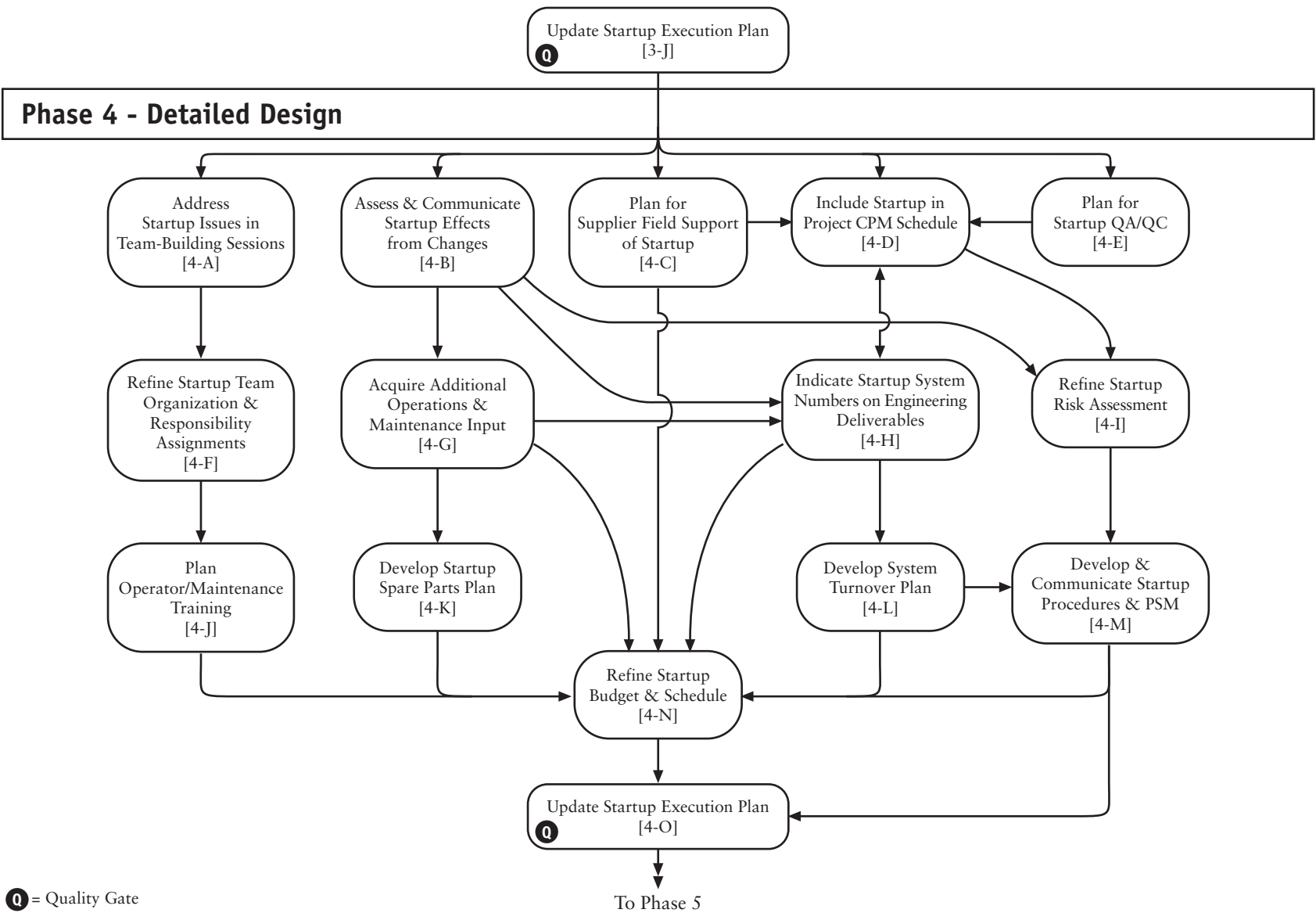


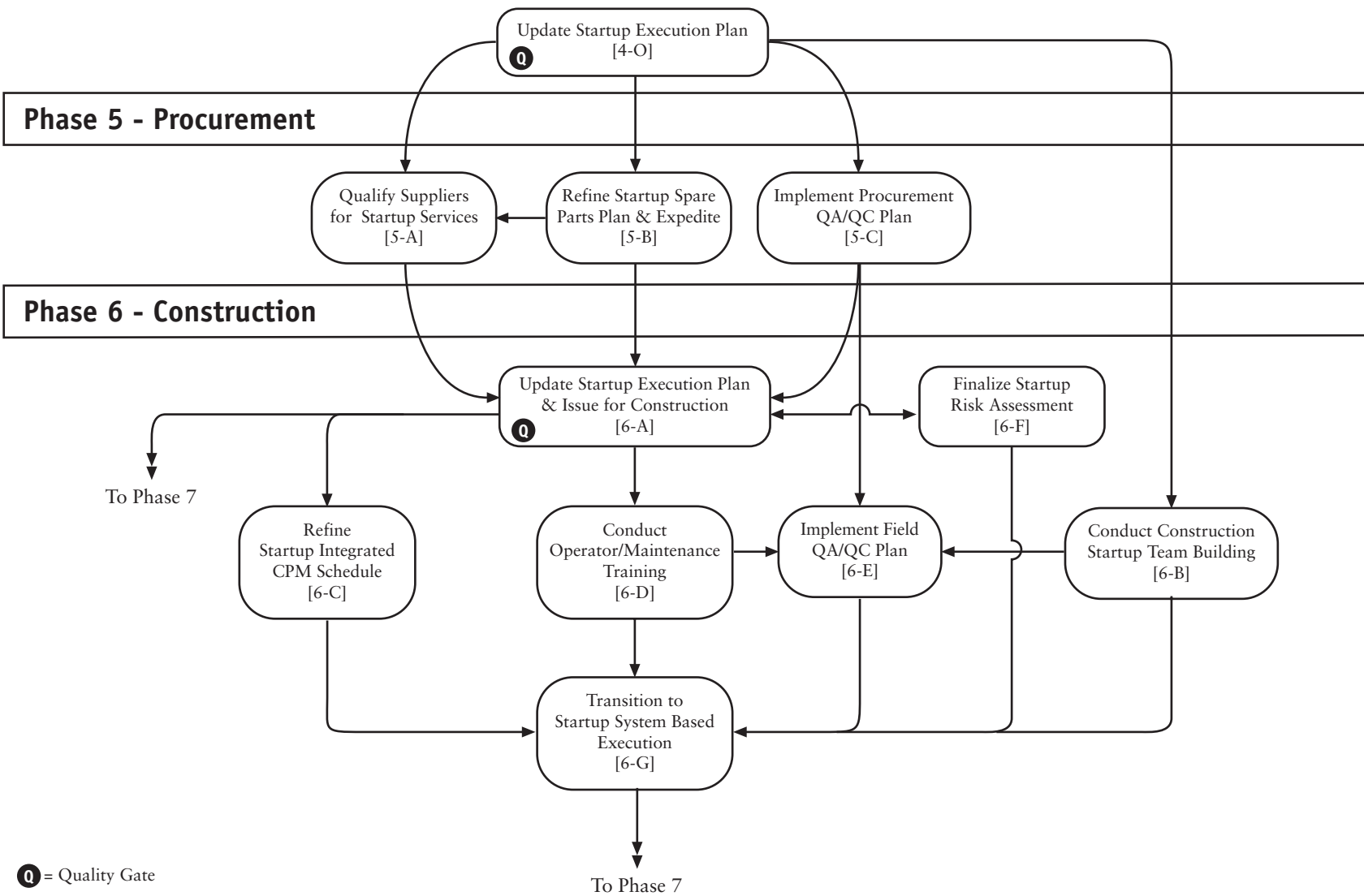
Phase 2 - Conceptual Development & Feasibility

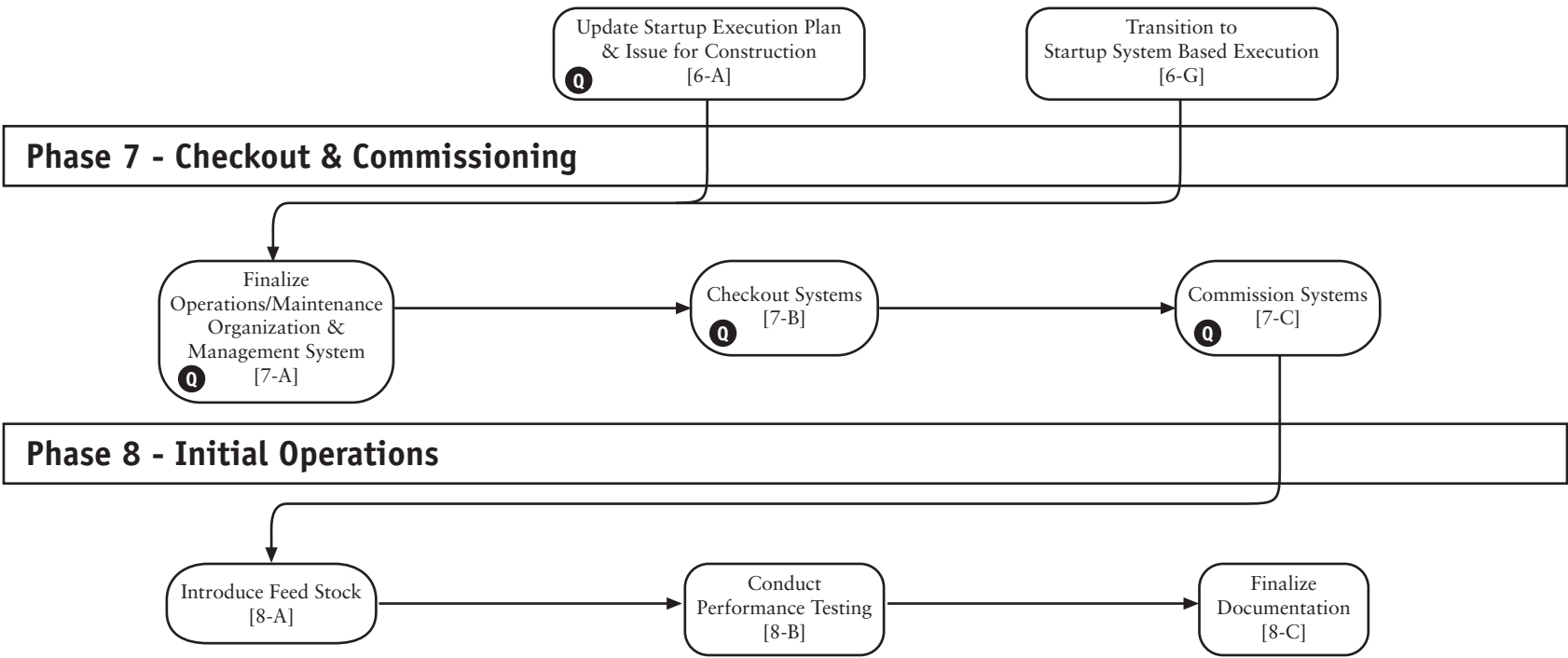


Phase 3 - Front-End Engineering









Q = Quality Gate

Startup Planning Priorities

Properly and thoroughly implemented, all 45 startup activities contained in the Startup Planning Model will significantly increase the predictability of startup success. However, some of the planning activities are more important than others. The Startup Planning Model includes eight activities that are particularly important. These are designated as “Quality Gates” or checkpoints for assessing the thoroughness of startup planning. These Quality Gates include the following activities:

Table 1.2. Startup Planning Quality Gates

Title
Recognize the impact of startup on project economics
Update the Startup Execution Plan
Finalize the Operations & Maintenance organization and management systems
Check-out systems
Commission systems
Finalize documentation

The Startup Planning Model should be viewed as a flexible collection of best practices to be customized to suit the needs of the user. Users will want to customize the model to reflect unique organizational structures and terminology and to integrate with other project approaches and procedures.

Responsibility and Accountability for Planning

Startup success requires a team approach with active planning participation of all project stakeholders. Accordingly, the Planning for Startup Model is targeted to a wide variety of audiences. Messages are

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targeted to manufacturing business unit management, plant operations and maintenance management, owner project management, and contractor project management:

Common Messages for All Audiences:

- Project success is highly sensitive to the level of startup success.
- Startup success is driven by the degree or extent of planning for startup.
- Startup success requires a commitment to startup planning by all three management entities: business unit, plant operations, and owner project management.

Manufacturing Business Unit Management:

- The manager of the business unit must take the lead in defining startup objectives.

Plant Operations & Maintenance Management:

- Plant operations and maintenance personnel are responsible for many important startup planning activities in front-end engineering and detailed design phases.

Owner Project Management:

- The owner's project manager is the overseer of the startup planning process and is fundamentally accountable for startup planning and success.

Barriers to Successful Startup Planning

Startup planning is not easy and has many barriers. Overall, 140 barriers to the 45 activities have been identified. These barriers can be grouped by common themes:

- Ineffective communication
- Schedule pressures
- Lack of personnel, information, or other resources
- Denial of potential problems
- Planning efforts being applied too late

Challenges (or barriers) to startup planning activities in the early phases of projects are dominated by denial of potential problems and lack of information or other resources. Challenges (or barriers) to startup planning activities during detailed design are dominated by communication problems. Everyone involved in startup planning should be aware of the challenges and barriers to effective planning, and those who are either accountable or responsible for the planning activities should make special efforts to confront these challenges to minimize their impact to the project. All challenges must be treated in a deliberate and focused manner, or the impacts can be substantial.

Overview of Tools

The Startup Planning Model is supported with a total of 26 tools. As shown in Table 1.3, many of the 26 tools support startup planning activities in either the front-end engineering or detailed design phases, which are critical opportunities for startup planning.

Table 1.3. Startup Planning Tools by Phase

Project Phase	No. of Tools
1: Requirements Definition & Technology Transfer	2
2: Conceptual Development & Feasibility	3
3: Front-End Engineering	12
4: Detailed Design	8
5: Procurement	0
6: Construction	0
7: Checkout & Commissioning	1
8: Initial Operations	0

While all 26 tools (listed in Table 1.4) are important and can facilitate startup planning in some beneficial way, arguably, two tools stand out as most important and can be used to *substantially* improve the quality of startup planning. These two tools are the SuPER tool (Tool 1-A-2) for evaluating the degree of startup planning, and the Startup Execution Plan (Tool 3-B-2), a mechanism for integrating all startup planning developments.

The SuPER Tool

Effective startup planning requires a thorough, well-planned, and monitored approach. In order to accomplish this, the Startup Planning Evaluation Rating (SuPER) Tool was developed to enable the tracking and monitoring of startup planning efforts. The concept is simple. At any point in the project execution process, startup planners should collectively assess the current level of startup planning and compare that level with the targeted planning level (also provided in Tool 1-A-2). In this way, managers can easily assess the level of startup planning and identify planning deficiencies.

Table 1.4. Startup Planning Tools

Tool #	Tool Name
1-A-1	Plot of Startup Planning vs. Startup Success
1-A-2	Startup Planning Assessment Tool
2-A	Integration of Startup Planning into Conceptual Project Schedule
2-B	Example of Startup Cost Estimating Sheet
2-C	Financial Risk Assessment Checklist
3-A	Checklist of Typical Startup Objectives
3-B-1	Transition from Construction to Operations
3-B-2	Sample Table of Contents for the Startup Execution Plan
3-B-3	Checklist of Startup Quality Gates
3-C-1	Sample Organization Chart
3-C-2	Sample RACI Chart
3-D	Guidelines for Defining Startup Systems
3-E-1	P&ID Flowchart
3-E-2	P&ID Checklist of Information Elements
3-F	Startup Risk Checklist
3-H	Common Startup Needs Supported by Suppliers
3-I	Checklist of Typical Startup Activities
4-B	Checklist of Change Impacts on Startup
4-E	Common Needs for Pre-Shipment Testing
4-H	Example of Startup System Coding System
4-J-1	Example of Table of Contents of an Operator Training Plan
4-J-2	Example of Table of Contents of an Operator Manual
4-K	Example of Table of Contents of a Spare Parts Plan
4-L-1	Example of System Turnover Plan Table of Contents
4-L-2	Examples of Turnover Criteria Checklists and Certifications
7-B	Checkout and Commissioning Checklist

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The numerical rating scheme can serve as a useful and informative incentive for further startup planning. These weightings incorporated into the SuPER tool are based on an analysis of actual project startups and the respective degrees of planning found in both successful and unsuccessful startups. In addition, the SuPER tool has been demonstrated on an actual industry project and found to be very useful in monitoring the overall startup planning process.

How do SuPER scores correlate to startup success indices? To conduct this analysis, final SuPER scores for 20 actual startups were estimated and analyzed with associated startup success indices. The regression analysis indicates a strong relationship between planning and startup success and serves to further validate the startup planning model, and in particular, the SuPER tool.

Startup Execution Plan

A Startup Execution Plan should be developed and treated on every project as the document with which to integrate all startup planning activities. Beyond the guidance contained in activity profile 3-B, the development of the Startup Execution Plan is facilitated with three tools contained in the startup planning model:

- Tool 3-B-1: Schedule Drivers and Phase Transitions: a reminder that planning must recognize the work packaging paradigms unique to the various project phases and the associated transitions between each.
- Tool 3-B-2: Sample Table of Contents for the Startup Execution Plan: guidance on the types of information that should be addressed in the execution plan.
- Tool 3-B-3: Checklist of Startup Quality Gates: guidance on the Quality Gate concept and how to exploit it for the benefit of startup planning.

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Similarities with Constructability

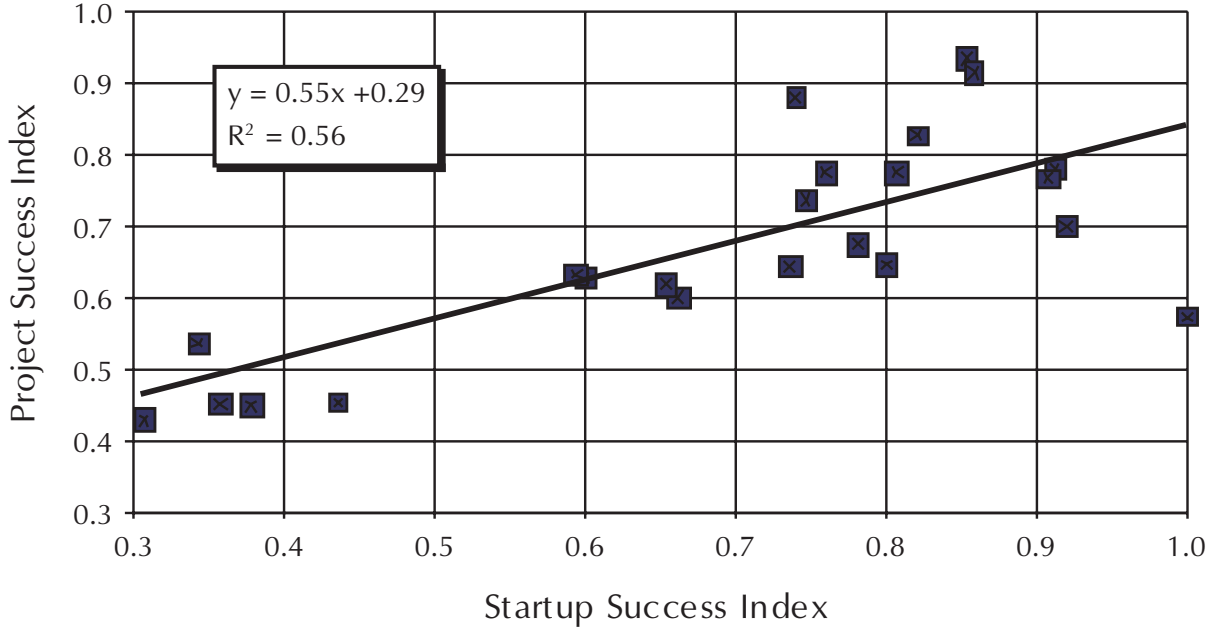
The Planning for Startup Model bears a close resemblance to CII's Constructability best practices in several ways:

- Up-front planning is required for optimal down-stream execution.
- Planning must be viewed as a front-end investment with a corresponding down-stream payoff.
- Planning is an integrative activity, requiring the pulling together of the knowledge, skills, and talents of many project participants.

1-A: Ensure Senior Management Commitment to Integrated Startup Planning and Needed Resources

-
- A. **Phase:** Requirements Definition and Technology Transfer
- B. **Key Concepts:** Business unit management and key project leaders must be equally committed to the development of a startup plan as a key element of an integrated overall Project Execution Plan. Operations management must be convinced to provide startup resources throughout the project planning process.
- C. **Deliverables:** A document that clearly identifies project goals, major risks, and key responsibilities. Key startup expertise should be identified, especially experienced operations personnel, to interface early-on and throughout critical project phases.
- D. **Motive/Rationale:** Adequate support and early input from operations is crucial to startup success, along with mutual understanding of project-specific startup needs and risks.
- E. **Responsibility:** Business Unit Manager or delegate
Accountability: Business Unit Manager or delegate
Consult: Owner Project Manager, Plant Manager
Inform: Planner/scheduler
- F. **Quality Gate/Sequencing Constraints:** This is not a quality gate. However, senior plant management commitment to startup must exist before effective startup planning can occur.
- G. **Basic Steps:** Understand the project business plan and the technology transfer aspect; identify all key owner manufacturing representatives; understand the criticality of the project schedule; and understand the order-of-magnitude of planning efforts required for a successful startup.
- H. **Tools Needed/Provided:**
- Provided: graphical plot of project success vs. startup success; SuPER tool for periodic evaluation of startup planning efforts
- Needed: tools for assessing and ensuring management commitment to needed startup resources
- I. **Challenges to Successful Implementation:**
- Limited manufacturing resources available at this phase
 - Current paradigms on planning and manning for startup

Tool 1-A-1. Project Success vs. Startup Success (n=23)



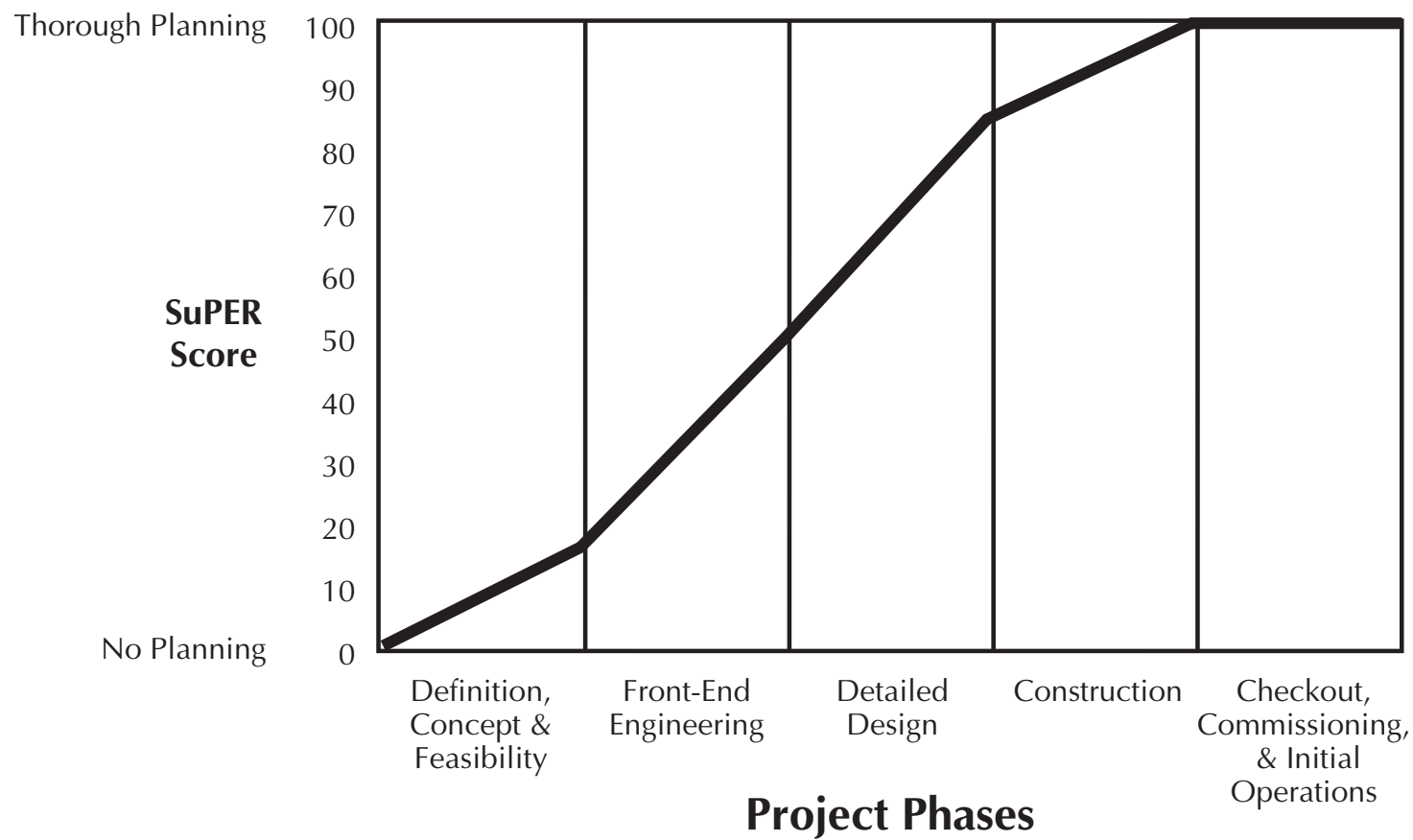
Tool 1-A-2: The SuPERTOOL: Startup Planning Evaluation Rating *vers. 3.0* (Sheet 1 of 2)

		Project:				Date:	
		Evaluator:					
Act. No.	Planning Activity	No Execution	Minimal Effort	With Deficiencies	With Minor Deficiencies	Thoroughly Executed	Score
1-A	Ensure senior management commitment to SU planning	0	1	3	4	5	_____
2-A	Seek a realistic forecast of startup duration	0	1	1	3	4	_____
2-B	Estimate startup costs	0	0	1	1	1	_____
2-C	Recognize the impact of startup on project economics	0	1	3	4	5	_____
Definition, Concept, & Feasibility Phase Total		0	3	8	12	15	
3-A	Establish startup objectives	0	1	2	4	5	_____
3-B	Develop the Startup Execution Plan	0	1	3	4	5	_____
3-C	Make the startup team assignments	0	0	1	2	3	_____
3-D	Identify startup systems	0	1	3	4	5	_____
3-E	Acquire Operations & Maintenance input	0	1	1	3	4	_____
3-F	Assess startup risks	0	1	1	2	2	_____
3-G	Analyze startup incentives	0	0	1	1	1	_____
3-H	Identify startup procurement requirements	0	1	1	2	2	_____
3-I 4-N	Refine/update the startup budget & schedule	0	0	1	1	1	_____
3-J 4-O 6-A	Update the Startup Execution Plan	0	1	3	4	5	_____
Front End Engineering Phase Total		0	7	17	27	33	
						Total This Sheet:	

Tool 1-A-2: The SuPERTOOL: Startup Planning Evaluation Rating *vers. 3.0* (Sheet 2 of 2)

		Project:				Date:	
		Evaluator:					
Act. No.	Planning Activity	No Execution	Minimal Effort	With Deficiencies	With Minor Deficiencies	Thoroughly Executed	Score
4-A	Address startup issues in team building sessions	0	0	1	1	1	_____
4-B	Assess & communicate startup effects from changes	0	0	1	1	1	_____
4-C	Plan for supplier field support of startup	0	0	1	1	2	_____
4-D	Include startup in the project CPM schedule	0	1	2	3	4	_____
4-E	Plan for startup QA/QC	0	0	1	1	1	_____
4-F	Refine startup team organiz'n & respons'b'ty assignm'ts	0	1	1	3	4	_____
4-G	Acquire additional O&M input	0	1	1	2	3	_____
4-H	Indicate startup system numbers on engr. deliverables	0	1	1	2	3	_____
4-I 6-F	Refine/update startup risk assessment	0	1	1	1	2	_____
4-J	Plan operator/maintenance training	0	1	2	3	4	_____
4-K	Develop startup spare parts plan	0	0	1	1	1	_____
4-L	Develop system turnover plan	0	1	1	3	4	_____
4-M	Develop & communicate startup procedures & PSM	0	1	1	3	4	_____
5-A	Qualify suppliers for startup services	0	0	1	1	1	_____
5-B	Refine/update startup spare parts plan & expedite	0	0	1	1	1	_____
5-C	Implement procurement QA/QC plan	0	0	1	1	1	_____
Detailed Design & Procurement Phase Total		0	8	18	28	37	
6-B	Conduct Construction-Startup team building	0	0	1	1	1	_____
6-C	Refine/update startup integrated CPM schedule	0	1	2	3	4	_____
6-D	Conduct operator/maintenance training	0	1	1	3	4	_____
6-E	Implement field QA/QC plan	0	0	1	1	1	_____
6-G	Transition to startup systems-based execution	0	1	2	4	5	_____
Construction Phase Total		0	3	7	12	15	_____
Maximum Total: All Phases		0	21	50	79	100	_____
Total This Sheet:							
Total Sheet 1:							
GRAND TOTAL:							

Tool 1-A-2. SuPER Score Target Profile



2-A: Seek a Realistic Forecast of Startup Duration

-
- A. **Phase:** Concept Development and Feasibility
 - B. **Key Concepts:** An appropriate duration for startup activities must be included in the project plan at this point.
 - C. **Deliverables:** Integrated project milestone schedule showing startup duration.
 - D. **Motive/Rationale:** Since startup duration forecasts are usually treated as commitments, they should be carefully established and adequately reflected in the overall project schedule.
 - E. **Responsibility:** Construction Project Manager, Startup Manager, Planner/Scheduler
Accountability: Owner Project Manager
Consult: Manufacturing Operations Representative, Construction Manager
Inform: Plant Manager
 - F. **Quality Gate/Sequencing Constraints:** Not a quality gate
 - G. **Basic Steps:**
 - 1. In estimating the startup duration, consider the following:
 - Business and marketing plan; technology transfer package.
 - Historical basis (have similar projects been completed that can provide insight to startup durations for this project?).
 - Type of process (is the process batch, continuous, other).
 - Size and complexity of unit to be started.
 - Number of startup systems and number of pieces of equipment.
 - Availability of check-out and startup personnel.
 - Extent of effort in qualification and validation activities.
 - Seasonal impacts, including special curing/drying requirements.
 - Risk assessment.
 - Pretreatment (i.e., catalyst).
 - Environmental constraints during startup (how long not in compliance?).
 - 2. After taking these issues into consideration, the planner should determine whether or not to include any contingency in the estimated duration.
 - H. **Tools Needed/Provided:**
Needed: corporate database of historical durations
 - I. **Challenges to Successful Implementation:**
 - Startup durations are often under-estimated, and occasionally overlooked altogether.

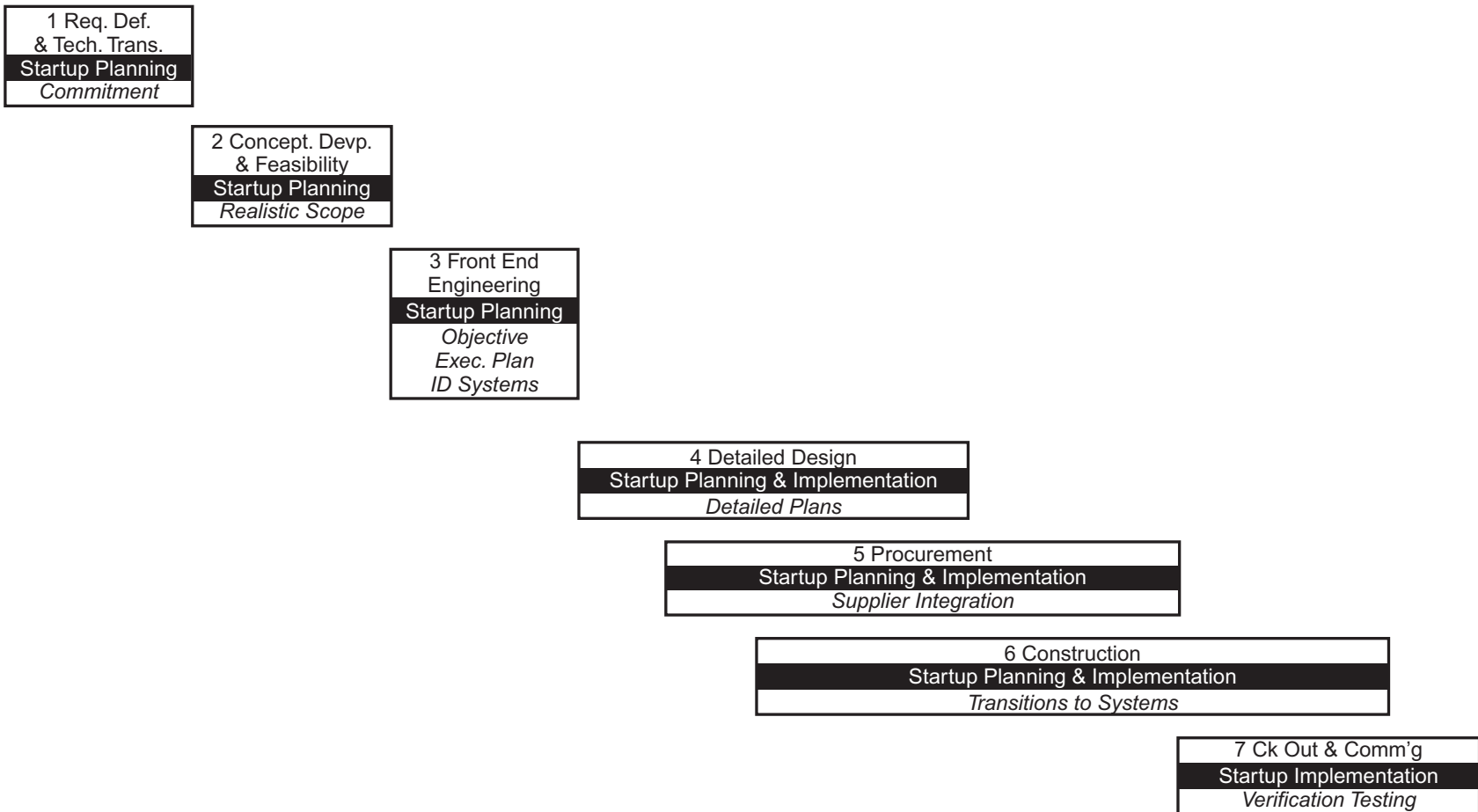
2-B: Estimate Startup Costs

-
- A. **Phase:** Concept Development and Feasibility
 - B. **Key Concepts:** Seek to recognize all startup expenses that will be incurred.
 - C. **Deliverables:** Order of magnitude cost estimate for startup activities
 - D. **Motive/Rationale:** This step will help ensure that overall project budgets contain an adequate allowance for startup prior to appropriation approval. This estimate can also serve as input to analyzing startup impact on overall project economics.
 - E. **Responsibility:** Startup Manager, Planner/Scheduler, Estimator
Accountability: Owner Project Manager
Consult: Manufacturing Operations Representative
Inform: Plant Manager
 - F. **Quality Gate/Sequencing Constraints:** Not a quality gate
 - G. **Basic Steps:**
 - 1. Ensure that the best possible basis documentation is used.
 - 2. Consider or include the following in the startup cost estimate:
 - A well-defined basis for beginning and ending points, such that meaningful cost estimates can be included for startup operations.
 - Pre-startup costs for startup planning and training.
 - Factors such as work-hours, raw material, and auxiliary material.
 - Agreed-upon endpoint for raw material charges (usually when quality and salable product is being made).
 - An agreed-upon endpoint for work-hour charges.
 - Capitalization vs. expensing of startup costs (policies vary).
 - Manner of charging for punch list items and minor plant modifications (e.g., charged to either construction or startup).
 - Adequate contingency for unknowns.
 - 3. Ensure compatibility between startup cost estimate and planned duration.
 - H. **Tools Needed/Provided:**
Provided: example of startup cost estimate sheet
Needed: historical database of startup costs by project type and size
 - I. **Challenges to Successful Implementation:**
 - Uncertain basis information (e.g., PFDs and P&IDs)
 - Little credible historical data
 - Variable accounting practices for tracking these costs
 - Present paradigm: this activity is rarely done this early, if at all

2-C: Recognize the Impact of Startup on Project Economics

-
- A. **Phase:** Concept Development and Feasibility
 - B. **Key Concepts:** Company senior management must recognize that startup can have a major impact on project duration, overall project costs, and overall project economics.
 - C. **Deliverables:** Detailed statement pertaining to an estimate of potential financial risk associated with a delayed or unsuccessful startup.
 - D. **Motive/Rationale:** Early on-line plant operation generates revenue sooner, reduces interest expense, and reduces startup expense. Overly optimistic estimates of project payback can cloud a realistic sense of financial risk.
 - E. **Responsibility:** Manufacturing Operations Representative, Contractor Project Manager, Startup Manager
Accountability: Owner Project Manager
Consult: Planner/Scheduler, Estimator
Inform: Plant Manager
 - F. **Quality Gate/Sequencing Constraints:** This activity should be treated as a quality gate.
 - G. **Basic Steps:**
 1. The startup team must be proficient with the chosen technology in order to successfully deal with the emerging problems associated with starting up new technology.
 2. Project venture objectives must be clearly understood for optimal project and startup planning so that venture economics can be realized.
 3. Conduct an economic analysis of startup costs versus early/on-time/late product delivery. In conducting sensitivity analyses of “what-if” scenarios, take the following questions into consideration: Is the product in short supply? How much product can be sold in the first year? What are the lost profits for each day the plant is not on-stream with salable product? What is the capital versus profit trade-off? Should extra capital be expended to ensure on-time product with adequate quality? Has the project team focused on optimizing engineering, construction, and startup in a global sense vs. suboptimization?
 4. This evaluation must be repeated during each of the pre-startup phases.
 - H. **Tools Needed/Provided:**
 Provided: financial risk assessment checklist
 Needed: video: “Trip to Abilene”
 - I. **Challenges to Successful Implementation:**
 - Such “reality checks” are usually politically sensitive and difficult to accept.

Tool 2-A: Integration of Startup Planning into Conceptual Project Schedule



Tool 2-B: Example of Startup Cost Breakdown Structure (page 1 of 4)

Item #	Item	Planning effort (Work -ours)	Implementation effort (Work -urs)	Material Cost	Services Contract Cost
1	Requirements Definition & Technology Transfer Engineering efforts Phase Subtotal				
2	Conceptual Development & Feasibility Engineering efforts				
3	Manufacturing/Operations efforts				
4	Maintenance efforts				
5	Outside services: labs, consultants, certifications Phase Subtotal				
6	Front-End Engineering Engineering efforts				
7	Manufacturing/Operations efforts				
8	Maintenance efforts				
9	Outside services: labs, consultants, certifications Phase Subtotal				

Tool 2-B: Example of Startup Cost Breakdown Structure (page 2 of 4)

Item #	Item	Planning effort (Work-Hours)	Implementation effort (Work-Hours)	Material Cost	Services Contract Cost
	Detailed Design				
11	Manufacturing/Operations efforts				
12	Maintenance efforts				
13	Outside services: labs, consultants, certifications				
14	Training program development				
	Phase Subtotal				
	Procurement				
15	Engineering efforts				
16	Construction efforts				
17	Manufacturing/Operations efforts				
18	Maintenance efforts				
19	Outside services: suppliers, labs, consultants, certifications				
20	Training program development				
21	Materials & equipment expense				
22	Utilities				
23	Feedstock, catalyst, raw material, product handling				
	Phase Subtotal				

Tool 2-B: Example of Startup Cost Breakdown Structure (page 3 of 4)

Item #	Item	Planning effort (Work-Hours)	Implementation effort (Work-Hours)	Material Cost	Services Contract Cost
24	Construction				
25	Engineering efforts				
26	Construction efforts				
27	Manufacturing/Operations efforts				
28	Maintenance efforts				
29	Outside services: suppliers, labs, consultants, certifications				
30	Training program development and implementation				
31	Materials & equipment expense				
31	Utilities				
	Phase Subtotal				
32	Check-out & Commissioning				
33	Engineering efforts				
34	Construction efforts				
35	Manufacturing/Operations efforts				
36	Maintenance efforts				
37	Outside services: suppliers, labs, consultants, certifications				
37	Training program				

Tool 2-B: Example of Startup Cost Breakdown Structure (page 4 of 4)

Item #	Item	Planning effort (Work-Hours)	Implementation effort (Work-Hours)	Material Cost	Services Contract Cost
	Check-out & Commissioning (continued)				
38	Material & equipment expense				
39	Utilities				
40	Feedstock, catalyst, raw material, product handling				
	Phase Subtotal				
	Initial Operations				
41	Engineering efforts				
42	Construction efforts				
43	Manufacturing/Operations efforts				
44	Maintenance efforts				
45	Outside services: suppliers, labs, consultants, certifications				
46	Material & equipment expense				
47	Utilities				
48	Feedstock, catalyst, raw material, product handling				
	Phase Subtotal				

Tool 2-C: Startup Financial Risk Assessment Checklist (page 1 of 2)

#	Risk Issues	Risk Assessment				Not Applicable	Comments
		Low	Med.	High	Uncertain		
A	Organizational Experience						
	Owner/Contractor Startup Mgr.						
	Owner/Contractor Startup Team						
	Owner/Licensors Pilot Plant Team						
	Key Supplier(s)						
	Other:						
B	Process Technology						
	Degree of Definition						
	New or Proven						
	Complexity						
	Pilot Plant Experience						
	Automation & Controls Experience						
	Equipment/System Redundancies						
	Other:						
C	Market for Product						
	Market Window						
	Demand Level						
	Break-Even Production Level						
	Sales Price Elasticity (Competition)						
	Market Form Acceptance						
	Market Share (Loss or Gain)						
	Magnitude of Profit Loss if Late						
	Other:						

Note: This checklist is not all-inclusive, but is intended primarily to stimulate discussion.

Tool 2-C: Startup Financial Risk Assessment Checklist (page 2 of 2)

#	Risk Issues	Risk Assessment				Not Applicable	Comments
		Low	Med.	High	Uncertain		
D	Schedule Issues						
	Level of Project Scope Definition						
	Realistic Milestone Dates						
	Status of Long Lead Procurement						
	Permitting Delay Impacts						
	Effect of Incentives						
	Level of Liquidated Damages						
	Labor Probs./Coll. Bargaining Agreement						
	Other:						
E	Funding Issues						
	Realistic Budget						
	Realistic Contingency & Eff. Mgmt.						
	Expected Labor Productivity						
	Other:						
F	Existing Plant/Site						
	Adequacy of Utilities						
	Accessibility/Congestion						
	Impact to Ongoing Operations						
	Other:						
G	Miscellaneous						
	Handling of Hazardous Material						
	Off-Spec Product Disposal						
	Quality of Startup Planning						
	Inherent Safety Hazards						
	Other:						

Note: This checklist is not all-inclusive, but is intended primarily to stimulate discussion.

3-A: Establish Startup Objectives

-
- A. **Phase:** Front-End Engineering
 - B. **Key Concepts:** Startup success requires that startup objectives be thoroughly defined and communicated. Alignment of startup objectives between business unit, plant operations, and project management must be sought and periodically monitored.
 - C. **Deliverables:** Listing of specific and measurable startup objectives
 - D. **Motive/Rationale:** In order to achieve startup success, it must be defined specifically for each project.
 - E. **Responsibility:** Business Unit Manager, Owner Project Manager, Plant Manager
Accountability: Business Unit Manager
Consult: Contractor Project Manager
Inform: Manufacturing Operations Representative, Planner/Scheduler
 - F. **Quality Gate/Sequencing Constraints:** This activity is not a quality gate.
 - G. **Basic Steps:**
 1. Assign the role of Startup Manager.
 2. Assemble key personnel responsible for formulating startup objectives.
 3. Propose, discuss, and evaluate startup objectives.
 4. Thoroughly define startup objectives and establish associated priorities.
 5. Document and communicate startup objectives throughout the project team.
 - H. **Tools Needed/Provided:**
 Provided: listing of typical startup objectives.
 - I. **Challenges to Successful Implementation:**
 - Lack of understanding of startup objectives and their importance on the part of the business unit.
 - Misalignment of startup objectives between project management and business unit personnel.

3-B: Develop the Startup Execution Plan

-
- A. **Phase:** Front-End Engineering
 - B. **Key Concepts:** The Startup Execution Plan must be a part of the overall Project Execution Plan. It should be formally and thoroughly developed.
 - C. **Deliverables:** A first issue of the Startup Execution Plan that addresses all important aspects of startup.
 - D. **Motive/Rationale:** The Startup Execution Plan provides a framework for systematic integrated planning necessary to ensure successful implementation.
 - E. **Responsibility:** Manufacturing Operations Representative, Startup Manufacturing Operations Representative, Project Team
Accountability: Owner Project Manager
Consult: Contractor Project Manager, Planner/Scheduler
Inform: Plant Manager
 - F. **Quality Gate/Sequencing Constraints:** This activity is not a quality gate, but should occur early in Front-End Engineering.
 - G. **Basic Steps:**
 - 1. Gather key contributors to the Startup Execution Plan and discuss contents and drafting responsibilities. The Startup Plan should include a detailed listing of all startup objectives (see activity 3-A). The Startup Plan should establish the criteria for the following: startup philosophy; commitment to startup quality gates; identification of startup systems on engineering documents; identification of needed resources for startup execution and operations; startup responsibilities (including those of suppliers and operators); conceptual schedule, addressing processes, areas, utilities, etc.; operator training needs; startup raw material needs; identification of startup risks; plans for check-out/commissioning and initial operations. Considerations in developing the startup philosophy include product priorities, schedule phases and sequencing, production ramp-up curve, and integration with shutdowns, along with other schedule “drivers.”
 - 2. Draft the respective parts or components of the plan.
 - 3. Gather as a team, review all component drafts and refine.
 - 4. Issue the Plan, and begin to identify needs for refinement.
 - H. **Tools Needed/Provided:**

Provided: discussion on sequence drivers, sample Table of Contents for the Startup Execution Plan, checklist of Startup Quality Gates
 - I. **Challenges to Successful Implementation:**
 - Resource/expertise constraints at this point in the project life

3-C: Make Startup Team Assignments

-
- A. **Phase:** Front-End Engineering
 - B. **Key Concepts:** Identify all the key roles and responsibilities needed in executing a successful startup. Recognize the need for these critical resources.
 - C. **Deliverables:** Organization chart and RACI chart addressing startup resources. (A RACI chart is a matrix that assigns responsibility, accountability, those to consult, and those to inform on an activity-by-activity basis.)
 - D. **Motive/Rationale:** To provide the needed resources to carry out startup activities; and to encourage early participation in startup planning by operations, contractor, and supplier organizations.
 - E. **Responsibility:** Owner Project Manager, Manufacturing Operations Representative, Startup Manager
Accountability: Owner Project Manager
Consult: Plant Manager, Contractor Project Manager
Inform: Planner/Scheduler
 - F. **Quality Gate/Sequencing Constraints:** This is not a quality gate. However, the startup organization chart should be developed near the end of the Front-End Engineering effort.
 - G. **Basic Steps:**
 1. Consult the Startup Execution Plan, refining the draft organization chart. The organization chart must be compatible with the RACI table.
 2. Put names on the organization chart, considering areas requiring special expertise. Consider having the Safety Manager and the QA/QC Manager report to both the Construction Manager and the Startup Manager.
 3. Communicate the assignments.
 4. Review responsibilities with all assignees; get feedback; resolve responsibility questions.
 5. Identify contractor and supplier startup responsibilities.
 - H. **Tools Needed/Provided:**
 Provided: sample organization chart, sample RACI chart, definitions of titles and roles
 - I. **Challenges to Successful Implementation:**
 - Availability of needed personnel to accomplish this
 - Defining team roles and responsibilities too late in the project
 - Failure in recognizing needed resources

3-D: Identify Startup Systems

-
- A. **Phase:** Front-End Engineering
 - B. **Key Concepts:** Breakdown the entire project into major startup systems in order to facilitate construction and startup planning and control. A detailed breakdown into subsystems will occur later in the detailed design phase.
 - C. **Deliverables:** Listing of startup systems
 - D. **Motive/Rationale:** To identify systems for scoping, planning, and sequencing startup activities.
 - E. **Responsibility:** Contractor Project Manager, Startup Manager, Project Team
Accountability: Owner Project Manager
Consult: Manufacturing Operations Representative
Inform:
 - F. **Quality Gate/Sequencing Constraints:** This is not a quality gate. However, all startup systems should be identified by the completion of Front-End Engineering.
 - G. **Basic Steps:**
 - 1. Consult the Startup Execution Plan and use it as a basis for this activity.
 - 2. Recognize all contracting strategy limitations of the project.
 - 3. Use P&IDs to breakdown the plant into startup systems. Get early input from operations, process design, controls, construction, and maintenance.
 - 4. Indicate startup system boundaries on the P&IDs.
 - 5. Conduct cross-checks: will operations and control systems support the startup logic? Will the construction sequence support the startup logic? Will environmental testing criteria support the startup logic? Will available owner staffing support the startup logic?
 - 6. Establish the listing of startup systems.
 - H. **Tools Needed/Provided:**

Provided: sample listing of startup systems
 - I. **Challenges to Successful Implementation:**
 - Incomplete or poorly defined project definition
 - Lack of knowledge of the plant operations plan
 - Lack of available owner operations and maintenance personnel
 - Incomplete or unfrozen P&IDs
 - Late selection of owner furnished equipment

3-E: Acquire Operations & Maintenance Input

-
- A. Phase:** Front-End Engineering
- B. Key Concepts:** A complete front-end package must include input from Operations and Maintenance. Much of this input will either directly or indirectly facilitate startup. Buy-in by O&M personnel is critical to project success.
- C. Deliverables:** O&M comments on PFDs, P&IDs, plot plans, equipment lists; discussion and documentation of O&M needs from Engineering and Procurement.
- D. Motive/Rationale:** Effective O&M input during front-end engineering is required for startup success.
- E. Responsibility:** Manufacturing Operations Representative, Startup Manager
Accountability: Owner Project Manager
Consult: Plant Manager, Contractor Project Manager
Inform: Planner/Scheduler
- F. Quality Gate/Sequencing Constraints:** This activity is not a quality gate, but key documents for detailed design (i.e., P&IDs, plot plans, equipment lists, and equipment layouts) should not be issued without adequate input.
- G. Basic Steps:**
1. Conduct O&M input meetings, addressing the following issues:
 - Specific maintenance requirements: preferred suppliers, spares, access needed, and supplier data requirements.
 - Specific operation requirements: process control, operator preferences, and access requirements.
 - Specific checkout requirements: safety, acceptance criteria, staffing, interlocks, hazards, communication, and lockouts.
 - Specific startup requirements: system sequence, timing, utilities needed, safety procedures, and environmental requirements.

Output from the meetings will be in the form of a list of critical issues that will be followed-up on to ensure incorporation into the front end package.
 2. Plan for continuing involvement of O&M in startup planning.
- H. Tools Needed/Provided:**
- Provided: P&ID flowchart, P&ID checklist of information elements
- Needed: Operator ergonomic checklist, checklist of accessibility needs, checklist of maintenance equipment & facilities needs
- I. Challenges to Successful Implementation:**
- Lack of adequate/available plant staffing
 - Little training and few tools to help in reviews

3-F: Assess Startup Risks

-
- A. **Phase:** Front-End Engineering
- B. **Key Concepts:** Startup risks must be assessed early-on in order to minimize their impact. Documented startup lessons learned can be very helpful in this effort.
- C. **Deliverables:** A listing of potential risks to successful startup and associated estimates of impact.
- D. **Motive/Rationale:** Overlooked risks can severely impact startup schedule, cost performance, and other measures of success. Early detection efforts are needed in order to reduce or contain these loss potentials.
- E. **Responsibility:** Manufacturing Operations Representative, Startup Manager
Accountability: Owner Project Manager
Consult: Contractor Project Manager, Planner/Scheduler, Process Licensor
Inform: Plant Manager
- F. **Quality Gate/Sequencing Constraints:** This activity is not a quality gate, but should occur before approval of appropriation request.
- G. **Basic Steps:**
1. Consult the Startup Execution Plan.
 2. Review startup lessons learned to date.
 3. Identify risks associated with the process technology.
 4. Identify risks associated with the controls automation.
 5. Address degrees of redundancy and planned levels of maintenance.
 6. Identify risks associated with environmental concerns.
- H. **Tools Needed/Provided:**
- Provided: startup risk checklist
- Needed: pilot plant data, listing of startup risk management strategies and contingency plans
- I. **Challenges to Successful Implementation:**
- Senior management is often uncomfortable with documented risks.
 - Concept of risk involves difficult notions of probability.
 - Often there is no in-house expertise to assess risk; must therefore be purchased as a service and is thus easily dismissed as a non-essential “luxury.”
 - Desire to remain optimistic and to “move forward.”
 - Little or no tracking of startup lessons learned.

3-G: Analyze Startup Incentives

-
- A. **Phase:** Front-End Engineering
 - B. **Key Concepts:** Consider incentives as a way to improve startup performance.
 - C. **Deliverables:** A recommendation to senior management on whether or not to implement an incentive system for startup.
 - D. **Motive/Rationale:** Incentive systems can increase the likelihood of overall startup success by motivating project personnel to even greater performance.
 - E. **Responsibility:** Owner Project Manager, Contractor Project Manager
Accountability: Owner Project Manager
Consult: Startup Manager
Inform: Manufacturing Operations Representative, Planner/Scheduler
 - F. **Quality Gate/Sequencing Constraints:** Not a quality gate, but should be done prior to budget approval.
 - G. **Basic Steps:**
 1. Consult the Startup Execution Plan as the basis. Assess any special justification for an incentive system, such as critical schedule or environmental performance.
 2. Propose more than one approach for analysis.
 3. Evaluate proposed incentive systems, thoroughly analyzing both advantages and disadvantages. Anticipate all side-effects, including those on suppliers, contractors, and operators.
 4. The keys to successful startup incentive systems include the following:
 - well-defined performance metrics
 - focus on overall team performance, not just that of the contractor
 - ensure that startup incentives are consistent and compatible with any overall project incentive systems; avoid competing or conflicting incentive systems
 - don't key incentives to mechanical completion
 5. Thoroughly plan and document the incentive system. Ensure that goals are clear and measurable. Ensure that benefits are meaningful.
 - H. **Tools Needed/Provided:** none
 - I. **Challenges to Successful Implementation:**
 - Lack of clear, measurable performance objectives
 - Plans that accomplishing one set of objectives at the expense of others
 - Change in key personnel or modifications to incentive plans mid-way through the project

3-H: Identify Startup Procurement Requirements

-
- A. **Phase:** Front-End Engineering
 - B. **Key Concepts:** Ensure that startup needs are incorporated into project procurement plans.
 - C. **Deliverables:** A procurement plan that includes startup needs.
 - D. **Motive/Rationale:** Ensure that suppliers support startup needs and objectives.
 - E. **Responsibility:** Contractor Project Manager, Startup Manager, Procurement Manager
Accountability: Owner Project Manager
Consult: Plant Manager
Inform: Planner/Scheduler
 - F. **Quality Gate/Sequencing Constraints:** This is not a single quality gate, but must be done prior to issuance of inquiries and the narrowing down of bidder lists.
 - G. **Basic Steps:**
 - 1. Prepare a list of startup items that need to be procured and integrate startup procurement with overall procurement activities.
 - 2. Establish procurement responsibilities (owner, engineer, etc.).
 - 3. Identify long-lead items (to ensure timely deliveries and thereby avoid schedule impacts on startup dates). Establish if early release of funds will be required.
 - 4. Identify preferred material items (from Operations and Maintenance).
 - 5. Address startup aspects of bidder qualification, such as pre-shipment testing and qualification capabilities, needs for startup support, training, expediting, etc.
 - 6. Identify preferred suppliers and contractors. Visit and prequalify new product suppliers.
 - 7. Address the issues of modularization and preassembly, processing of supplier data, spare parts, and the scope and responsibility for pre-shipment testing.
 - H. **Tools Needed/Provided:**
 - Provided: listing of common startup needs supported by suppliers
 - Needed: database of performance record of previous suppliers
 - I. **Challenges to Successful Implementation:**
 - Little or no feedback on startup procurement matters
 - Non-approved subcontractors
 - Inability to prequalify suppliers in the public sector

3-I: Refine Startup Budget & Schedule

-
- A. **Phase:** Front-End Engineering
 - B. **Key Concepts:** Utilizing the most recent information, update both the startup budget and schedule and reflect these developments in the Appropriation Request.
 - C. **Deliverables:** Updated startup budget and schedule
 - D. **Motive/Rationale:** Planning tools should be kept current, in this case, in order to provide the best possible forecasts for the Appropriation Request.
 - E. **Responsibility:** Startup Manager, Planner/Scheduler, Estimator
Accountability: Contractor Project Manager
Consult: Owner Project Manager, Manufacturing Operations Representative
Inform:
 - F. **Quality Gate/Sequencing Constraints:** This activity is not a quality gate, but must be a high priority.
 - G. **Basic Steps:**
 1. Use the Startup Execution Plan and previous startup planning steps in the Front-End Engineering phase as the basis for review and refinements.
 2. Ensure that all major startup activities and cost factors are identified (such as work hours, raw materials, spare parts, etc.), and consider associated costs such as travel and subsistence.
 3. Estimate the cost of training operators.
 4. Conduct final budget and schedule reviews with appropriate personnel and issue revised documents.
 - H. **Tools Needed/Provided:**
 Provided: checklist of typical startup activities
 - I. **Challenges to Successful Implementation:**
 - Lack of sufficient resources and information to develop credible estimates and schedules
 - Current paradigms in which this activity is given low priority

3-J: Update the Startup Execution Plan

-
- A. **Phase:** Front-End Engineering
 - B. **Key Concepts:** The Startup Execution Plan should be updated as new project information becomes known. As stated previously, this should be a part of the overall Project Execution Plan and should be formally and thoroughly developed. It should be formally issued as part of the Front-End Engineering Package.
 - C. **Deliverables:** A revised, updated Startup Execution Plan that addresses all important aspects of startup. This should be included as part of the Front-End Engineering Package.
 - D. **Motive/Rationale:** The Startup Execution Plan provides a framework for systematic integrated planning necessary to ensure successful implementation.
 - E. **Responsibility:** Startup Manager
Accountability: Contractor Project Manager
Consult: Owner Project Manager, Manufacturing Operations Representative, Process Licensor, Project Team
Inform: Business Unit Manager, Plant Manager, Planner/Scheduler
 - F. **Quality Gate/Sequencing Constraints:** This update should be treated as a quality gate, occurring as a final step in Front End Engineering.
 - G. **Basic Steps:**
 - 1. Build upon and expand the previously developed Startup Execution Plan (activity 3-B). Incorporate the most recent startup budget and schedule (activity 3-I), startup procurement requirements (activity 3-H), startup incentive systems (activity 3-G), assessment of startup risks (activity 3-F), listing of startup systems (activity 3-D), startup team assignments (activity 3-C), and any other salient information.
 - 2. Reevaluate the use and effectiveness of startup quality gates.
 - 3. Draft any new parts or components of the plan, such as the plans for check-out/commissioning and initial operations, and procedures for problem identification and resolution during check-out/commissioning.
 - 4. Gather as a team, review all component drafts and refine.
 - 5. Re-issue the Plan as a base document for the detailed design phase.
 - H. **Tools Needed/Provided:**
Provided: see activity 3-B
 - I. **Challenges to Successful Implementation:**
 - Resource/expertise constraints at this point in the project life

Tool 3-A: Listing of Typical Startup Objectives (page 1 of 8)

- | | |
|--|--|
| 1. Product Quality: | Product quality meets or exceeds quality goals as established at authorization. |
| 2. Product Quantity: | Production quantity rate is at or above that established at project authorization. |
| 3. Schedule Performance: | Startup duration is at or below that duration planned for at authorization. |
| 4. Safety Performance: | No reportable injuries or incidents during startup (consistent with overall project objectives). |
| 5. Environmental Performance: | All environmental targets are met. There are no reportable releases or spills during startup. |
| 6. Operations Team Performance: | Operations team is thoroughly prepared for all challenges it may encounter prior to commercial operations. |
| 7. Impact to On-Going Operations: | Minimal impact to on-going operations; no unplanned impacts to on-going operations. |
| 8. Level of Effort Required by the Startup Team: | Actual startup work hours and resources are at or below planned level of effort. |

Tool 3-A: Listing of Typical Startup Objectives (page 2 of 8)

Beyond defining startup objectives, measuring and tracking startup success from project to project can increase the likelihood of future startup success by motivating teams to ever-improving levels of performance.

As shown above, research indicates that a successful startup requires successful performance in eight different areas:

- Product quality
- Product quantity
- Schedule performance
- Safety performance
- Environmental compliance
- Operations team performance
- Impact to ongoing operations
- Level of stress experienced by startup team

With the use of *criteria performance scores* and *criteria importance weightings*, these eight criteria can be integrated into a single startup *success index score*. Such a score allows for ready comparisons between startups, company-wide benchmarking, and even industry-wide benchmarking.

A criterion performance score is a quantitative measure of how a particular startup performs relative to an established target associated with one of the eight criteria. For example, as shown in Table 3-A.2, with respect to the impact of a startup to on-going operations, five levels of relative performance or satisfaction have been established. Similarly, as shown in Table 3-A.3, five levels of relative satisfaction have been established for each of the eight startup success criteria.

A criteria importance weighting is a quantitative measure of how important a particular success criterion is relative to all other seven criteria. Each criterion can be assigned one of five levels of relative importance:

- Most important
- Above average importance
- Average importance
- Below average importance
- Least important

Tool 3-A: Listing of Typical Startup Objectives (page 3 of 8)

Table 3-A.2: Performance Scores Associated with Criterion
“Impact to Ongoing Operations”

Level of Satisfaction	Impact to Ongoing Operations	Criteria Performance Score
Extremely satisfied	No impact to ongoing operations	5
Very satisfied	Minimal impact to ongoing operations	4
Satisfied	No unanticipated impacts to on-going operations	3
Dissatisfied	Ongoing operations were impacted	2
Very dissatisfied	Ongoing operations were significantly impacted	1

By weighting the least important criteria with a value of one, criteria of below average importance with a value of two, etc., normalized criterion importance weightings can be derived by determining the relative contribution of each criteria to the sum total of importance weightings for all eight criteria. This is best illustrated with an example, as presented in Table 3-A.4.

In this way, importance weightings can be determined for each startup success criterion and these will be consistent on a relative basis (e.g., the same weightings for all criteria will result if all are assigned the same level of importance).

Fig. 3-A.1 graphically depicts the average importance weightings for the eight criteria based on 23 actual startups analyzed. The weightings of all eight criteria fall into a relatively tight range: between 0.10 and 0.14. Thus, at least for the startups analyzed, on average, all eight criteria are nearly equally meaningful to startup success.

Now, given the availability of both *criteria performance scores* and *criteria importance weightings*, a single startup success index score can be computed by simply multiplying one by the other and summing up for all eight criteria. (Criteria performance scores should be divided by 5 in order to achieve a 0 to 1 scale.)

Tool 3-A: Listing of Typical Startup Objectives (page 4 of 8)

Table 3-A.3. Startup Success Criteria Performance and Scores

Success Criterion	Satisfaction Level (Score)				
	☐ Extremely Satisfied (5)	☐ Very Satisfied (4)	☐ Satisfied (3)	☐ Dissatisfied (2)	☐ Very Dissatisfied (1)
Product Quality Performance	Product quality consistently exceeded project goals.	Product quality goals were consistently met.	Product quality goals were met with expected amounts of off-spec material.	Product quality met specification most of the time but the amount of off-spec material was higher than expected.	Product quality was met only with significant process and construction rework.
Product Quantity Performance	Production rates consistently exceeded project goals.	Production rates met project goals.	Production rates were marginally less than planned but customers were not affected.	Plant did not meet production rates set at project authorization.	Production rates were significantly lower than planned and required significant construction rework.
Schedule Performance	The startup duration was significantly less than estimated. The process was on-line sooner than expected.	The startup duration was as planned.	The startup duration was as planned but meeting the schedule required extra levels of labor and/or materials.	The startup duration exceeded plan and meeting the schedule required heroic efforts on the part of the startup team.	The startup duration far exceeded the original plan.