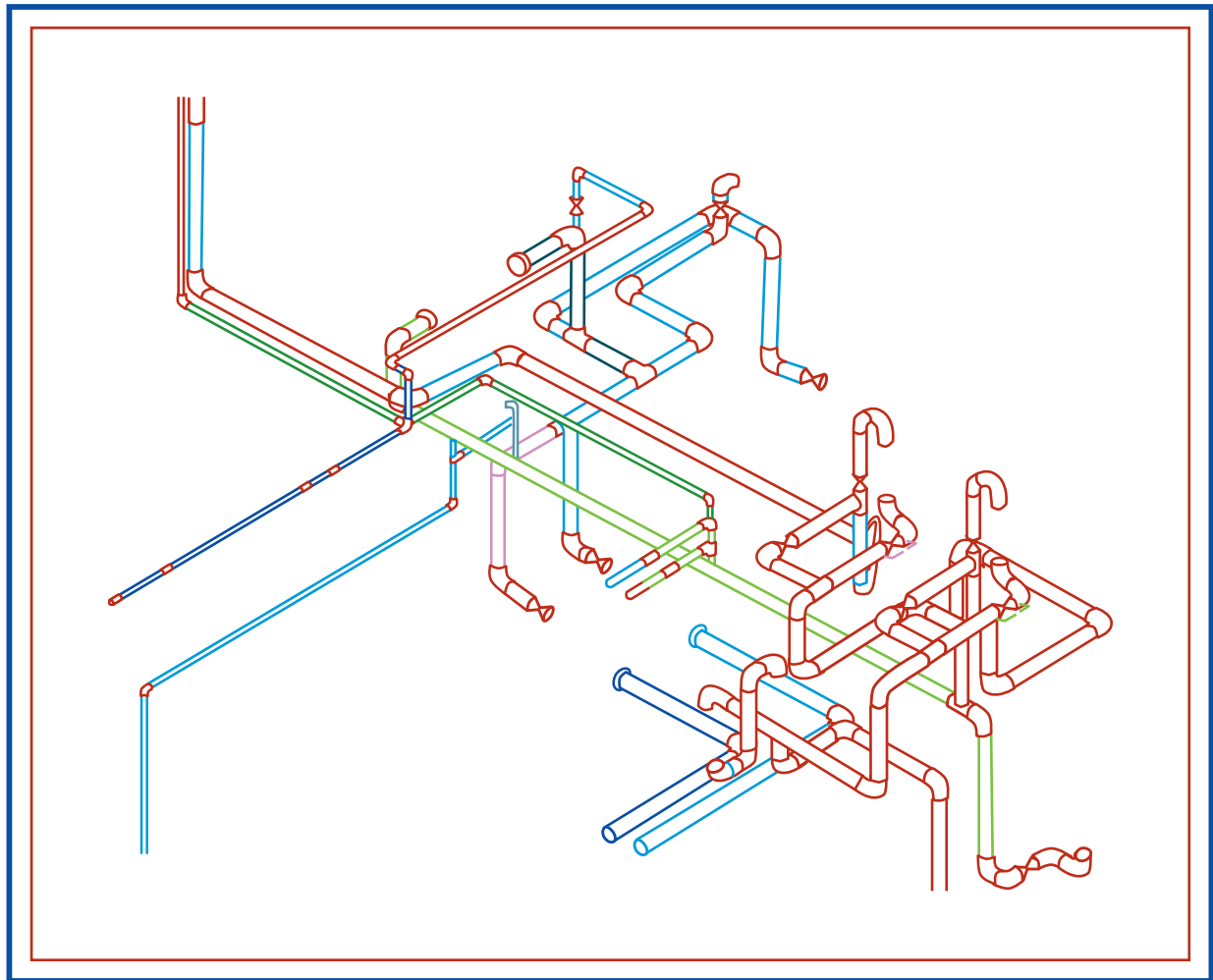


Tools

for Enhancing the Piping Engineering Process





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Tools for Enhancing the Piping Engineering Process

Prepared by the

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Executive Summary

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The piping function is frequently inefficient. Previous research indicates that potential savings from improving the piping function are about \$3.8 million for an average heavy industrial project costing \$190 million. The CII Piping Function Research Team involved more than 100 industry experts to identify drivers of these problematic processes, to collect best practices, and to develop solution tools for improving piping function efficiency.

The major causes for this inefficiency pertain to engineering development processes for (1) piping and instrumentation diagrams (P&IDs), (2) supplier data, and (3) packaged units. Research indicates that three drivers of P&ID problems are inefficient sequencing and prioritization, inefficient procedures for P&ID development and review, and inefficient communication of P&ID uncertainty. In the supplier data process, communication, coordination and selection duration are three major problems. For packaged units, supplier quality issues and design issues are major areas influencing piping function efficiency.

Several tools have been developed by the CII Piping Function Research Team to improve the efficiency of the piping function. These tools, categorized into policies, procedures, checklists, and roles, are described in this publication.

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Chapter 1

Introduction

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Since the early 1980s the construction industry has realized that the piping function is the most costly and least efficient function within industrial projects. The Business Roundtable has estimated that the potential savings from improving the piping function are about \$3.8 million for an average heavy industrial project costing \$190 million.

Previous research found that solving problems at the early stage of a project can often be the most cost-effective approach for projects. However, enhancing the engineering development processes of P&IDs, supplier data, and packaged units in order to improve the piping function has largely been ignored.

In 1993, the Construction Industry Institute chartered the Piping Function Research Team (RT #47, also called “the research team” in this publication). The research team identified 14 problematic areas in the industrial project piping function and determined that the two most desirable areas for research were P&ID rework and design document rework from late supplier data and packaged units.

The research team reached consensus on two issues: first, too many uncertainties in the piping process are the key factor in the inefficiency of the piping function; and second, the piping function can be greatly enhanced by minimizing uncertainties during the engineering development processes of the P&IDs, supplier data, and packaged units.

Major Problems in Piping Functions

This section briefly discusses the three areas of uncertainty in the piping function.

Piping and Instrumentation Diagrams

P&IDs are schematic drawings showing the arrangement of all process and utility equipment, piping, and instrumentation. P&IDs are an extension of process flow diagrams (PFDs) and are used as the basis for detailed engineering design. P&IDs evolve with the development of a project; a finished P&ID carries complete information for all equipment, piping, process control, and instrumentation, and the interrelationships these elements have. P&IDs play a significant role in process

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piping design, construction, and start-up. Figure 1.1 is a flowchart depicting the role of P&IDs in industrial plant engineering and construction. The research team determined that artificially frozen P&IDs and late P&ID changes are key symptoms of the inefficient P&ID development process.

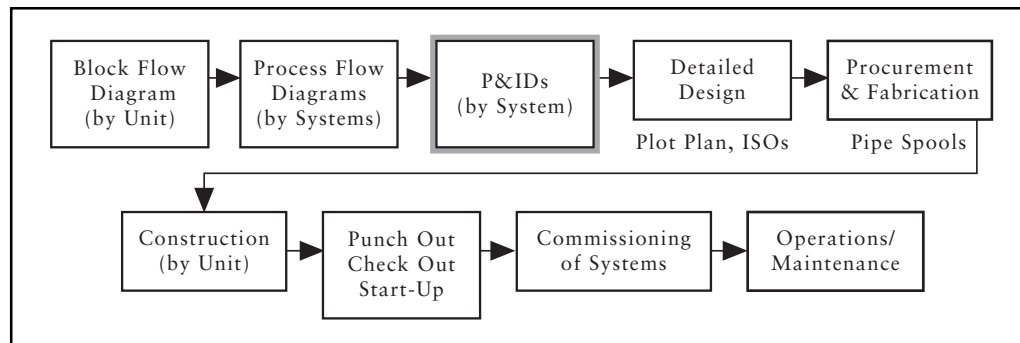


Figure 1.1. Flowchart for Industrial Plant Engineering and Construction

P&ID is an acronym for the following technical terms: Piping and Instrumentation Diagram (Drawing), Piping and Instrument Diagram, or Process and Instrument Diagram. Sometimes, P&IDs are referred to as Engineering Flow Diagrams (EFDs), Engineering Line Diagrams (ELDs), Flow Sheets, or Mechanical Flow Diagrams (MFDs).

Supplier Data

Supplier data are major information sources for design documents (P&IDs and isometrics). Unfortunately, supplier documents are often missing, late, or contain inaccurate information when needed to support accelerated engineering design programs. This causes non-certified (uncertain) data to be incorporated into the design documents, which are then sent downstream into the process. Associated delays and uncertainties affect the piping function in the following ways:

- Re-design of piping interfaces and/or transitions
- Misfabrication of pipe spools
- Rework of pipe spools at the fabrication shop
- On-line piping rework and on-site piping rerouting.

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Packaged Units

A packaged unit is a self-contained system consisting of various pieces of equipment that are piped and/or wired together, supported on a common base (or bases), and designed, fabricated, and furnished by a specialty supplier from a remote site. Sometimes called skid-mounted units, these are smaller than units fabricated for an entirely modular approach to plant construction.

Similar to supplier data, packaged units can become a source of delays and uncertainties for the design effort. In addition to design issues, however, packaged units present problems for on-site installation since they frequently cause piping rework and/or rerouting.

Research Objectives and Scope

Table 1.1 shows the scope of this study. Industrial projects, excluding commercial piping (plumbing), located in the U.S. were the major sources for this investigation. The organizations involved in the research were CII owner companies and CII contractor companies.

Table 1.1. Research Scope Definition

Research Scope	
Type of Projects	Industrial Projects: • Petrochemical Plants • Chemical Plants • Petroleum Plants • Gas Treatment Plants • Offshore Oil Well Platforms • Offshore Gas Well Platforms
Nature of Projects	• New Projects • Expansion Projects • Remodel Projects
Location of Projects	U.S.

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Types of Tools

The tools for enhancing the piping engineering development processes are categorized and explained as follows:

Policy:

- A high-level overall plan embracing general goals and acceptable procedures.
- A predetermined course of action established as a guide toward accepted business strategies and objectives. The policy reflects an overall organizational attitude; it provides a long-range guide for action. An established policy sets limits which management is expected to follow. A policy does not tell a person exactly what to do, but does point out the direction to go.
- A policy reflects an overall organizational purpose and provides a long-range strategy for action.

Procedure:

- A particular way of accomplishing something or of acting.
- A series of steps followed in a regular definite order.
- A series of instructions for a computer that has a name by which it can be called into action.
- The means by which a policy can be accomplished. The procedure lays out the steps usually followed in performing a recurring type of work. A procedure establishes uniform methods for routine or repetitive matters.
- A procedure lays out a series of steps or instructions for performing a recurring type of activity.

Checklist:

- A complete list of necessary and/or desirable items with which engineers perform a scrutinized cross-check in an effort to ensure these items are properly addressed.
- A checklist presents desirable items and allows engineers to check their documents to ensure accuracy and completeness.

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Role:

- Function; a socially expected behavior pattern usually determined by an individual's status.
- A norm that goes with a position or occupation. Roles and role pairs govern the behavior of the person holding the position.
- A role is a functional position created in an organization to perform a particular task.

Chapter 2

Tools for Enhancing the P&ID Development Process

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Drivers and Causes of Inefficient P&ID Development Process

Research found that late P&ID changes are primarily the result of “artificially frozen” P&IDs. Artificially frozen P&IDs are those containing information elements that have not been finalized. Three key drivers that lead to artificially frozen P&IDs and late P&ID changes are:

- Lack of sequencing and prioritization in the P&ID development process.
- Inefficient P&ID development procedures and review checklists.
- Inefficient communication of P&ID uncertainty.

Inefficient Sequencing and Prioritization in the P&ID Development Process — Need for Tools

Lack of sequencing and prioritization is the primary driver that leads to artificially frozen P&IDs and to late P&ID changes. The research team found that the causes for this include: (1) missing necessary activities in the P&ID development process, (2) lack of a graphical flowchart, (3) vague design contract terms, and (4) less than optimal project management priorities.

When P&ID development activities are not properly sequenced and prioritized, projects can suffer from the following negative effects:

- Lack of timely input from multi-discipline, operations, maintenance, safety, construction, and supplier groups
- Lack of coordination both within and outside the project team
- Incomplete or untimely P&ID reviews
- Incomplete, or uncoordinated P&IDs
- Numerous “holds” on P&IDs
- Artificially frozen P&IDs
- Late P&ID changes.

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Tools for Improving Sequencing and Prioritization

In order to sequence and prioritize P&ID development activities effectively, the following information is needed: (1) a detailed breakdown of the P&ID development activities for each P&ID development stage; (2) a flowchart depicting the relationships between these activities; and (3) a paradigm change to recognize the need for more pre-project planning.

Several tools were developed to address these needs. They should be implemented in parallel:

- Tool #1-A: Procedure — Integrated Flowchart for P&ID development process
- Tool #1-B: Procedure — Information and Decisions for P&ID Development Stages
- Tool #1-C: Procedure — Use of the Integrated P&ID Development Flowchart
- Tool #2-A: Policy — Owner Project Team Formation for Early Input
- Tool #2-B: Policy — Tactics for Overcoming Barriers to Owner Project Team Formation

Tool #1-A: Procedure — Integrated P&ID Development Flowchart

An integrated P&ID development flowchart (Figure 2.1) was developed by the research team in an effort to curtail uncertainty that persists in unstructured approaches to P&ID development. It is intended to improve the sequencing and prioritization of P&ID activities. This flowchart was initially based upon an owner company's descriptive P&ID development guidelines, and then was continuously refined as additional inputs were solicited. The final version is shown in Figure 2.1. This figure integrated the research team's input and several companies' P&ID development guidelines/flowcharts. It also was validated by industry experts in terms of positive impacts on projects and ease of implementation. Tool #1-A should be used in conjunction with Tools #1-B and #1-C.

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The Integrated P&ID Development Flowchart provides the following functions:

- identifies the activities needed in the P&ID development process (concentrating on proper prioritizing and sequencing)
- illustrates the interrelationships between various activities
- facilitates reaching an agreement between project participants on the steps of the development process
- provides a basis for comparison with existing P&ID development flowcharts, so as to identify opportunities for improvement
- serves as a training aid for understanding the entire P&ID process
- facilitates commitment to information “fixity” (or stability) by dividing the evolutionary process into discrete stages
- alters the “recycle” paradigm: all P&ID information evolves slowly.

The research team found the following six stages best describe the flow of the P&ID development process:

1. AFP: Approval for preliminary review
2. AFM: Approval for multi-disciplinary review
3. AFO: Approval for owner review
4. AFD: Approval for detailed design
5. AFC: Approval for construction
6. AFS: Approval for start-up and operations.

Figure 2.1 depicts the six P&ID development stages and their activities. The stages are shown in oval shapes at the bottom of the figure. The oval shapes on the left are the predecessors to the ovals to their right. Above each stage are the essential activities (shown vertically) for completing each stage. The arrows indicate the sequence of the P&ID development. The shadowed blocks are P&ID review activities. The double-lined blocks are P&ID development milestones.

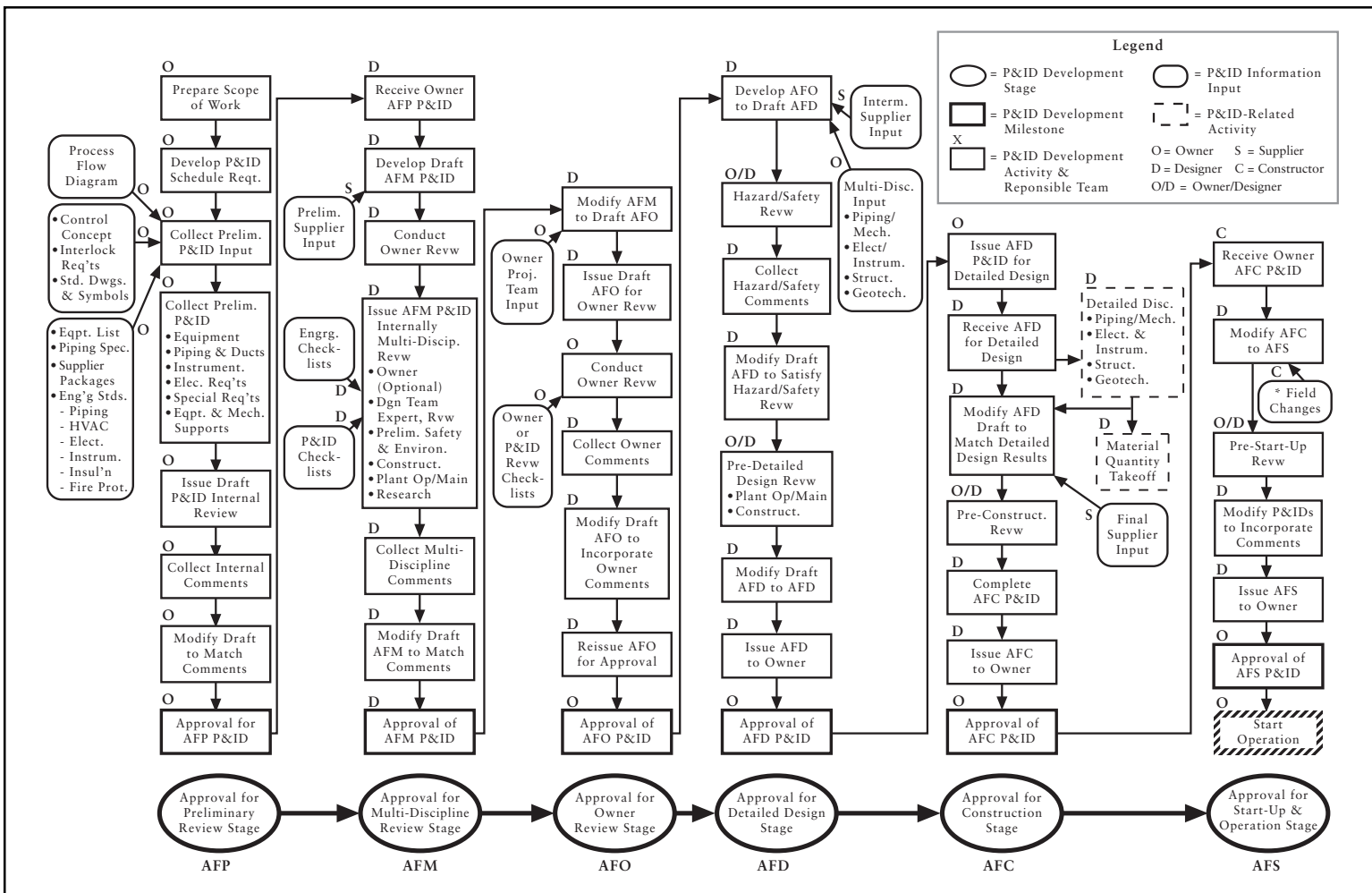


Figure 2.1. Tool #1-A: Procedure — Integrated Flowchart for P&ID Development Process

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A milestone, shown above every oval, is a checkpoint or “quality gate” at the end of each P&ID development stage. It should communicate the degree of progress of that stage. A milestone also is a formalized activity for approving the content of P&IDs for follow-on P&ID development.

The key activities of the integrated P&ID development flowchart can be divided into the following categories:

- information collection, such as process flow diagrams (PFDs) and interlocks
- preparation of P&IDs
- issuance of P&IDs
- P&IDs reviews
- collection of review comments
- modification to P&IDs
- approval of P&IDs.

Tool #1-B: Procedure — Information and Decisions for P&ID Development Stages

The research team prepared Table 2.1 to describe the information and decisions needed for each of the P&ID development stages. This table assists the completion of Figure 2.1. Tool #1-B should be used in conjunction with Tools #1-A and #1-C.

Tool #1-C: Procedure — Use of the Integrated P&ID Development Flowchart

To use the integrated P&ID flowchart effectively, it is suggested that users follow the steps shown in Figure 2.2 (page 13). This tool should be used in conjunction with Tools #1-A and #1-B.

Table 2.1. Tool #1-B: Procedure — Information and Decisions Needed for Each P&ID Development Stage

P&ID Development Stage	Information Needed	Decision Needed
AFP	- Owner's project work scope - Process flow diagram - Control concept - Standard drawings and symbols - Equipment list - Piping specification, if available - Supplier packages available - Engineering standards	- Owner's process design approval of AFP P&IDs
AFM:	- Engineering checklists - Preliminary supplier input - Multi-discipline review comments from both the owner and design firms - Expert review comments, such as safety and environmental, construction, plant operations and maintenance, and research groups	- Multi-discipline's approval of AFM P&IDs
AFO	- Owner's review comments - Owner's review checklist	- Owner's approval of AFO P&IDs
AFD	- Hazard/safety review comments - Secondary expert review comments: plant operations/maintenance and construction - Intermediate supplier input - Final multi-discipline input, such as piping/mechanical, electrical/instrument, and civil - Owner's approval of AFD P&IDs	- Consensus of design team that information is solid
AFC	- Final supplier input - As-designed safety, environmental review data	- Owner's approval of AFC P&IDs
AFS	- Last operations/maintenance/safety and other field changes	- Owner's approval of AFS P&IDs

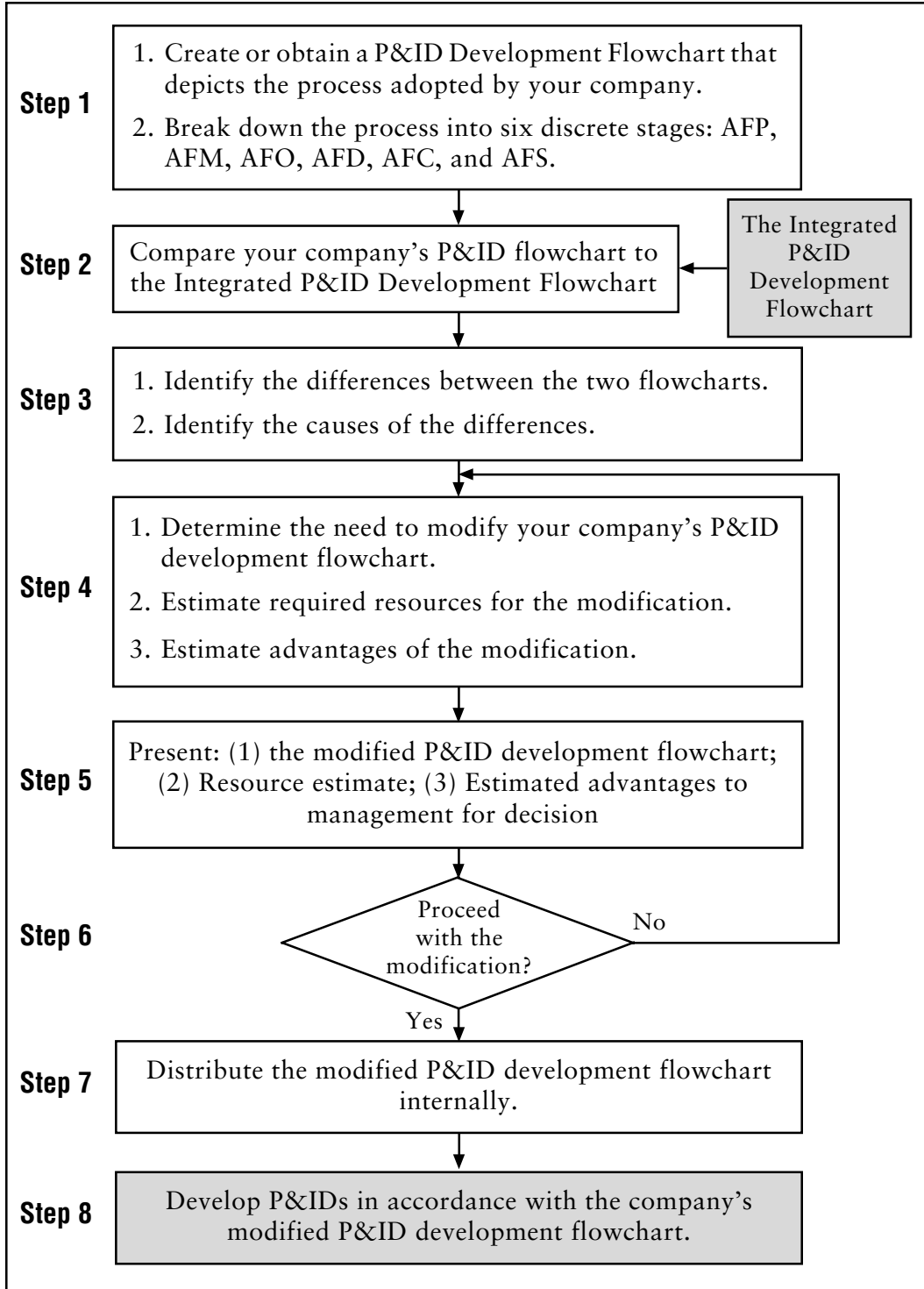


Figure 2.2. Tool #1-C — Procedure — The Process for Using the Integrated P&ID Development Flowchart

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Tool #2-A: Policy — Owner Project Team Formation for Early Input

To deal with untimely input to P&IDs, some owners have changed their traditional approach of soliciting information input so as to maximize the chances of their projects' success. These owners are now not only obtaining early input into the P&IDs from the process groups, but are soliciting input from design engineering groups as well as construction and maintenance personnel (Figure 2.3).

In the 1990s many owners changed the conventional timing for incorporating internal and external input into their P&ID development process. Figure 2.3, which is composed of Figures 2.3.1 and 2.3.2, depicts that change. This figure is adapted from a diagram of a project effort input concept provided by a CII owner company. Figure 2.3.1 depicts that owners in the 1980s requested P&ID information primarily from manufacturing/operations units and the process engineering group at the early stages of P&ID reviews: AFP, AFM, and AFO. Other information input, from the design engineering group, construction group, process control group, and suppliers, generally took place in the later stages, i.e., AFD, AFC, and AFS. However, this owner and several other experts interviewed have agreed that late input often leads to P&ID changes. Typically, this late input includes comments from the operations/maintenance group, construction group, and package unit suppliers.

With both domestic and international markets getting more competitive and leading to smaller profit margins, progressive owners are looking for approaches where they can realize a cost-benefit ratio. Acquiring both external and internal input earlier in the process is one key approach. Figure 2.3.2 demonstrates how some owners organize task forces to better integrate P&ID information input. The early inputs that begin in the AFM stage come not only from manufacturing units and process engineering groups, but also from design engineering, process control, construction/maintenance, and certain key suppliers.

Supplier input, a type of external input in the P&ID development process, is a continuous effort, not a discrete activity. The Integrated P&ID Development Flowchart (Figure 2.1) reveals that the optimal time and contents for supplier input are as follows:

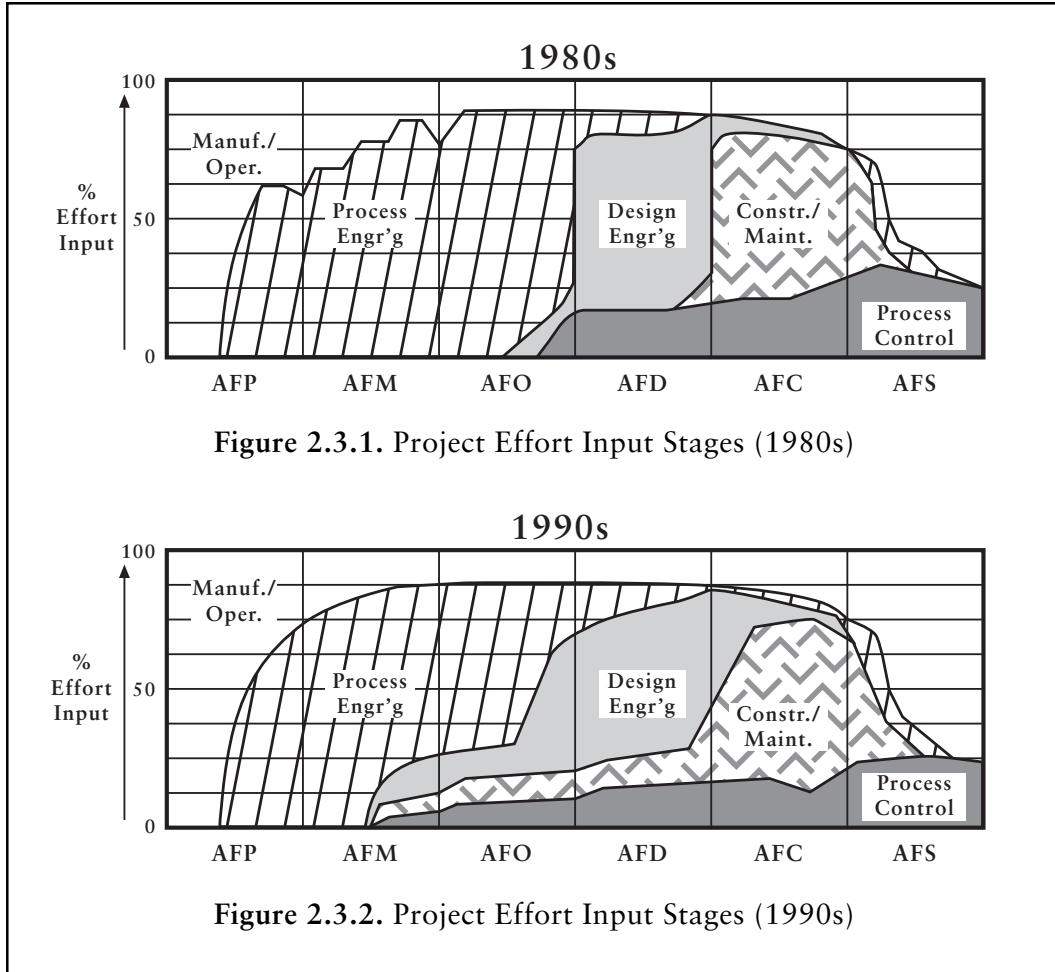


Figure 2.3. Comparison of Project Effort Input for 1980s and 1990s

- Preliminary supplier input: AFM stage, for acquiring supplier package designation, preliminary information, and interface concepts;
- Intermediate supplier input: AFD stage, for freezing supplier package designation, supplier details as required, and interface details;
- Final supplier input: AFC stage, for certifying the supplier information provided.