CONSTRUCTION INDUSTRY INSTITUTE

PDRI

Project Definition Rating Index

INDUSTRIAL PROJECTS

IMPLEMENTATION RESOURCE 113-2

PDRI: Project Definition Rating Index

Industrial Projects

Prepared by

Construction Industry Institute

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Implementation Resource 113-2

July 1996

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EXECUTIVE SUMMARY

As demonstrated in research results published previously by CII, and new data presented in this document, greater pre-project planning efforts lead to improved performance on industrial projects in the area of cost, schedule, and operational characteristics. Unfortunately, until now, industry has lacked non-proprietary tools to assist in performing this critical stage of the project.

The Project Definition Rating Index (PDRI) for Industrial Projects is a powerful and simple tool that helps meet this need by offering a method to measure project scope definition for completeness. A PDRI score of 200 or less has been shown to greatly increase the probability of a successful project.

The PDRI offers a comprehensive checklist of up scope definition elements in an easy-to use score sheet format. The PDRI score sheet is supported by detailed descriptions of these elements. Each element is also weighted based on its relative importance to the other elements. An individual, or team, can therefore evaluate the status of their project definition effort during pre-project planning and determine their score, or level of effort. Furthermore, since the PDRI element score relates to its risk, high risk areas that need further work can easily be isolated.

The PDRI can benefit both owner and contractor companies and provides numerous benefits to the project team. These include : a detailed checklist for work planning, standardized scope definition terminology, facilitation of risk assessment, pre-project planning progress monitoring, aid in communication of requirements between participants, method of reconciling differences between project participants, a training tool, and a benchmarking basis.

Also in development is a WindowsTM-based software package that will assist in scoring your projects. This software package allows for file transfer and reporting capabilities to assist in analyzing pre-project planning status and should be available in the Fall of 1996.

This implementation guide contains chapters describing the PDRI, why it should be used, how to score a project, how to analyze a PDRI score and a path forward for the using this tool. Each of these chapters is supported by extensive background material in the Appendices.

CHAPTER 1 : WHAT IS THE PDRI?

The PDRI is a simple and easy-to-use tool for measuring the degree of scope development on industrial projects.

The Project Definition Rating Index (PDRI) was created by the Construction Industry Institute (CII) Front End Planning Research Team. It identifies and precisely describes each critical element in a scope definition package and allows a project team to quickly predict factors impacting project risk. It is intended to evaluate the completeness of scope definition at any point prior to the time a project is considered for authorization to perform detailed design and construction.

This document is the first in a series of scope definition checklists to assist in pre-project planning (or programming) for industrial, building, and infrastructure projects. This particular version was developed specifically for use on industrial projects, which include the following types of facilities:

- Oil / Gas production facilities
- Chemical plants
- Paper mills
- Power plants
- Food processing plants
- Textile mills
- Pharmaceutical plants
- Steel / Aluminum mills
- Manufacturing facilities
- Refineries

The PDRI consists of three main sections, each of which is broken down into a series of categories which, in turn, are further broken down into elements, as pictorially shown in Figure 1.1. A complete list of the sections, categories, and elements is given in Figure 1.2.

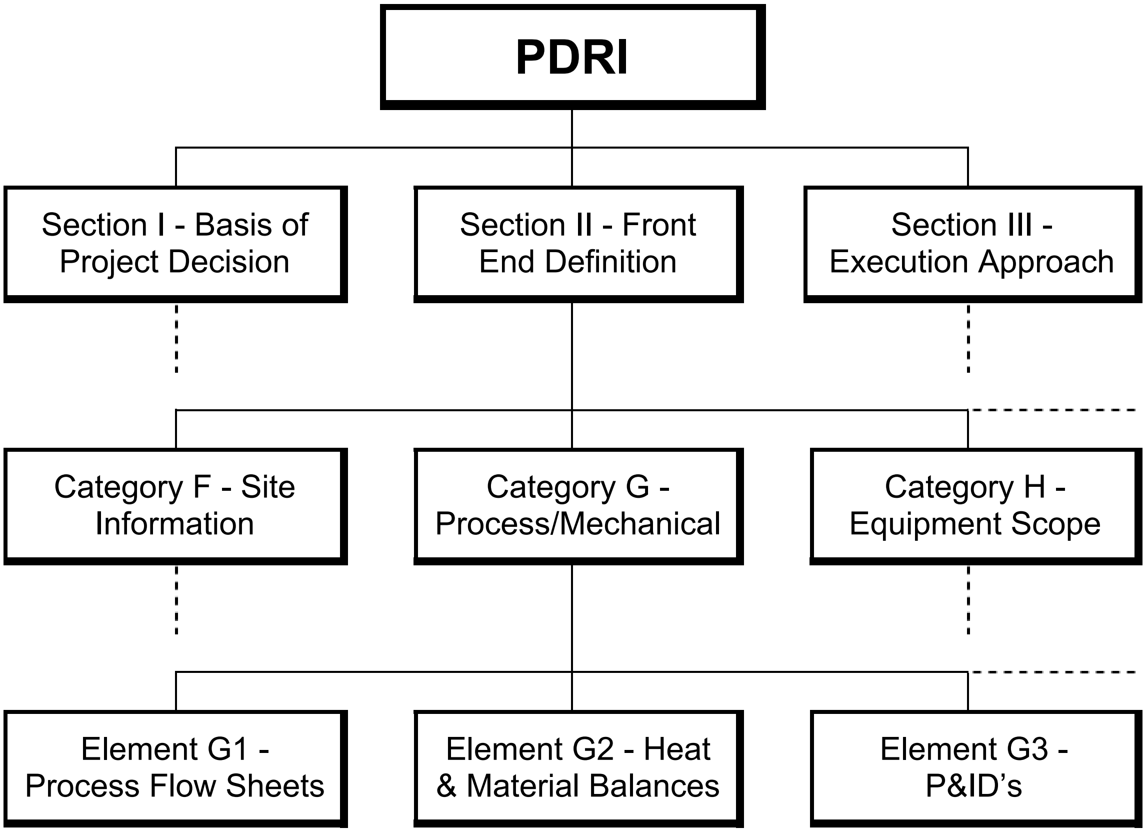

Figure 1.1. PDRI Hierarchy

STRUCTURE OF THIS DOCUMENT

This handbook consists of five main chapters followed by seven appendices of supporting information. Chapter 2 highlights how the PDRI can be used to improve project performance on industrial projects. Chapter 3 provides detailed instructions for scoring a project using the PDRI. Chapter 4 describes the various ways in which PDRI scores can be analyzed to assess a project's potential for success. The final chapter summarizes the major uses and benefits of the PDRI and offers suggestions for implementing it on future projects.

I. BASIS OF PROJECT DECISION

A. Manufacturing Objectives Criteria
- A1. Reliability Philosophy
- A2. Maintenance Philosophy
- A3. Operating Philosophy

B. Business Objectives
- B1. Products
- B2. Market Strategy
- B3. Project Strategy
- B4. Affordability / Feasibility
- B5. Capacities
- B6. Future Expansion Considerations
- B7. Expected Project Life Cycle
- B8. Social Issues

C. Basic Data Research & Development
- C1. Technology
- C2. Processes

D. Project Scope
- D1. Project Objectives Statement
- D2. Project Design Criteria
- D3. Site Chars. Available vs. Required
- D4. Dismantling & Demolition Req'mts
- D5. Lead / Discipline Scope of Work
- D6. Project Schedule

E. Value Engineering
- E1. Process Simplification
- E2. Design & Material Alternatives Considered / Rejected
- E3. Design For Constructability Analysis

II. FRONT END DEFINITION

F. Site Information
- F1. Site Location
- F2. Surveys & Soil Tests
- F3. Environmental Assessment
- F4. Permit Requirements
- F5. Utility Sources with Supply Conds.
- F6. Fire Prot. & Safety Considerations

G. Process / Mechanical
- G1. Process Flow Sheets
- G2. Heat & Material Balances
- G3. Piping & Instrmt. Diags. (P&ID's)
- G4. Process Safety Mgmt. (PSM)
- G5. Utility Flow Diagrams
- G6. Specifications
- G7. Piping System Requirements
- G8. Plot Plan
- G9. Mechanical Equipment List
- G10. Line List
- G11. Tie-in List
- G12. Piping Specialty Items List
- G13. Instrument Index

H. Equipment Scope
- H1. Equipment Status
- H2. Equipment Location Drawing
- H3. Equipment Utility Requirements

I. Civil, Structural, & Architectural
- I1. Civil / Structural Requirements
- I2. Architectural Requirements

J. Infrastructure
- J1. Water Treatment Requirements
- J2. Loading / Unloading / Storage Facilities Requirements
- J3. Transportation Requirements

K. Instrument & Electrical
- K1. Control Philosophy
- K2. Logic Diagrams
- K3. Electrical Area Classifications
- K4. Substation Requirements / Power Sources Identified
- K5. Electric Single Line Diagrams
- K6. Instrument & Electrical Specs.

III. EXECUTION APPROACH

L. Procurement Strategy
- L1. Identify Long Lead / Critical Equipment & Materials
- L2. Procurement Procedures & Plans
- L3. Procurement Resp. Matrix

M. Deliverables
- M1. CADD / Model Requirements
- M2. Deliverables Defined
- M3. Distribution Matrix

N. Project Control
- N1. Project Control Requirements
- N2. Project Accounting Req'mts
- N3. Risk Analysis

P. Project Execution Plan
- P1. Owner Approval Requirements
- P2. Engr. / Constr. Plan & Approach
- P3. Shut Down/Turn-Around Req'mts
- P4. Pre-Commissioning Turnover Sequence Requirements
- P5. Startup Requirements
- P6. Training Requirements

Figure 1.2. PDRI SECTIONS, Categories, and Elements

CHAPTER 2 : BENEFITS OF THE PDRI

Effective pre-project planning improves project performance in terms of both cost and schedule. The majority of industry participants recognize the importance of scope definition during pre-project planning and its potential impact on project success. Previous research conducted by CII has shown that higher levels of pre-project planning effort can result in significant cost and schedule savings as shown in Table 2.1.

Table 2.1. Cost and Schedule Performance for Varying Levels of Pre-Project Planning Effort

Pre-Project Planning Effort		Cost		Schedule
High		- 4%		- 13%
Medium	20%	- 2%	39%	+ 8%
Low		+ 16%		+ 26%
		(- cost underrun) (+ cost overrun)		(- ahead of schedule) (+ behind schedule)

Until now, however, the industry has been lacking a practical, non-proprietary method for determining the degree of scope development on a project. The PDRI is the first publicly available tool of its kind. It allows a project planning team to quantify, rate, and assess the level of scope development on projects prior to authorization for detailed design or construction. A significant feature of the PDRI is that it can be utilized to fit the needs of almost any individual project, small or large. Elements that are not applicable to a specific project can be zeroed out, thus eliminating them from the final scoring calculation.

The PDRI is quick and easy to use. It is a "best practice" tool that will provide numerous benefits to the construction industry. A few of these include:

- A **checklist** that a project team can use for determining the necessary steps to follow in defining the project scope
- A listing of **standardized scope definition terminology** throughout the construction industry
- An industry standard for rating the completeness of the project scope definition package to facilitate **risk assessment** and prediction of escalation, potential for disputes, etc.
- A means to **monitor progress** at various stages during the pre-project planning effort
- A tool that aids in **communication** between owners and design contractors by highlighting poorly defined areas in a scope definition package
- A means for project team participants to **reconcile differences** using a common basis for project evaluation
- A **training tool** for companies and individuals throughout the industry
- A **benchmarking tool** for companies to use in evaluating completion of scope definition versus the performance of past projects, both within their company and externally, in order to predict the probability of success on future projects

WHO SHOULD USE THE PDRI?

Anyone wishing to improve the overall performance on their projects should use the PDRI.

The PDRI can benefit both owner and contractor companies. Owner companies can use it as an assessment tool for establishing a comfort level at which they are willing to authorize projects. Contractors can use it as a method of identifying poorly defined project scope definition elements. The PDRI provides a means for all project participants to communicate and reconcile differences using an objective tool as a common basis for project scope evaluation.

CHAPTER 3 : INSTRUCTIONS FOR SCORING A PROJECT

Scoring a project is as easy as 1-2-3.

Individuals involved in the pre-project planning effort should use the Project Score Sheet shown in Appendix B when scoring a project. It allows a pre-project planning team to quantify the level of scope definition at any stage of the project on a 1000 point scale.

The PDRI consists of three main sections, each of which is broken down into a series of categories which, in turn, are further broken down into elements. Scoring is performed by evaluating and determining the definition level of individual elements. Note that the elements are described in Appendix C, Element Descriptions. Elements should be rated numerically from 0 to 5. Think of this as a "zero defects" type of evaluation. Elements that are as well defined as possible should receive a perfect definition level of "one." Elements that are completely undefined should receive a definition level of "five." All other elements should receive a "two," "three," or "four" depending on their levels of definition. Those elements deemed not applicable for the project under consideration should receive a "zero," thus not affecting the final score. The definition levels are defined as follows:

Definition Levels

0 = Not Applicable
1 = Complete Definition
2 = Minor Deficiencies
3 = Some Deficiencies
4 = Major Deficiencies
5 = Incomplete or Poor Definition

Some elements should be rated with a simple YES or NO response indicating that they either exist or do not exist within the project definition package. In Appendix C these elements are indicated by a (Y/N) icon. In the Project Score Sheet in Appendix B, these elements have boxes 2, 3, and 4 darkened. A YES corresponds to a definition level of 1. A NO corresponds to a definition level of 5.

To score an element, first **read its corresponding description in Appendix C.** Some elements contain a list of items to be considered when evaluating their levels of definition. These lists may be used as checklists. Next, **refer to the Project Score Sheet in Appendix B.** Most elements have five pre-assigned scores, one for each of the five possible levels of definition. **Please choose only one definition level (0, 1, 2, 3, 4, or 5)** for that element based on your perception of how well it has been addressed. (Remember, only levels 0, 1, or 5 can be chosen for Y/N elements.) Once you have chosen the appropriate definition level for the element, **write the value of the score that corresponds to the level of definition chosen in the "Score" column.** Do this for each of the seventy elements in the Project Score Sheet. **Be sure to score each element.**

Each of the element scores within a category should be added to produce a total score for that category. The scores for each of the categories within a section should then be added to arrive at a section score. Finally, the three section scores should be added to achieve a total PDRI score.

EXAMPLE:

Consider, for example, that you are a member of a pre-project planning team responsible for developing the scope definition package for a retrofit to an existing chemical plant. Your team has identified major milestones throughout pre-project planning at which time you plan to use the PDRI to evaluate the current level of "completeness" of the scope definition package. Assume that at the time of this particular evaluation the scope development effort is underway, but it is not yet complete.

Your responsibility is to evaluate how well the project infrastructure requirements have been identified and defined to date. This information is covered in Category J of the PDRI as shown below and consists of three elements: "Water Treatment Requirements," "Loading / Unloading / Storage Facilities Requirements," and "Transportation Requirements."

CATEGORY Element	**Definition Level**						**Score**
	0	**1**	**2**	**3**	**4**	**5**	
J. INFRASTRUCTURE (Maximum Score = 25)							
J1. Water Treatment Requirements	0	1	3	5	7	10	
J2. Loading / Unloading / Storage Facilities Req'mts	0	1	3	5	7	10	
J3. Transportation Requirements	0	1				5	
CATEGORY J TOTAL							

Definition Levels

0 = Not Applicable **2 = Minor Deficiencies** **4 = Major Deficiencies**
1 = Complete Definition **3 = Some Deficiencies** **5 = Incomplete or Poor Definition**

To fill out Category J, Infrastructure, follow these steps:

Step 1: Read the description for each element in Appendix C (page 58). Some elements contain a list of items to be considered when evaluating their levels of definition. These lists may be used as checklists.

Step 2: Collect all data that you may need to properly evaluate and select the definition level for each element in this category. This may require obtaining input from other individuals involved in the scope development effort.

Step 3: Select the definition level for each element as described below and shown on the next page.

Element J1: Requirements for treating process and sanitary wastewater have been well defined. However, procedures for handling storm water runoff and treatment have not been identified. You feel that this element has some *minor deficiencies* that should be addressed prior to authorization of the project. **Definition Level = 2**.

Element J2: Your team decides that this element is *not applicable* to your particular project. **Definition Level = 0**.

Element J3: Although your team plans to specify methods for receiving and shipping materials within the plant, it has not yet been done. This element is to be evaluated on a Yes/No basis. It is *incomplete*. **Definition Level = 5**.

CATEGORY Element	Definition Level 0	1	2	3	4	5	Score
J. INFRASTRUCTURE (Maximum Score = 25)							
J1. Water Treatment Requirements	0	1	(3)	5	7	10	3
J2. Loading / Unloading / Storage Facilities Req'mts	(0)	1	3	5	7	10	0
J3. Transportation Requirements	0	1				(5)	5
CATEGORY J TOTAL							**8**

<u>**Definition Levels**</u>

0 = Not Applicable
1 = Complete Definition
2 = Minor Deficiencies
3 = Some Deficiencies
4 = Major Deficiencies
5 = Incomplete or Poor Definition

<u>Step 4</u>: For each element, write the score that corresponds to its level of definition in the "Score" column. Add the element scores to obtain a category score. In this example, Category J has a total score of 8.

Repeat this process for each element in the PDRI. Add element scores to obtain category scores. Add category scores to obtain section scores. Add section scores to obtain a total PDRI score. A completed PDRI score sheet for a power plant project is included in Appendix D for reference.

Ideally, the project team gets together to conduct a single PDRI evaluation. If that is not possible, an alternate approach is to have key individuals evaluate the project separately, then come together and evaluate it together and reach a meeting of the minds.

Once a score is obtained, it can be analyzed in various ways in order to determine a project's probability of success. The real benefit of the PDRI is realized when scores are correlated with a measurement of project success. The following chapter will help you analyze your score and determine the strong and weak areas in your scope definition package.

CHAPTER 4 : WHAT DOES A PDRI SCORE MEAN?

A low PDRI score represents a project definition package that is well defined and, in general, corresponds to an increased probability for project success. Higher scores signify that certain elements within the project definition package lack adequate definition.

To validate the quality of the PDRI, the Front End Planning Research Team tested it on thirty-two projects. For each of these projects, PDRI scores and project success ratings were computed. An analysis of these data yielded a strong correlation between low (good) PDRI scores and high project success.

The analysis revealed that a significant difference in performance between the projects scoring above 200 and the projects scoring below 200.

The validation projects scoring below 200 outperformed those scoring above 200 in three important design/construction outcome areas: cost performance, schedule performance, and the relative value of change orders compared to the authorized cost, as shown in Figure 4.1. The validation project results are discussed in greater detail in Appendix E.

Performance	PDRI Score < 200	PDRI Score > 200	Δ
Cost	-5.1%	+18.0%	+23.1%
Schedule	+0.8%	+14.0%	+13.2%
Change Orders	+2.6%	+7.7%	+5.0%
	(N= 18)	(N = 14)	

Figure 4.1. Summary of Cost, Schedule, and Change Order Performance for the PDRI Validation Projects Using a 200 Point Cutoff

ANALYZING PDRI SCORES -- WHAT TO LOOK FOR?

Of course, the PDRI is of little value unless the user takes action based on the analysis and uses it in management of the project. Among the potential uses when analyzing the PDRI score are the following:

- Track project progress during pre-project planning using the PDRI score as a macro-evaluation tool. Individual elements, categories, and sections can be tracked as well. Remember that the method of scoring the project over time (whether individual or team-based) should be consistent because it is a subjective rating.
- Compare project to project scores over time in order to look at trends in developing scope definition within your organization.
- Compare different types of projects (e.g., pharmaceutical v. petrochemical v. steel mill; or grass roots v. retrofit) and determine your acceptable PDRI score for those projects and identify critical success factors from that analysis. It can also be used to compare projects done for different clients or different size projects with the same client.

- Determine a comfort level (PDRI score) at which you are willing to authorize projects. Depending on the nature of your business, your internal scope definition practices and requirements, etc., you may wish to use a score other than 200 as a benchmark for project authorization.
- Look at weak areas for your project on a section, category, or element level for each project over time. For instance, if 14 of the 70 elements rate 5 (no definition), 20 percent of the elements are not defined at all. By adding these element's scores, one can see how much risk they bring to the project relative to 1000 points. This provides an effective method of risk analysis since each element, category and section is weighted relative to each other in terms of potential risk exposure. Use the PDRI score to redirect effort by the project team.
- The individual element scores can be used to highlight the "critical few" elements either through that element's score or definition level. Also, remember that these scores were developed for a generic project. Your project, however, may have unique requirements that must be met. Therefore, examine the level of definition in some amount of detail.

Oftentimes, market demand or other pressures to reduce project cycle times warrant the authorization of projects with underdeveloped definition. In these instances, the amount of time available for defining the scope of the project decreases. Thus, the ability to quickly and accurately predict factors that may impact project risk becomes more critical. To minimize the possibility of problems during the detailed design, construction, and startup phases of a project, the pre-project planning effort should focus on the critical few elements that, if poorly defined, could have the greatest potential to negatively impact project performance. Figures 4.2 and 4.3 summarize the ten highest ranking elements dealing with the business and technical issues involved in the planning of an industrial project, respectively. Descriptions for these elements are given in Appendix C.

1. Products
2. Capacities
3. Technology
4. Processes
5. Site Characteristics Available vs. Required
6. Market Strategy
7. Project Objectives Statement
8. Project Strategy
9. Project Design Criteria
10. Reliability Philosophy

TOTAL POINTS = 350 / 1000

Figure 4.2. Ten Highest Ranking *Business* Elements

1.	Process Flow Sheets
2.	Site Location
3.	P&ID's
4.	Heat & Material Balances
5.	Environmental Assessment
6.	Utility Sources With Supply Conditions
7.	Mechanical Equipment List
8.	Specifications - Process / Mechanical
9.	Plot Plan
10.	Equipment Status
	TOTAL POINTS = 229 / 1000

Figure 4.3. Ten Highest Ranking *Technical* Elements

POTENTIAL PDRI APPLICATIONS

You may wish to keep your own database of PDRI scores for various project sizes and types. As more projects are completed and scored using the PDRI, your ability to accurately predict the probability of success on future projects should improve. The PDRI may serve as a gauge for your company in deciding whether or not to authorize the detailed design and construction of a project. You may also wish to use it as an external benchmark for measurement against the practices of other industry leaders.

Once a PDRI score is obtained, it is important to correlate the score to a measurement of project success. The measurement of project success used by the Front End Planning Research Team is a project success rating based upon critical performance factors in the execution and operation of the capital facility. In general, lower PDRI scores represent scope definition packages that are well-defined and correspond to higher project success ratings. Higher PDRI scores, on the other hand, signify that certain elements in the scope definition package lack adequate definition and, if authorization is granted, result in poorer project performance and a lower success rating. An explanation in Appendix E includes instructions for measuring project success, specifically addressing the method of computing values for each of variables comprising the success rating index.

You will probably want to track your project estimates minus contingency when plotting them versus the PDRI scores. The original estimates are then compared to the final outcome of the project to evaluate its success versus these goals. (Note that the authorization values used in Appendix E are the project estimates with contingency and allowances included). Plot these authorization estimates to develop a curve for determining contingency allowance on future projects. See the Contingency plots located in Appendix E as an example. The more projects you plot, the more accurate your ability to predict contingency.

USE OF PDRI ON SMALL PROJECTS

The PDRI can be customized to meet each company's needs. If necessary, it can be "scaled-down" for use on smaller projects, such as retrofit projects which tend to be short in duration.

In recent years the U.S. construction industry has seen an increase in the number of long-term partnering relationships between owners and E/P/C contractors. Oftentimes, owners select their E/P/C partners for performing engineering and/or construction on their retrofit/upgrade improvement projects. These projects are “small” and frequent in nature as well as short in duration. On an individual basis, the scope of these projects may not encompass many of the elements contained in the PDRI. In particular, some of the Business Decision elements found in Section I of the PDRI may not be clearly defined on these projects. Although business planning is generally performed on an owner's overall program of small projects, it may be difficult to determine if specific business decisions directly apply to one individual project.

In these situations a company wishing to incorporate the PDRI into their pre-project planning program may need to customize it to fit the needs of their smaller projects. Since the PDRI was purposely developed to be generic in nature, a company can delete any elements that specifically do not apply on certain types of projects.

If a company decides to create a scaled-down version of the PDRI, it must be aware of the fact that this procedure will alter the maximum possible score from 1000 points to some lower number. Each time an element is deleted from the checklist, the maximum score for the project is reduced by that element's total weight. Further, not only will the maximum score be reduced, but the lowest possible score that can be achieved with complete definition also will drop from 70 points to some lower number.

Any company choosing to create a scaled-down version of the PDRI must also determine a new target score at which they feel comfortable authorizing a project for detailed design and construction. Although the research presented in this document suggests that a total score of 200 be reached in order to improve the chances for project success, a company using a scaled-down version of the PDRI will have to collect internal data and determine its own threshold authorization score. For example, if the company's scaled-down version has a maximum possible score of 752 (after certain elements are deleted from the score sheet), it may determine that a score of 150 must be reached before authorizing its small projects for execution.

A more appropriate alternative for identifying a target value may be to determine a certain percentage of the scaled-down maximum score that must be reached before the project will be authorized, rather than striving for a specific score such as 150 points. Instead of reaching 150 point the company may choose to ensure that 80% of the project's definition be complete, for example, before authorization. In effect, this yields the same results, however, given the lower risk generally associated with smaller projects, a percentage may be a more meaningful value. Of course, the threshold score (or percentage) may vary depending on the owner's comfort level and experience with the engineering and construction firms selected for the project.

To further refine its scaled-down version, a company may wish to keep its own database of PDRI scores for small projects. As more projects are completed and scored using the PDRI, the company's ability to accurately predict the probability of success on future projects should improve.

CHAPTER 5 : CONCLUDING REMARKS

The Project Definition Rating Index (PDRI) can benefit both owner and contractor companies. Owner companies can use it as an assessment tool for establishing a comfort level at which they are willing to authorize projects. Contractors can use it as a means of negotiating with owners in identifying poorly defined project scope definition elements. The PDRI provides a forum for all project participants to communicate and reconcile differences using an objective tool as a common basis for project scope evaluation. Anyone wishing to improve the overall performance on their industrial projects should use the PDRI.

HOW TO IMPROVE PERFORMANCE ON FUTURE PROJECTS

Based on the results of the research and the experience of the Front End Planning Research Team, the following suggestions are offered to individuals or companies who adopt the PDRI with the desire to improve performance on their industrial projects:

- **Commit to pre-project planning.** Previous research has confirmed that effective planning in the early stages of industrial projects can greatly enhance cost, schedule, and operational performance while minimizing the possibility of financial failures and disasters.

- **Use the <u>Pre-Project Planning Handbook</u> developed by CII.** It outlines in detail all of the steps required for ensuring the successful execution of pre-project planning on capital projects (CII 1995). The PDRI fits well into Chapter 4 of the Handbook which discusses the development of a project definition package. However, the PDRI can be used at any point in the pre-project planning process to monitor progress and redirect future scope definition efforts.

- Use the PDRI as a tool to **gain and maintain project team alignment** during pre-project planning. Research has shown that scope definition checklists are effective in helping with team alignment.

- **Adjust the PDRI as necessary to meet the specific needs of your project.** The PDRI was designed so that certain elements considered not applicable on a particular project can be "zeroed out," thus eliminating them from the final scoring calculation.

- **Use the PDRI to continuously improve project performance.** Build your own internal database of projects that are scored using the PDRI. Compute PDRI scores at the time of authorization along with success ratings once projects are completed using the criteria presented in this document. Based upon the relationship between PDRI scores and project success, establish your own basis for the level of scope definition that you feel is acceptable for authorizing future projects.

- **Use caution when authorizing projects with PDRI scores greater than 200.** Research has shown a direct correlation between high PDRI scores and poor project performance.

- **Use the PDRI on every project!** It is the only publicly available tool of its kind that can effectively quantify, rate, and assess the level of scope development on industrial projects prior to authorization for detailed design and construction.

POTENTIAL USES OF THE PDRI

The PDRI is a “best practice” tool that will provide numerous benefits to the construction industry. Research has shown that the PDRI can effectively be used to improve the predictability of project performance. However, the PDRI alone will not ensure successful projects but, if combined with sound business planning, alignment, and good project execution, it can greatly improve the probability of meeting or exceeding project objectives.

APPENDIX A : HOW THE PDRI WAS DEVELOPED

The CII Front End Planning Research Team was formed in 1994 to produce effective, simple, and easy-to-use pre-project planning tools that extend the work of the Pre-Project Planning Research Team so that owner and contractor companies can better achieve business, operational, and project objectives. To accomplish the goal of developing scope definition tools, the Front End Planning Research Team established the following objectives:

> Quantify scope definition efforts and correlate them to the predictability of achieving project objectives. Secondary objectives included:
>
> - Produce a tool for measuring project scope development based on industry best practices and a methodology for benchmarking the degree of scope definition through the use of a weighted index. This weighted index is called the Project Definition Rating Index (PDRI).
> - Develop three versions of the PDRI -- one for industrial, one for commercial, and one for infrastructure projects.
> - Ensure that the PDRI is easy to use and understand.

In order to meet its objectives, the research team decided to develop an industrial projects version of the PDRI first, as this version best aligned with the majority of the members' expertise. They began by examining past research in project scope definition. In addition to the work completed by the Pre-Project Planning Research Team, previous studies by CII and by the Rand Corporation discuss the reasons why inadequate scope definition has traditionally been a problem on construction projects resulting in cost overruns and poor project performance (Broaddus 1995, Merrow et al. 1981, Merrow 1988, Myers and Shangraw 1986, and Smith and Tucker 1983). John W. Hackney (1992) pioneered one of the first attempts at quantifying and defining the specific elements required for proper scope definition. Although his work is good, it has not been widely accepted, perhaps due to its complexity. Apart from Hackney's work, however, the research team found the industry lacking in a non-proprietary method for benchmarking the level of the pre-project planning effort or the degree of scope definition on a project. Further, the industry lacked documentation defining the differences between the scope definition requirements for industrial, building, and infrastructure projects. From these findings, the research team realized that its primary challenge was to develop a simple and easy-to-use tool for project scope definition. This tool must identify and precisely define each critical element in a scope definition package and allow a project team to quickly predict factors impacting project risk.

To develop a detailed list of the required elements within a good scope definition package, the research team utilized four primary sources: their internal expertise, a literature review, documentation from a variety of owner and contractor companies, and a separate workshop of project managers and estimators. Rough topic categories were obtained from Hackney, previous CII work, and through using the team's internal expertise. This preliminary list was expanded using scope definition documentation from 14 owner and contractor companies. Through affinity diagramming and nominal group techniques, the list was further refined and agreement reached regarding exact terms and nomenclature of element descriptions. Once this was completed, a separate workshop of six individuals representing one owner and three engineering/construction companies who had not seen the approach previously was held to "fine tune" the list of elements and their descriptions. The final list consists of seventy elements grouped into fifteen categories and further grouped into three main sections. This list, which forms the basis of the Project Definition Rating Index, is presented earlier in Figure 1.2.

Since the team hypothesized that all elements were not equally important with respect to their potential impact on overall project success, each needed to be weighted relative to one another. Higher weights were to represent the most important elements that, if completely undefined, would have the greatest effect on the accuracy of the total installed cost (TIC) estimate at authorization. To develop credible weights, the research team felt that a broad range of industry expertise would provide the best input. Therefore, fifty-four experienced project managers and estimators representing a mix of thirty-one owner and contractor companies were invited to two workshops. One workshop was held in the Northeast and the other in the Southwest to obtain an equitable representation from different geographic regions. At each workshop, the participants were asked to weight each element in importance based upon their own experience. This input then was used to determine the individual element weights. A total of 38 usable scores sheets resulted from these workshops. The individual element weights are shown in the Project Score Sheet in Appendix B. The magnitude of the weights assigned to each element in column 5 (incomplete or poor definition) indicate the relative importance of each element in the scope definition package.

The weighting process is fairly complex and beyond the scope of this Handbook. Suffice it to say that each of the 38 weighted score sheets were based on a standard project that the respondent, or respondent team, had recently completed. The respondent scored each element based on the impact that it would have on total installed cost of the facility in question in terms of level of definition. The 38 score sheets were then each normalized to 1000 points to produce a mean value for each element. Statistical tests were performed looking at standard deviation, kurtosis, and skewness of the individual element weights. The completed PDRI was also used to score several real projects as a validation of its effectiveness. For more information on this methodology see Gibson and Dumont (1995).

APPENDIX B : PROJECT SCORE SHEET

SECTION I - BASIS OF PROJECT DECISION							
CATEGORY Element	**Definition Level**						**Score**
	0	**1**	**2**	**3**	**4**	**5**	
A. MANUFACTURING OBJECTIVES CRITERIA (Maximum Score = 45)							
A1. Reliability Philosophy	0	1	5	9	14	20	
A2. Maintenance Philosophy	0	1	3	5	7	9	
A3. Operating Philosophy	0	1	4	7	12	16	
CATEGORY A TOTAL							
B. BUSINESS OBJECTIVES (Maximum Score = 213)							
B1. Products	0	1	11	22	33	56	
B2. Market Strategy	0	2	5	10	16	26	
B3. Project Strategy	0	1	5	9	14	23	
B4. Affordability/Feasibility	0	1	3	6	9	16	
B5. Capacities	0	2	11	21	33	55	
B6. Future Expansion Considerations	0	2	3	6	10	17	
B7. Expected Project Life Cycle	0	1	2	3	5	8	
B8. Social Issues	0	1	2	5	7	12	
CATEGORY B TOTAL							
C. BASIC DATA RESEARCH & DEVELOPMENT (Maximum Score = 94)							
C1. Technology	0	2	10	21	39	54	
C2. Processes	0	2	8	17	28	40	
CATEGORY C TOTAL							
D. PROJECT SCOPE (Maximum Score = 120)							
D1. Project Objectives Statement	0	2				25	
D2. Project Design Criteria	0	3	6	11	16	22	
D3. Site Characteristics Available vs. Req'd	0	2				29	
D4. Dismantling and Demolition Req'mts	0	2	5	8	12	15	
D5. Lead/Discipline Scope of Work	0	1	4	7	10	13	
D6. Project Schedule	0	2				16	
CATEGORY D TOTAL							
E. VALUE ENGINEERING (Maximum Score = 27)							
E1. Process Simplification	0	0				8	
E2. Design & Material Alts. Considered/Rejected	0	0				7	
E3. Design For Constructability Analysis	0	0	3	5	8	12	
CATEGORY E TOTAL							
Section I Maximum Score = 499				**SECTION I TOTAL**			

Definition Levels

0 = Not Applicable
1 = Complete Definition
2 = Minor Deficiencies
3 = Some Deficiencies
4 = Major Deficiencies
5 = Incomplete or Poor Definition

SECTION II - FRONT END DEFINITION

CATEGORY Element	Definition Level						Score
	0	1	2	3	4	5	
F. SITE INFORMATION (Maximum Score = 104)							
F1. Site Location	0	2				32	
F2. Surveys & Soil Tests	0	1	4	7	10	13	
F3. Environmental Assessment	0	2	5	10	15	21	
F4. Permit Requirements	0	1	3	5	9	12	
F5. Utility Sources with Supply Conditions	0	1	4	8	12	18	
F6. Fire Protection & Safety Considerations	0	1	2	4	5	8	
CATEGORY F TOTAL							
G. PROCESS / MECHANICAL (Maximum Score = 196)							
G1. Process Flow Sheets	0	2	8	17	26	36	
G2. Heat & Material Balances	0	1	5	10	17	23	
G3. Piping & Instrumentation Diagrams (P&ID's)	0	2	8	15	23	31	
G4. Process Safety Management (PSM)	0	1	2	4	6	8	
G5. Utility Flow Diagrams	0	1	3	6	9	12	
G6. Specifications	0	1	4	8	12	17	
G7. Piping System Requirements	0	1	2	4	6	8	
G8. Plot Plan	0	1	4	8	13	17	
G9. Mechanical Equipment List	0	1	4	9	13	18	
G10. Line List	0	1	2	4	6	8	
G11. Tie-in List	0	1	2	3	4	6	
G12. Piping Specialty Items List	0	1	1	2	3	4	
G13. Instrument Index	0	1	2	4	5	8	
CATEGORY G TOTAL							
H. EQUIPMENT SCOPE (Maximum Score = 33)							
H1. Equipment Status	0	1	4	8	12	16	
H2. Equipment Location Drawings	0	1	2	5	7	10	
H3. Equipment Utility Requirements	0	1	2	3	5	7	
CATEGORY H TOTAL							
I. CIVIL, STRUCTURAL, & ARCHITECTURAL (Maximum Score = 19)							
I1. Civil/Structural Requirements	0	1	3	6	9	12	
I2. Architectural Requirements	0	1	2	4	5	7	
CATEGORY I TOTAL							
J. INFRASTRUCTURE (Maximum Score = 25)							
J1. Water Treatment Requirements	0	1	3	5	7	10	
J2. Loading/Unloading/Storage Facilities Req'mts	0	1	3	5	7	10	
J3. Transportation Requirements	0	1				5	
CATEGORY J TOTAL							

Definition Levels

0 = Not Applicable
1 = Complete Definition
2 = Minor Deficiencies
3 = Some Deficiencies
4 = Major Deficiencies
5 = Incomplete or Poor Definition

SECTION II - FRONT END DEFINITION (continued...)							
CATEGORY Element	Definition Level						Score
	0	**1**	**2**	**3**	**4**	**5**	
K. INSTRUMENT & ELECTRICAL (Maximum Score = 46)							
K1. Control Philosophy	0	1	3	5	7	10	
K2. Logic Diagrams	0	1				4	
K3. Electrical Area Classifications	0	0	2	4	7	9	
K4. Substation Req'mts Power Sources Ident.	0	1	3	5	7	9	
K5. Electric Single Line Diagrams	0	1	2	4	6	8	
K6. Instrument & Electrical Specifications	0	1	2	3	5	6	
CATEGORY K TOTAL							
Section II Maximum Score = 423					**SECTION II TOTAL**		

SECTION III - EXECUTION APPROACH							
CATEGORY Element	Definition Level						Score
	0	**1**	**2**	**3**	**4**	**5**	
L. PROCUREMENT STRATEGY (Maximum Score = 16)							
L1. Identify Long Lead/Critical Equip. & Mat'ls	0	1	2	4	6	8	
L2. Procurement Procedures and Plans	0	0	1	2	4	5	
L3. Procurement Responsibility Matrix	0	0				3	
CATEGORY L TOTAL							
M. DELIVERABLES (Maximum Score = 9)							
M1. CADD/Model Requirements	0	0	1	1	2	4	
M2. Deliverables Defined	0	0	1	2	3	4	
M3. Distribution Matrix	0	0				1	
CATEGORY M TOTAL							
N. PROJECT CONTROL (Maximum Score = 17)							
N1. Project Control Requirements	0	0	2	4	6	8	
N2. Project Accounting Requirements	0	0	1	2	2	4	
N3. Risk Analysis	0	1				5	
CATEGORY N TOTAL							

Definition Levels

0 = Not Applicable **2 = Minor Deficiencies** **4 = Major Deficiencies**
1 = Complete Definition **3 = Some Deficiencies** **5 = Incomplete or Poor Definition**

SECTION III - EXECUTION APPROACH (continued...)							
CATEGORY Element	Definition Level						Score
	0	1	2	3	4	5	
P. PROJECT EXECUTION PLAN (Maximum Score = 36)							
P1. Owner Approval Requirements	0	0	2	3	5	6	
P2. Engineering/Construction Plan & Approach	0	1	3	5	8	11	
P3. Shut Down/Turn-Around Requirements	0	1				7	
P4. Pre-Commiss. Turnover Sequence Req'mts	0	1	1	2	4	5	
P5. Startup Requirements	0	0	1	2	3	4	
P6. Training Requirements	0	0	1	1	2	3	
						CATEGORY PTOTAL	
Section III Maximum Score = 78						**SECTION III TOTAL**	

PDRI TOTAL SCORE

(Maximum Score = 1000)

<u>Definition Levels</u>

0 = Not Applicable
1 = Complete Definition
2 = Minor Deficiencies
3 = Some Deficiencies
4 = Major Deficiencies
5 = Incomplete or Poor Definition

APPENDIX C : ELEMENT DESCRIPTIONS

The following descriptions have been developed to help generate a clear understanding of the terms used in the Project Score Sheet located in Appendix B. Some descriptions include checklists to clarify concepts and facilitate ideas when scoring each element.

The descriptions are listed in the same order as they appear in the Project Score Sheet. They are organized in a hierarchy by section, category, and element, as shown earlier in Figure 1.1. The Project Score Sheet consists of three main sections, each of which is broken down into a series of categories which, in turn, are further broken down into elements. Scoring is performed by evaluating the levels of definition of the elements, which are described in this appendix. The sections and categories are organized as follows:

SECTION I BASIS OF PROJECT DECISION

This section consists of information necessary for understanding the project objectives. The completeness of this section determines the degree to which the project team will be able to achieve alignment in meeting the project's business objectives.

CATEGORIES:

A - Manufacturing Objectives Criteria
B - Business Objectives
C - Basic Data Research & Development
D - Project Scope
E - Value Engineering

SECTION II FRONT END DEFINITION

This section consists of processes and technical information elements that should be evaluated to fully understand the scope of the project.

CATEGORIES:

- **F - Site Information**
- **G - Process / Mechanical**
- **H - Equipment Scope**
- **I - Civil, Structural, & Architectural**
- **J - Infrastructure**
- **K - Instrument & Electrical**

SECTION III EXECUTION APPROACH

This section consists of elements that should be evaluated to fully understand the requirements of the owner's execution strategy.

CATEGORIES:

- **L - Procurement Strategy**
- **M - Deliverables**
- **N - Project Control**
- **P - Project Execution Plan**

The following pages contain detailed descriptions for each element in the Project Definition Rating Index (PDRI).

SECTION I - BASIS OF PROJECT DECISION

A. MANUFACTURING OBJECTIVES CRITERIA

A1. Reliability Philosophy

A list of the general design principles to be considered to achieve dependable operating performance from the unit. Evaluation criteria should include:

- Justification of spare equipment
- Control, alarm, and safety systems redundancy
- Extent of providing surge and intermediate storage capacity to permit independent shutdown of portions of the plant
- Mechanical / structural integrity of components (metallurgy, seals, types of couplings, bearing selection, etc.)

A2. Maintenance Philosophy

A list of the general design principles to be considered to meet unit up-time requirements. Evaluation criteria should include:

- Scheduled unit / equipment shutdown frequencies and durations
- Equipment access / monorails / cranes
- Maximum weight or size requirements for available repair equipment
- Equipment monitoring requirements (vibrations monitoring, etc.)

A3. Operating Philosophy

A list of the general design principles that need to be considered to support the routine scheduled production from the unit in order to achieve the projected overall on-stream time or service factor. Evaluation criteria should include:

- Level of operator coverage and automatic control to be provided
- Operating time sequence (ranging from continuous operation to five day, day shift only)
- Necessary level of segregation and clean out between batches or runs
- Desired unit turndown capability
- Design requirements for routine startup and shutdown

B. BUSINESS OBJECTIVES

B1. Products

A list of product(s) to be manufactured and their specifications. It should address items such as:

- Chemical composition
- Physical form
- Raw materials
- Allowable impurities
- By-products
- Wastes

B2. Market Strategy

Has a market strategy been developed and clearly communicated? It must identify the driving forces (other than safety) for the project and specify what is most important from the viewpoint of the business group. It should address items such as:

- Cost
- Schedule
- Quality

B3. Project Strategy

Has a project strategy been defined that supports the market strategy in relation to the following items:

- Cost
- Schedule
- Quality

B4. Affordability / Feasibility

Have items that may improve the affordability of the project been considered? These should include incremental cost criteria such as:

- Consideration of feedstock availability and transport to the job site
- Performing an analysis of capital and operating cost versus sales and profitability

Results of these studies should be communicated to the project team.

B5. Capacities

The design output of a given specification product from the unit. Capacities are usually defined as:

- On-stream factors
- Yield
- Design rate

B6. Future Expansion Considerations

A list of items to be considered in the unit design that will facilitate future expansion. Evaluation criteria should include:

- Providing space for a possible new reactor train
- Providing tie-ins to permit a duplicate or mirror image unit that can be added without necessitating a shutdown
- Guidelines for over design of structural systems to allow for additions

B7. Expected Project Life Cycle

This is the time period that the unit is expected to be able to satisfy the products and capacities required. Have requirements for ultimate disposal and dismantling been considered? These requirements should include:

- Cost of ultimate dismantling and disposal
- Dismantling equipment requirements
- Presence of contaminants
- Disposal of hazardous materials
- Possible future uses

B8. Social Issues

Evaluation of various social issues such as:

- Domestic culture vs. international culture
- Community relations
- Labor relations
- Government relations
- Education / training
- Safety and health considerations

C. BASIC DATA RESEARCH & DEVELOPMENT

C1. Technology

The chemistry used to convert the raw materials supplied to the unit into the finished product. Proven technology involves least risk, while experimental technology has a potential for change. Technology can be evaluated as:

- Existing / proven
- Duplicate
- New
- Experimental

C2. Processes

A particular, specific sequence of steps to change the raw materials into the finished product. Proven processes involve the least risk, while experimental processes have a potential for change. Processes can be evaluated as:

- Existing / proven
- Duplicate
- New
- Experimental

D. PROJECT SCOPE

D1. Project Objectives Statement (Y/N)

This is a mission statement that defines the project objectives and priorities for meeting the business objectives. It is important to obtain total agreement from the entire project team regarding these objectives and priorities to ensure alignment.

D2. Project Design Criteria

The requirements and guidelines which govern the design of the project. Evaluation criteria should include:

- Level of design detail required
- Climatic data
- Codes & standards
  - National
  - Local
- Utilization of engineering standards
  - Owner's
  - Contractor's
  - Mixed

D3. Site Characteristics Available vs. Required (Y/N)

An assessment of the available vs. the required site characteristics. Evaluation criteria should include:

- Capacity
  - Utilities
  - Fire water
  - Flare systems
  - Cooling water
  - Storm water containment system
  - Power
  - Pipe racks
  - Waste treatment / disposal
- Type of buildings / structures
- Amenities
  - Food service
  - Change rooms
  - Medical facilities
  - Recreation facilities
  - Ambulatory access
- Product shipping facilities
- Material receiving facilities
- Material storage facilities
- Product storage facilities
- Security

D4. Dismantling and Demolition Requirements

Has a scope of work been defined for the dismantling of existing equipment and/or piping which may be necessary for completing new construction? Evaluation criteria should include:

- Timing
- Permits
- Approval
- Safety requirements
- Hazardous operations
- Plant / operations requirements
- Narrative (scope of work) for each system
- Are the systems that will be dismantled...
  - Named & marked on process flow diagrams
  - Named & marked on P&ID's
  - Denoted on line lists and equipment lists
  - Denoted on piping plans or photo-drawings

D5. Lead / Discipline Scope of Work

This is a complete narrative description of the project, generally discipline oriented. This should be developed through the use of the Work Breakdown Structure (WBS) (Halpin et al. 1987).

D6. Project Schedule (Y/N)

Has the project milestone schedule been developed, analyzed, and agreed upon by the major project participants? This should involve obtaining early constructability input from:

- Operations
- Engineering
- Construction

E. VALUE ENGINEERING

E1. Process Simplification (Y/N)

Identify activities (through studies, reviews, etc.) for reducing the number of steps or the amount of equipment needed in the process in order to optimize performance.

E2. Design & Material Alternatives Considered / Rejected (Y/N)

Is there a structured approach in place to consider design and material alternatives? Has it been implemented?

E3. Design For Constructability Analysis

Is there a structured approach for constructability analysis in place? Have provisions been made to provide this on an ongoing basis? This would include examining design options that minimize construction costs while maintaining standards of safety, quality, and schedule.

CII defines constructability as, "the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives. Maximum benefits occur when people with construction knowledge and experience become involved at the very beginning of a project" (CII 1986).

SECTION II - FRONT END DEFINITION

F. SITE INFORMATION

F1. Site Location (Y/N)

Has the geographical location of the proposed project been defined? This involves an assessment of the relative strengths and weaknesses of alternate site locations. A site that meets owner requirements and maximizes benefits for the owner company should be selected. Evaluation of sites may address issues relative to different types of sites (i.e. global country, local, "inside the fence," or "inside the building"). This decision should consider the long-term needs of the owner company (CII 1995). The selection criteria should include items such as:

- General geographic location
  - Access to the targeted market area
  - Near sources of raw materials
  - Local availability and cost of skilled labor (e.g. construction, operation, etc.)
  - Available utilities
  - Existing facilities
- Land availability and costs
- Access (e.g. road, rail, marine, air, etc.)
- Construction access and feasibility
- Political constraints
- Legal constraints
- Regulatory constraints
- Financing requirements
- Social issues
- Weather
- Climate

F2. Surveys & Soil Tests

Survey and soil test evaluations of the proposed site should include items such as:

- Topography map
- Overall plant plot plan
- General site description (e.g. terrain, existing structures, spoil removal, areas of hazardous waste, etc.)
- Definition of final site elevation
- Benchmark control system
- Spoil area (i.e. location of on-site area or off-site instructions)
- Seismic requirements
- Water table
- Soil percolation rate & conductivity
- Existing contamination
- Ground water flow rates and directions
- Downstream uses of ground water
- Need for soil treatment or replacement
- Description of foundation types
- Allowable bearing capacities
- Pier / pile capacities

F3. Environmental Assessment

Evaluation of the site by characteristics such as:

- Location in an EPA air quality non-compliance zone
- Location in a wet lands area
- Environmental permits now in force
- Location of nearest residential area
- Ground water monitoring in place
- Containment requirements
- Existing environmental problems with the site
- Past / present use of site

F4. Permit Requirements

Is there a permitting plan in place? The local, state, and federal government permits necessary to construct and operate the unit should be identified. These should include items such as:

- Construction
- Local
- Environmental
- Transportation
- Fire
- Building
- Occupancy
- Special

F5. Utility Sources With Supply Conditions

Has a list been made identifying availability / nonavailability of site utilities needed to operate the unit with supply conditions of temperature, pressure, and quality? This should include items such as:

- Potable water
- Drinking water
- Cooling water
- Fire water
- Sewers
- Electricity (voltage levels)
- Instrument air
- Plant air
- Gases
- Steam
- Condensate

F6. Fire Protection & Safety Considerations

A list of fire and safety related items to be taken into account in the design of the facility. These items should include fire protection practices at the site, available firewater supply (amounts and conditions), special safety requirements unique to the site, etc. Evaluation criteria should include:

- Eye wash stations
- Safety showers
- Fire monitors & hydrants
- Foam
- Evacuation plan
- Security fencing
- Deluge requirements
- Wind direction indicator devices (i.e. wind socks)
- Alarm systems
- Medical facilities

G. PROCESS / MECHANICAL

G1. Process Flow Sheets

Drawings that provide the process description of the unit. Evaluation criteria should include:

- Major equipment items
- Flow of materials to and from the major equipment items
- Primary control loops for the major equipment items
- Sufficient information to allow sizing of all process lines

G2. Heat & Material Balances

Heat balances are tables of heat input and output for major equipment items (including all heat exchangers) within the unit. Material balances are tables of material input and output for all equipment items within the unit. The documentation of these balances should include:

- Special heat balance tables for reaction systems
- Information on the conditions (e.g. temperature and pressure)
- Volumetric amount (GPM, ACFM, etc.)

G3. Piping and Instrumentation Diagrams (P&ID's)

These are often referred to by different companies as:

EFD's - Engineering Flow Diagrams
MFD's - Mechanical Flow Diagrams
PMCD's - Process & Mechanical Control Diagrams

In general, P&ID's are considered to be a critical element within the scope definition package of an industrial project. Since incomplete information on P&ID's is frequently identified as a source of project escalation, it is important to understand their level of completeness. It often requires several iterations, or passes, to obtain all of the necessary information from each discipline specialist. During each iteration, additional information is added to the P&ID's. Thus, it is unlikely for P&ID's to be completely defined in a project's scope definition package.

G3. Piping and Instrumentation Diagrams (P&ID's)
(continued...)

It is important, however, to assess which iterations have occurred to date as well as the items that have been defined or are currently being developed.

The following list can be used as an aid in evaluating the current state of development of the P&ID's.

- **EQUIPMENT**
  - Number of items
  - Name of items
  - Type or configuration
  - Spare item requirements
  - Data on & sizing of equipment / drive mechanisms
  - Horsepower / energy consumption
  - Nozzle sizes
  - Insulation / tracing
  - Vendor data (if vendor designed)
  - Seal arrangements (as required)
  - Packaged equipment details

- **PIPING**
  - Line sizes
  - Line specifications
  - Flow arrows and continuations
  - Secondary flows
  - Specification breaks
  - Insulation and tracing
  - Sample points
  - Reducers
  - Vent and sewer designations
  - Line numbers (supplied by piping)
  - Tie-ins designated
  - Any expansion and flexible joints shown
  - Piping design details added (as necessary)

G3. Piping and Instrumentation Diagrams (P&ID's)
(continued...)

- **VALVES**
  - Process needed valves
  - Valves needed for maintenance
  - Bypasses, blocks, and bleeds
  - Drains, vents, freeze protection, etc.
  - Type of valve designated
  - Non-line sized valves indicated
  - Control valves sized
  - Miscellaneous designated valves added
  - Valve tags added (not always done)
  - Valve design details added (as necessary)

- **PIPING SPECIALTY ITEMS**
  - Identification of items
  - Numbering of items (usually by piping)
  - Specialty item design details (as necessary)

- **UTILITIES**
  - Main connections and continuations
  - Remaining connections and continuations
  - Overall distribution and control
  - Utilities design details

- **INSTRUMENTATION**
  - Elements, loops, and functions
  - Primary elements
  - Local panel or control house location
  - Control panel or CRT location
  - Computer inputs and outputs
  - Process steam traps (may be specialty items)
  - Hard wired interlocks
  - Motor controls (need schematics)
  - Type of primary elements
  - Instrument numbers
  - Uniform logic control details
  - Indicator lights
  - Instrumentation design details (as necessary)

G3. Piping and Instrumentation Diagrams (P&ID's)
(continued...)

- **SAFETY SYSTEMS**
  - Process Safety Management Hazard Analysis review
  - Key process relief valves
  - Remaining relief valves
  - Failure mode of control valves
  - Car sealed valves (as necessary)
  - Relief valve sizes (instrumentation / process check)
  - Relief system line sizes
  - System design details (as necessary)

- **SPECIAL NOTATIONS**
  - Identification of sloped lines
  - Barometric legs (seals)
  - Critical elevations and dimensions
  - Vendor or designer supplied notes
  - Critical locations (valves, etc.)
  - Notes on venting or draining
  - Vessel trim notes
  - Startup and shutdown notes
  - Design detail notes (as necessary)

G4. Process Safety Management (PSM)

This refers to OSHA Regulation 1910.119 compliance requirements. Has the owner clearly communicated the requirements, methodology, and responsibility for the various activities?

G5. Utility Flow Diagrams

Utility flow diagrams are similar to P&ID's in that they show all utility lines from generation or supply (i.e. pipeline). They are generally laid out in a manner to represent the geographical layout of the plant.

Utility flow diagrams are evaluated using the same criteria as P&ID's.

G6. Specifications

General specifications for the design, performance, manufacturing, material, and code requirements should include items such as:

- Classes of equipment (e.g. pumps, exchangers, vessels, etc.)
- Process pipe heating
  - Process
  - Freeze
  - Jacketed
- Process pipe cooling
  - Jacketed
  - Traced
- Piping
- Protective coating
- Insulation
- Valves
- Bolts / gaskets

G7. Piping System Requirements

Pipe stress criteria should be provided to establish guidelines for analysis of piping systems and equipment such as:

- Allowable forces and moments on equipment
- Graphical representation of piping line sizes that require analysis based on:
  - Temperature
  - Pressure
  - Cyclic conditions
  - Flex
  - Stress
  - Pulsation
  - Seismic

G8. Plot Plan

The plot plan will show the location of new work in relation to adjoining units. It should include items such as:

- Plant grid system with coordinates
- Unit limits
- Gates & fences
- Off-site facilities
- Tank farms
- Roads & access ways
- Roads
- Rail facilities
- Green space
- Buildings
- Major pipe racks
- Laydown areas
- Construction / fabrication areas

G9. Mechanical Equipment List

The mechanical equipment list should identify all mechanical equipment by tag number, in summary format, to support the project. The list should define items such as:

- Existing sources
  - Modified
  - Dismantled
  - Relocated
  - Rerated
- New sources
  - Purchased new
  - Purchased used
- Relative sizes
- Weights
- Location
- Capacities
- Materials
- Power requirements
- Flow diagrams
- Design temperature and pressure
- Insulation & painting requirements
- Equipment related ladders and platforms

G10. Line List

The line list designates all pipe lines in the project (including utilities). It should include items such as:

- Unique number for each line
  - Size
  - Termination
  - Origin
  - Reference drawing
- Normal and upset operating
  - Temperature
  - Pressure
- Design temperature & pressure
- Test requirements
- Pipe specifications
- Insulation requirements
- Paint requirements

G11. Tie-in List

A list of all piping tie-ins to existing lines. It should include items such as:

- Location
- Insulation removal requirements
- Decontamination requirements
- Reference drawings
- Pipe specifications
- Timing / schedule
- Type of tie-in / size
  - Hot tap
  - Flange
  - Weld
  - Cold cut
  - Screwed
  - Cut & weld

G12. Piping Specialty Items List

This list is used to specify in-line piping items not covered by piping material specifications. It should identify all special items by tag number, in summary format. It should include items such as:

- Tag numbers
- Quantities
- Piping plans referenced
- Piping details
- Full purchase description
- Materials of construction
- P&ID's referenced
- Line / equipment numbers

G13. Instrument Index

This is a complete listing of all instruments by tag number. Evaluation criteria should include:

- Tag number
- Instrument type
- Service
- P&ID number
- Manufacturer
- Model number
- Line number
- Relieving devices (e.g. relief valves, rupture disks, etc.)

H. EQUIPMENT SCOPE

H1. Equipment Status

Has the equipment been defined, inquired, bid tabbed, or purchased? This includes all engineered equipment such as:

- Process
- Electrical
- Mechanical
- HVAC
- Instruments
- Specialty items
- Distributed control systems

Evaluation criteria should include:

- Equipment data sheets - how complete?
- Number of items inquired
- Number of items with approved bid tabs
- Number of items purchased

H2. Equipment Location Drawings

Equipment location / arrangement drawings identify the specific location of each item of equipment in a project. These drawings should identify items such as:

- Elevation views of equipment and platforms
- Top of steel for platforms and pipe racks
- Paving and foundation elevations
- Coordinates of all equipment

H3. Equipment Utility Requirements

This should consist of a tabulated list of utility requirements for all equipment items.

I. CIVIL, STRUCTURAL, & ARCHITECTURAL

I1. Civil / Structural Requirements

Civil / structural requirements should include the following:

- Structural drawings
- Pipe racks / supports
- Elevation views
- Top of steel for platforms
- High point elevations for grade, paving, and foundations
- Location of equipment and offices
- Construction materials (e.g. concrete, steel, client standards, etc.)
- Physical requirements
- Seismic requirements
- Minimum clearances
- Fireproofing requirements
- Corrosion control requirements / required protective coatings
- Enclosure requirements (e.g. open, closed, covered, etc.)
- Secondary containment
- Dikes
- Storm sewers
- Client specifications (e.g. basis for design loads, etc.)
- Future expansion considerations

I2. Architectual Requirements

The following checklist should be used in defining building requirements.

- Building use (e.g. activities, functions, etc.)
- Space use program indicating space types, areas required, and the functional relationships between spaces and number of occupants
- Service, storage, and parking requirements
- Special equipment requirements
- Requirements for building location / orientation
- Nature / character of building design (e.g. aesthetics, etc.)
- Construction materials
- Interior finishes
- Fire resistant requirements
- Explosion resistant requirements
- "Safe haven" requirements
- Acoustical considerations
- Safety, security, and maintenance requirements
- Fire detection and / or suppression requirements
- Utility requirements (i.e. sources and tie-in locations)
- HVAC requirements
- Electrical requirements
  - Power sources with available voltage & amperage
  - Special lighting considerations
  - Voice and data communications requirements
  - UPS and / or emergency power requirements
- Outdoor design conditions (e.g. minimum and maximum yearly temperatures)
- Indoor design conditions (e.g. temperature, humidity, pressure, air quality, etc.)
- Special outdoor conditions
- Special ventilation or exhaust requirements
- Equipment / space special requirements with respect to environmental conditions (e.g. air quality, special temperatures, etc.)
- Americans With Disabilities Act requirements

J. INFRASTRUCTURE

J1. Water Treatment Requirements

Items for consideration should include:

- Wastewater treatment
  - Process waste
  - Sanitary waste
- Waste disposal
- Storm water containment & treatment

J2. Loading / Unloading / Storage Facilities Requirements

A list of requirements identifying raw materials to be unloaded and stored, products to be loaded along with their specifications, and Material Safety Data Sheets. This list should include items such as:

- Instantaneous and overall loading / unloading rates
- Details on supply and / or receipt of containers and vessels
- Storage facilities to be provided and / or utilized
- Specification of any required special isolation provisions
  - Double wall diking and drainage
  - Emergency detection (e.g. hydrocarbon detectors / alarms)
  - Leak detection devices or alarms

J3. Transportation Requirements (Y/N)

Specifications identifying implementation of "in-plant" transportation (e.g. roadways, concrete, asphalt, rock, etc.) as well as methods for receiving / shipping of materials (e.g. rail, truck, marine, etc.).

K. INSTRUMENT & ELECTRICAL

K1. Control Philosophy

The control philosophy describes the general nature of the process and identifies overall control systems hardware, software, simulation, and testing requirements. It should outline items such as:

- Continuous
- Batch
- Redundancy requirements
- Classification of interlocks (e.g. process, safety, etc.)
- Software functional descriptions
- Manual or automatic controls
- Alarm conditions
- On / off controls
- Block diagrams
- Emergency shut down
- Controls startup

K2. Logic Diagrams (Y/N)

The logic diagrams provide a method of depicting interlock and sequencing systems for the startup, operation, alarm, and shutdown of equipment and processes.

K3. Electrical Area Classifications

The electrical area classification plot plan is provided to show the environment in which electrical and instrument equipment is to be installed. This area classification will follow the guidelines as set forth in the latest edition of the National Electric Code. Installation locations should include the following:

- General purpose
- Hazardous
    - Class I: Gasses and vapors
    - Class II: Combustible dusts
    - Class III: Easily ignitable fibers
- Corrosive locations

K4. Substation Requirements / Power Sources Identified

Substation requirements should include the following:

- Number of substations required
- Electrical equipment rating required for each substation
- Specifications for all major electrical substation equipment
- Infrastructure required for each substation considering building type and environment, fencing, access, and substation yard materials

Clearly define power sources for the project in relation to:

- Location, voltage level, available power
- Electrical equipment available
- Electrical ratings and routes of power feeds from their sources to the project substations
- Specifications for special power sources should be described and provided (e.g. emergency generators or in-plant generation)
- Temporary construction power sources

K5. Electric Single Line Diagrams

A single line diagram indicates the components, devices, or parts of an electrical power distribution system. Single line diagrams are intended to portray the major system layout from the public utility's incoming transmission line to the motor starter bus. Depending on the size of the electrical system, the single line diagrams should include several levels of distribution such as:

- Incoming utility with owner substation / distribution to high and medium voltage motors and substations
- Unit substations and 480V distribution
- Motor control centers with distribution to motors, lighting panels, etc.

K6. Instrument & Electrical Specifications

These specifications should include items such as:

- Distributed Control System (DCS)
- Instrument data sheets
- Motor control and transformers
- Power and control components
- Power and control wiring (splicing requirements)
- Cathodic protection
- Lightning protection
- Grounding
- Electrical trace
- Installation standards
- Lighting standards
- Civil requirements for electrical installation
    - Protection / warning for underground cabling
    - Special slabs or foundations for electrical equipment
    - Concrete-embedded conduit

SECTION III - EXECUTION APPROACH

L. PROCUREMENT STRATEGY

L1. Identify Long Lead / Critical Equipment and Materials

Identify engineered equipment and material items with lead times that will impact the detailed engineering for receipt of vendor information or impact the construction schedule with long delivery times.

L2. Procurement Procedures and Plans

Specific guidelines, special requirements, or methodologies for accomplishing the purchasing, expediting, and delivery of equipment and materials required for the project. Evaluation criteria should include:

- Listing of approved vendors
- Client or contractor paper?
- Reimbursement terms and conditions
- Guidelines for supplier alliances, single source, or competitive bids
- Guidelines for engineered / field contracts
- Who assumes responsibility for owner-purchased items?
    - Financial
    - Shop inspection
    - Expediting
- Tax strategy
    - Engineered
    - Field materials
    - Labor
- Definition of source inspection requirements and responsibilities
- Definition of traffic / insurance responsibilities
- Definition of procurement status reporting requirements
- Additional / special owner accounting requirements
- Definition of spare parts requirements
- Local regulations (e.g. tax restrictions, tax advantages, etc.)

L3. Procurement Responsibility Matrix (Y/N)

Has a procurement responsibility matrix been developed?

M. DELIVERABLES

M1. CADD / Model Requirements

Computer Aided Drafting and Design (CADD) requirements should be defined. Evaluation criteria should include:

- Software system required by client (e.g. Autocad, Intergraph, etc.)
- Will the project be required to be designed using 2D or 3D CADD?
- If 3D CADD is to be used, will a walk through simulation be required?
- Application software (e.g. ADEV Pro-series, Cadpipe, PDS, etc.)
- Owner / contractor standard symbols and details
- How will data be received and returned to / from the owner?
  - Disk
  - Electronic transfer
  - Tape
  - Reproducibles

Physical model requirements depend upon the type required, such as:

- Study model
- Design check
- Block model
- Operator training

M2. Deliverables Defined

The following items should be included in a list of deliverables:

- Drawings
- Project correspondence
- Project Process Safety Management (PSM) documents
- Permits
- Project data books (quantity, format, contents, and completion date)
- Equipment folders (quantity, format, contents, and completion date)
- Design calculations (quantity, format, contents, and completion date)
- Spare parts special forms
- Loop folder (quantity, format, contents, and completion date)
- Procuring documents
- ISO's / field erection details
- As-built documents
- Quality assurance documents

M3. Distribution Matrix (Y/N)

A distribution matrix identifies most correspondence and all deliverables. It denotes who is required to receive copies of all documents at the various stages of the project.

N. PROJECT CONTROL

N1. Project Control Requirements

Has a method for measuring and reporting progress been established? Evaluation criteria should include:

- Change management procedures
- Cost control procedures
- Schedule / percent complete control procedures
- Cash flow projections
- Report requirements

N2. Project Accounting Requirements

Have all project specific accounting requirements been identified such as:

- Financial (client / regulatory)
- Phasing or area sub-accounting
- Capital vs. non-capital
- Report requirements
- Payment schedules

N3. Risk Analysis (Y/N)

Has a risk analysis for cost and schedule been performed?

P. PROJECT EXECUTION PLAN

P1. Owner Approval Requirements

Has owner clearly defined all documents that require owner approval such as:

- Milestones for drawing approval
  - Comment
  - Approval
  - Bid issues
  - Construction
- Durations of approval cycle compatible with schedule
- Individual(s) responsible for reconciling comments before return
- Types of drawings
- Purchase documents
  - Data sheets
  - Inquiries
  - Bid tabs
  - PO's
- Vendor information

P2. Engineering / Construction Plan & Approach

This is a documented plan identifying the methodology to be used in engineering and constructing the project. It should include items such as:

- Responsibility matrix
- Contracting strategies (e.g. lump sum, cost-plus, etc.)
- Subcontracting strategy
- Work week plan / schedule
- Organizational structure
- Work Breakdown Structure (WBS)
- Construction sequencing of events
- Safety requirements / program
- Identification of critical lifts and their potential impact on operating units
- QA / QC plan

P3. Shut Down / Turn-Around Requirements (Y/N)

Have any required shut downs or turn-arounds been identified, including definitions of the scope of work to be accomplished during such down times, scheduled instructions for the down time, and timing of outages?

P4. Pre-Commissioning Turnover Sequence Requirements

This defines the owner's required sequence for turnover of the project for pre-commissioning and startup activation. It should include items such as:

- Sequence of turnover
- Contractor's required level of involvement in pre-commissioning
- Contractor's required level of involvement in training
- Contractor's required level of involvement in testing
- Clear definition of mechanical / electrical acceptance requirements

P5. Startup Requirements

Have the startup requirements been defined and responsibility established?

P6. Training Requirements

Have the training requirements been defined and responsibility established?

APPENDIX D : SAMPLE OF A COMPLETED PDRI

Type of facility: Diesel Power Plant
Primary product: Electricity
Design capacity: 108 MW

Project site: Grassroots
Estimated project duration: 12 months
Estimated project cost: $112 million

SECTION I - BASIS OF PROJECT DECISION

CATEGORY Element	Definition Level 0	1	2	3	4	5	Score
A. MANUFACTURING OBJECTIVES CRITERIA (Maximum Score = 45)							
A1. Reliability Philosophy	0	1	5	9	14	20	14
A2. Maintenance Philosophy	0	1	3	5	7	9	7
A3. Operating Philosophy	0	1	4	7	12	16	12
						CATEGORY A TOTAL	**33**
B. BUSINESS OBJECTIVES (Maximum Score = 213)							
B1. Products	0	1	11	22	33	56	1
B2. Market Strategy	0	2	5	10	16	26	5
B3. Project Strategy	0	1	5	9	14	23	9
B4. Affordability/Feasibility	0	1	3	6	9	16	9
B5. Capacities	0	2	11	21	33	55	11
B6. Future Expansion Considerations	0	2	3	6	10	17	3
B7. Expected Project Life Cycle	0	1	2	3	5	8	2
B8. Social Issues	0	1	2	5	7	12	12
						CATEGORY B TOTAL	**52**
C. BASIC DATA RESEARCH & DEVELOPMENT (Maximum Score = 94)							
C1. Technology	0	2	10	21	39	54	21
C2. Processes	0	2	8	17	28	40	17
						CATEGORY C TOTAL	**38**
D. PROJECT SCOPE (Maximum Score = 120)							
D1. Project Objectives Statement	0	2				25	25
D2. Project Design Criteria	0	3	6	11	16	22	22
D3. Site Characteristics Available vs. Req'd	0	2				29	29
D4. Dismantling and Demolition Req'mts	0	2	5	8	12	15	5
D5. Lead/Discipline Scope of Work	0	1	4	7	10	13	4
D6. Project Schedule	0	2				16	2
						CATEGORY D TOTAL	**87**
E. VALUE ENGINEERING (Maximum Score = 27)							
E1. Process Simplification	0	0				8	8
E2. Design & Material Alts. Considered/Rejected	0	0				7	7
E3. Design For Constructability Analysis	0	0	3	5	8	12	8
						CATEGORY E TOTAL	**23**
Section I Maximum Score = 499						**SECTION I TOTAL**	**233**

SECTION II - FRONT END DEFINITION							
CATEGORY Element	Definition Level						Score
	0	1	2	3	4	5	
F. SITE INFORMATION (Maximum Score = 104)							
F1. Site Location	0	2				32	2
F2. Surveys & Soil Tests	0	1	4	7	10	13	7
F3. Environmental Assessment	0	2	5	10	15	21	15
F4. Permit Requirements	0	1	3	5	9	12	9
F5. Utility Sources with Supply Conditions	0	1	4	8	12	18	12
F6. Fire Protection & Safety Considerations	0	1	2	4	5	8	5
						CATEGORY F TOTAL	**50**
G. PROCESS / MECHANICAL (Maximum Score = 196)							
G1. Process Flow Sheets	0	2	8	17	26	36	2
G2. Heat & Material Balances	0	1	5	10	17	23	1
G3. Piping & Instrumentation Diagrams (P&ID's)	0	2	8	15	23	31	8
G4. Process Safety Management (PSM)	0	1	2	4	6	8	6
G5. Utility Flow Diagrams	0	1	3	6	9	12	3
G6. Specifications	0	1	4	8	12	17	1
G7. Piping System Requirements	0	1	2	4	6	8	2
G8. Plot Plan	0	1	4	8	13	17	8
G9. Mechanical Equipment List	0	1	4	9	13	18	4
G10. Line List	0	1	2	4	6	8	4
G11. Tie-in List	0	1	2	3	4	6	3
G12. Piping Specialty Items List	0	1	1	2	3	4	2
G13. Instrument Index	0	1	2	4	5	8	4
						CATEGORY G TOTAL	**48**
H. EQUIPMENT SCOPE (Maximum Score = 33)							
H1. Equipment Status	0	1	4	8	12	16	4
H2. Equipment Location Drawings	0	1	2	5	7	10	5
H3. Equipment Utility Requirements	0	1	2	3	5	7	5
						CATEGORY H TOTAL	**14**
I. CIVIL, STRUCTURAL, & ARCHITECTURAL (Maximum Score = 19)							
I1. Civil/Structural Requirements	0	1	3	6	9	12	3
I2. Architectural Requirements	0	1	2	4	5	7	2
						CATEGORY I TOTAL	**5**
J. INFRASTRUCTURE (Maximum Score = 25)							
J1. Water Treatment Requirements	0	1	3	5	7	10	5
J2. Loading/Unloading/Storage Facilities Req'mts	0	1	3	5	7	10	7
J3. Transportation Requirements	0	1				5	1
						CATEGORY J TOTAL	**13**

SECTION II - FRONT END DEFINITION (continued...)							
CATEGORY Element	Definition Level						Score
	0	1	2	3	4	5	
K. INSTRUMENT & ELECTRICAL (Maximum Score = 46)							
K1. Control Philosophy	0	1	3	5	7	10	3
K2. Logic Diagrams	0	1				4	1
K3. Electrical Area Classifications	0	0	2	4	7	9	0
K4. Substation Req'mts Power Sources Ident.	0	1	3	5	7	9	7
K5. Electric Single Line Diagrams	0	1	2	4	6	8	2
K6. Instrument & Electrical Specifications	0	1	2	3	5	6	2
						CATEGORY K TOTAL	15
Section II Maximum Score = 423						SECTION II TOTAL	145

SECTION III - EXECUTION APPROACH							
CATEGORY Element	Definition Level						Score
	0	1	2	3	4	5	
L. PROCUREMENT STRATEGY (Maximum Score = 16)							
L1. Identify Long Lead/Critical Equip. & Mat'ls	0	1	2	4	6	8	1
L2. Procurement Procedures and Plans	0	0	1	2	4	5	0
L3. Procurement Responsibility Matrix	0	0				3	0
						CATEGORY L TOTAL	1
M. DELIVERABLES (Maximum Score = 9)							
M1. CADD/Model Requirements	0	0	1	1	2	4	1
M2. Deliverables Defined	0	0	1	2	3	4	1
M3. Distribution Matrix	0	0				1	0
						CATEGORY M TOTAL	2
N. PROJECT CONTROL (Maximum Score = 17)							
N1. Project Control Requirements	0	0	2	4	6	8	0
N2. Project Accounting Requirements	0	0	1	2	2	4	0
N3. Risk Analysis	0	1				5	5
						CATEGORY N TOTAL	5

SECTION III - EXECUTION APPROACH (continued...)							
CATEGORY Element	Definition Level						Score
	0	1	2	3	4	5	
P. PROJECT EXECUTION PLAN (Maximum Score = 36)							
P1. Owner Approval Requirements	0	0	2	3	5	6	5
P2. Engineering/Construction Plan & Approach	0	1	3	5	8	11	3
P3. Shut Down/Turn-Around Requirements	0	1	[redacted]			7	0
P4. Pre-Commiss. Turnover Sequence Req'mts	0	1	1	2	4	5	1
P5. Startup Requirements	0	0	1	2	3	4	1
P6. Training Requirements	0	0	1	1	2	3	1
						CATEGORY P TOTAL	11
Section III Maximum Score = 78						**SECTION III TOTAL**	**19**

PDRI TOTAL SCORE **397**

(Maximum Score = 1000)

APPENDIX E : HOW TO MEASURE PROJECT SUCCESS

The project success rating recommended by the Front End Planning Research Team is adopted from previous CII research. In a study of the relationship between pre-project planning effort and project success, a previous research project examined the success level attained on fifty-three capital projects and determined that a positive correlation existed between success and the amount of effort expended in pre-project planning. An index was developed for measuring project success based on four performance variables. The variables and their definitions are as follows (Gibson and Hamilton 1994):

Budget Achievement: Adherence to the authorization budget, measured by the percent deviation between the actual cost and the authorized cost.

Schedule Achievement: Adherence to the authorized schedule for mechanical completion, measured by the percent deviation between the actual project duration and the authorized project duration.

Design Capacity: The nominal output rate (tons per year, barrels per day, kilowatts, etc.) of the facility which is used during engineering and design to size equipment and mechanical and electrical systems. This was measured by the percent deviation between the planned design capacity at authorization and the actual design capacity attained after six months of operation.

Plant Utilization: The percentage of days during the year that the plant actually produces product. This was measured by the percent deviation between the planned utilization rate at authorization and the actual utilization rate attained after six months of operation.

These four variables were analyzed and weighted to determine their relative importance in the success index. Combining the four variables and their corresponding weights yields the equation for computing the Project Success Rating. This equation is presented in Figure E.1 (Gibson and Hamilton 1994).

Project Success Rating =	$0.60 \times$ [0.55 (Budget Achievement Value) + 0.45 (Schedule Achievement Value)] + $0.40 \times$ [0.70 (Design Capacity Attainment Value) + 0.30 (Plant Utilization Attainment Value)]

Figure E.1. Equation for Computing the Project Success Rating

The values for the four variables in the equation are determined using the criteria shown in Figure E.2.

Variable	Range*	Value
Budget Achievement (Measured against authorized budget)	Under Authorized Budget At Authorized Budget Over Authorized Budget	5 3 1
Schedule Achievement (Measured against authorized budget)	Under Authorized Budget At Authorized Budget Over Authorized Budget	5 3 1
Percent Design Capacity Attained at 6 Months (Measured against planned capacity)	Over 100% of Planned 100% of Planned Under 100% of Planned	5 3 1
Plant Utilization Attained at 6 Months (Measured against planned utilization)	Over 100% of Planned 100% of Planned Under 100% of Planned	5 3 1
* Consider "At Authorized Budget" and "100% of Planned" to be within ± 2½%.		

Figure E.2. Scoring Criteria for the Project Success Variables

Each variable is assigned a value of 1, 3, or 5 depending on the project's performance in that particular area. For the Budget Achievement and Schedule Achievement variables, performance is measured by determining if the project's final cost and schedule are at, over, or under their authorized budgets. For the Design Capacity Attainment and Plant Utilization Attainment variables, performance is measured by determining if the project's design capacity and utilization rates are at, over, or under their planned rates after six months of operation. The values for each variable obtained using this criteria are entered into the equation in Figure E.1 to compute a Project Success Rating for the project. Potential values for the Project Success Ratings range between one and five, with one indicating the lowest level of success and five indicating the highest level of success.

Although the equation for computing Project Success Ratings does not include all of the possible criteria for determining a project's level of success, it does give a good indication of standard project performance. The equation is both easy to understand and simple to use. In addition, the information needed for determining the value of each variable is relatively easy to obtain. The rating also provides a good basis for comparing overall performance on various types of industrial projects. Your company may wish to use a different set of criteria for measuring project success, however, regardless of the methodology employed, it should be standardized for all similar types of projects. Forms for collecting and scoring success are given in Appendix F.

VALIDATION PROJECTS EXAMINED

To determine the quality of the PDRI and its ability to effectively predict project success, the Front End Planning Research Team validated it using actual projects. A total of thirty-two projects were scored using the PDRI. Success ratings were also determined and correlated to the PDRI scores. The validation projects ranged in size from an authorized cost of $1.1 million to $304.9 million. The types of projects ranged from chemical and gas production facilities to power plants and manufacturing facilities. Each was constructed in North America between 1988 and 1995.

VALIDATION PROJECT RESULTS

For all of the thirty-two validation projects, PDRI scores and success ratings were computed. The PDRI scores ranged from 82 to 456 (possible range of 70 to 1000) with a mean value of 231 and a median value of 181. The success ratings ranged from 1.00 to 4.20 (possible range of 1.00 to 5.00) with a mean value of 2.89 and a median value of

3.01. A scatter plot of “Success” vs. “PDRI Score” is shown in Figure E.3. A regression analysis of this plot yielded a coefficient of determination (R^2) of 0.40.

Analysis of the data revealed a significant difference in performance between the projects scoring above 200 and the projects scoring below 200. The validation projects scoring below 200 outperformed those scoring above 200 in three important design/construction outcome areas: cost performance, schedule performance, and the relative value of change orders compared to the authorized cost. Figure E.4 compares the performance between the projects in these three areas. As can be seen in this figure, projects scoring below 200, on average, outperformed those scoring above 200 in cost, schedule, and change orders by approximately 23 percent, 13 percent, and 5 percent, respectively. For additional information regarding the validation project results, including a detailed analysis of each project’s performance, refer to CII Source Document 113-11 (Gibson and Dumont 1995).

	PDRI Score		
Performance	**< 200**	**> 200**	**Δ**
Cost	-5.1%	+18.0%	+23.1%
Schedule	+0.8%	+14.0%	+13.2%
Change Orders	+2.6%	+7.7%	+5.0%
	(N= 18)	(N = 14)	

Figure E.4. Summary of Cost, Schedule, and Change Order Performance for the PDRI Validation Projects Using a 200 Point Cutoff

PDRI SCORES VERSUS COST AND SCHEDULE PERFORMANCE

PDRI scores were plotted versus both cost and schedule performance for each of the validation projects in Figures E.5 and E.6, respectively. These plots show a linear relationship between the two primary variables which can possibly be used as a basis for analyzing cost and schedule contingency allowances.

The plot for cost performance is shown in Figure E.5. As can be seen in this figure, the validation projects receiving higher PDRI scores, in general, experienced poorer cost performance than those receiving low scores. By computing the slope of the line plotted in this figure, the research team concluded that on 85 percent of the industrial projects constructed, an additional allowance of 0.061*P*[*] (computed as a percentage) should be added to the original authorization cost estimate. To state this in other terms, if an allowance of 0.061*P* was added to the original cost estimate, then a project would have an 85 percent chance of not exceeding its budget. Note

[*] *P* = Project score as computed using the Project Definition Rating Index (PDRI).

that the authorization cost and schedule estimates in this analysis included design allowances and contingency. Therefore, the plots understate the actual cost and schedule performance.

The plot for schedule performance is shown in Figure E.6. Again, the validation projects receiving higher PDRI scores overran their budgeted schedules by amounts greater than those receiving lower PDRI scores. By computing the slope of the line plotted in this figure, the research team concluded that on 85 percent of the industrial projects constructed, an allowance of 0.085*P* (computed as a percentage) should be added to the original authorization estimate of the project's design and construction duration. In other words, if an additional amount of time equivalent to 0.085*P* was added to the original authorized schedule estimate, then a project would have a 85 percent chance of not exceeding the schedule.

Attempts to use either of the cost or schedule plots for computing contingency allowances on future projects should be done with great caution. They are intended merely as examples to improve awareness of the industry's tendency to underestimate both cost and schedule performance on capital projects. Although a definitive relationship between low PDRI scores and high performance is illustrated, the sample size of the data used in the analysis is relatively limited and should only be used as an example of how to apply the data. Also, the evaluations of the level of definition of the validation projects' scope definition packages at authorization were conducted only after the projects were built, rather than at the actual time of authorization.

To improve the accuracy of the plots in Figures E.5 and E.6, more projects should be included to increase the size of the data sample. Preferably, the PDRI evaluations for these projects should be conducted at the time of authorization and then later compared to actual cost and schedule performance (less contingency and design allowance) once the projects are constructed and in operation. Each organization using these plots as a basis for computing contingency allowances may wish to develop their own internal database of projects. As information on future projects is collected and added to Figures E.5 and E.6, the ability of a company to accurately forecast the cost and time required for construction of industrial projects will greatly improve.

APPENDIX F : COMPUTING A SUCCESS RATING

The following questionnaire can be used to compute the relative success of projects.

PROJECT BACKGROUND INFORMATION

1.0. Date: ________________

1.1. Company Name: ____

1.2. Point of Contact:

1. Name: ____
2. Title: ____
3. Address: ____

   ____
4. Tel. No.: ____________________ Fax No.: ____________________

2.0. General Project Information:

1. Project Name: ____
2. Project Number: ____
3. In what town or city is the project located? ______________________

   In what state or province? __________________________________
4. What type of facility is this project?

   [ ] Oil/Gas Production Facility
   [ ] Chemical Plant
   [ ] Paper Mill
   [ ] Power Plant
   [ ] Food Processing Plant
   [ ] Refinery
   [ ] Textile Mill
   [ ] Pharmaceutical Plant
   [ ] Steel/Aluminum Mill
   [ ] Manufacturing Facility
   [ ] Other *(please specify)* __________________
5. What are the primary products produced by this plant?

   ____

6. What is the design capacity of the plant? ________________________

7. Which of the following best describes the site on which the project was built? *(If more than 25% of the project was a retrofit, please classify it as a Retrofit/Expansion.)*

[ ] Grassroots [ ] Retrofit/Expansion
[ ] Co-Located [ ] Other: ___________________

8. Was there anything unique about this project? *(Please check all that apply.)*

[ ] New process technology for the company/location
[ ] First of a kind process technology for the industry
[ ] Largest (scale)
[ ] Other (e.g. process, equipment, location, execution, etc.)
Please describe: ____________________________________
[ ] Not applicable

2.1. <u>Schedule Information</u>:

1. What was the date of major funding authorization? _________________

2. What was the planned duration of the execution schedule (from authorization to mechanical completion) at project authorization (in months)?

________ months

3. What was the actual date of mechanical completion? _______________

4. What was the planned duration of the startup schedule (from mechanical completion to beginning of commercial operation) at project authorization (in months)?

________ months

5. What was the actual date of beginning of commercial operation?

____

6. If there were any schedule extensions or reductions, please indicate the reason(s) in the appropriate box(es) below by supplying the duration(s) of the change(s) (in months) and whether it was an extension (Ext) or reduction (Red). *Please check all that apply.*

Delay	Mos.	Ext	Red	Delay	Mos.	Ext	Red
Scope/Design Change	____	[ ]	[ ]	Funding Change	____	[ ]	[ ]
Labor Shortage	____	[ ]	[ ]	Regulatory Change	____	[ ]	[ ]
Contract Dispute	____	[ ]	[ ]	Equipt. Availability	____	[ ]	[ ]
Weather	____	[ ]	[ ]	Const. Productivity	____	[ ]	[ ]
Strike	____	[ ]	[ ]	Engr. Productivity	____	[ ]	[ ]
Matl. Shortage/Delivery	____	[ ]	[ ]	Other	____	[ ]	[ ]
				(Please specify) ______________			

Do you have any additional comments regarding any causes or effects of schedule changes (e.g. special causes, freak occurrences, etc.)?

____

____

____

2.2. Cost Information:

1. What was the capital cost breakdown, by the following major cost categories, for the estimated cost at the time of major funding authorization and the actual final cost of the project? In order to assist you in completing the following page, guidelines for selected cost categories are provided below:

   Owner Costs: The direct owner incurred costs, excluding procured equipment or any subcontracts.

   Owner Procured Equipment / Materials: The costs associated with owner procurement of any equipment or materials inclusive of any capitalized subcontract costs (i.e. procurement by a subcontractor on an owner's purchase order).

   Engineer Procured Equipment / Materials: Any costs associated with procurement of equipment or materials on a reimbursable basis by a subcontract engineering organization.

Capital Cost Category	Estimated Cost at Authorization	Actual Cost
Owner Costs		
Owner Procured Equipment / Material		
Engineering & Design Services		
Engineer Procured Equipment / Material		
Construction Contractor Equipment, Materials, & Labor		
Commissioning & Turnover		
Startup		
Contingency		XXXXXXXXXX
Other		
Total Project Cost		

2. If there were any cost overruns or underruns, please indicate the reason(s) in the appropriate box(es) below by supplying the amount(s) (Amt) of the change(s) (in dollars) and whether it was an overrun (Ov) or underrun (Un). *Please check all that apply.*

Reason	Amt	Ov	Un	Reason	Amt	Ov	Un
Scope/Design Change	____	[ ]	[ ]	Funding Change	____	[ ]	[ ]
Schedule Change	____	[ ]	[ ]	Regulatory Change	____	[ ]	[ ]
Weather	____	[ ]	[ ]	Market Change	____	[ ]	[ ]
Strike	____	[ ]	[ ]	Constr. Productivity	____	[ ]	[ ]
Estimating Error	____	[ ]	[ ]	Engr. Productivity	____	[ ]	[ ]
Differing Site Conditions	____	[ ]	[ ]	Other	____	[ ]	[ ]
				(Please specify) ______________			

Do you have any additional comments regarding any causes or effects of cost extensions or reductions?

____

____

____

2.3. Change Information:

1. What was the total number of change orders issued (including engineering and construction)? ____________

2. What was the total dollar amount of all change orders? $ ___________

3. What was the net change in the completion date resulting from change orders? ____________ months

4. Did the changes increase or decrease the length of the original project duration?

   [ ] Increase [ ] Decrease

5. Were there any individual changes after project authorization that exceeded 1% of the project budget?

   [ ] No
   [ ] Yes - If "Yes," what were the total cumulative effects and the direction of these changes on:
   a. Cost: $ ________________. [ ] Increase or [ ] Decrease
   b. Schedule: _______ months. [ ] Increase or [ ] Decrease
   c. How many changes comprised 1% of the original contract amount or greater? ________________
   d. What were the reasons for the changes? *(Please check all that apply.)*

   [ ] Scope/Design Change
   [ ] Process Change
   [ ] Schedule Change
   [ ] Weather
   [ ] Differing Site Conditions
   [ ] Labor Productivity Change
   [ ] Other *(please specify)* ___________________________
   [ ] Market Change
   [ ] Funding Change
   [ ] Regulatory Change
   [ ] Strike
   [ ] Estimating Error
   [ ] Technology Change

Do you have any additional comments regarding any causes or effects of change orders?

____
____
____

2.4. Financial / Investment Information:

1. Project authorization decisions usually rely on specific project financial performance measures such as capital turnover, return on investment, return on equity, return on assets, etc. For the major financial criteria used on this project, how well has the actual financial performance matched the expected financial performance measurement using the scale below?

   Using a scale of 1 to 5, with 1 being fallen far short of expectations to 5 being far exceeded expectations at authorization, *please circle only one*.

fallen far short		matched closely		far exceeded
1	2	3	4	5

2. What type of specific project financial measurement was used to authorize the project (for example, Return on Assets, Return on Equity, Internal Rate of Return, Payback Period, etc.)?

   ____

2.5. Operating Information:

1. What percent of design capacity was planned or anticipated (at the time the project was authorized) and actually obtained 6 months after the end of startup?

	Planned	Obtained
Design capacity at 6 months after startup	______%	_______%

   Design capacity is defined as "the nominal output rate (tons per year, barrels per day, kilowatts, etc.) of the facility which is used during engineering and design to size equipment and mechanical and electrical systems."

2. What percent of plant utilization was planned or anticipated (at the time the project was authorized) and actually obtained 6 months after the end of startup?

	Planned	Obtained
Plant utilization at 6 months after startup	______%	_______%

   Plant utilization is defined as "the percentage of days that the plant actually produced product."

PROJECT SUCCESS INFORMATION

(Consider *"At"* within ± 2½%)

Cost Achievement: *At / Over / Under* Authorized Budget

$ _____________

Schedule Achievement: *At / Over / Under* Authorized Budget

______________ months

Percent Design Capacity at 6 Months: *At / Over / Under* 100% of Planned

______________ %

Plant Utilization at 6 Months: *At / Over / Under* 100% of Planned

______________ %

(Circle one choice for each.)

Variable	Range	Value
	Under Authorized Budget	5
Cost Achievement	At Authorized Budget	3
(Measured against authorized budget)	Over Authorized Budget	1
	Under Authorized Budget	5
Schedule Achievement	At Authorized Budget	3
(Measured against authorized budget)	Over Authorized Budget	1
Percent Design Capacity	Over 100% of Planned	5
Attained at 6 months	100% of Planned	3
(Measured against planned capacity)	Under 100% of Planned	1
Plant Utilization	Over 100% of Planned	5
Attained at 6 Months	100% of Planned	3
(Measured against planned utilization)	Under 100% of Planned	1

PROJECT SUCCESS RATING COMPUTATION

Project Success Rating = 0.60 × [0.55 (Budget Achievement Value) +
0.45 (Schedule Achievement Value)] +
0.40 × [0.70 (Design Capacity Attained Value) +
0.30 (Plant Utilization Attained Value)]

= 0.60 × [0.55 (__________) + 0.45 (_________)] +

0.40 × [0.70 (__________) + 0.30 (_________)]

= _______________

APPENDIX G : SUGGESTIONS FOR IMPROVEMENT

The CII Front End Planning Research Team welcomes any comments or suggestions regarding the Project Definition Rating Index, either the written version or the computer software. Feel free to use this sheet to submit any feedback or use the telephone and facsimile numbers listed below. Also, please provide your name and address when submitting your suggestions in case follow-up correspondence is necessary.

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Phone: (512) 471-4319
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Comments / Suggestions:

____

____

____

____

____

____

_____

Name: ______________________________

Address: ______________________________

____

____

Phone: ____________________

Fax: ____________________

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