



**PROJECT DEFINITION RATING INDEX (PDRI)
FOR INDUSTRIAL PROJECTS**

**by
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and
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**A Report to
The Construction Industry Institute
The University of Texas at Austin**

**Under the Guidance of the
Front End Planning Research Team**

**from
The University of Texas at Austin
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EXECUTIVE SUMMARY

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

Therefore, the CII Front End Planning Research Team was established to produce effective, simple, and easy-to-use pre-project planning tools so that owner and contractor companies can better achieve business, operational, and project objectives. Specifically, the research team created the Project Definition Rating Index (PDRI) for Industrial Projects, a comprehensive checklist of 70 scope definition elements presented in a score sheet format. The PDRI provides a means for an individual or a team to evaluate the status of an industrial project during pre-project planning and to determine a score that corresponds to its level of definition.

This research report discusses the development of the PDRI including the methodology used to create it, an analysis of its effectiveness in predicting project performance, a description of its potential uses, and a synopsis of the benefits it will provide to the U.S. construction industry.

The list of 70 PDRI elements originally was identified and categorized by the research team through an extensive literature review and an assessment of current industry “best practices.” The elements were weighted in order of importance using input from 54 experienced project managers and estimators. The following 10 elements were found to be most important:

- | | |
|------------------------|---|
| 1. Products | 6. Site Location |
| 2. Capacities | 7. P&IDs |
| 3. Technology | 8. Site Characteristics Available v. Required |
| 4. Processes | 9. Market Strategy |
| 5. Process Flow Sheets | 10. Project Objectives Statement |

Detailed descriptions for each element in the PDRI are given in Appendix K.

The PDRI was tested on a series of actual projects to determine if it effectively correlated the level of scope definition effort on industrial projects with the predictability of achieving project objectives. Success ratings were computed for the test projects and plotted against their PDRI scores. A linear regression of this plot yielded a coefficient of determination (R^2) of 0.40 between the two variables. This supported the conclusion that PDRI scores could effectively be linked to project success. The validation process also demonstrated that the PDRI was simple and easy-to-use.

The PDRI can provide 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.

In summary, the PDRI can effectively be used to improve the predictability of project performance and, when combined with sound business planning, alignment, and good project execution, can greatly improve the probability of meeting or exceeding project objectives.

1. INTRODUCTION

1.1. Background Information

In 1991, the Construction Industry Institute (CII) Pre-Project Planning Research Team embarked on an effort to define the pre-project planning process and to identify its benefits in the life cycle of a capital facility. This research team proved that the early stages of the project life cycle, such as business planning and pre-project planning, had a much greater influence on a project's outcome than later stages, as conceptually shown in Figure 1 (CII 1994b).

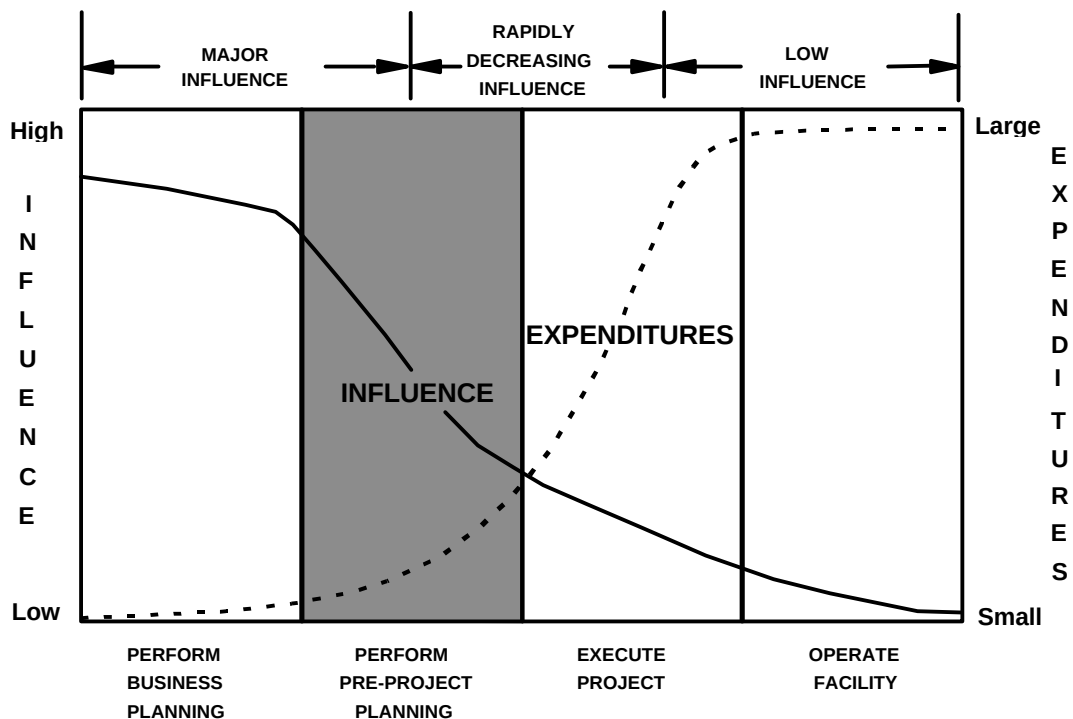


Figure 1. Influence and Expenditures Curves for the Project Life Cycle

As can be seen in this figure, a company's ability to influence overall project cost is greatest at the beginning of the project, when expenditures are relatively low, and decreases as the project progresses and expenditures become more significant.

The pre-project planning phase is paramount in the project life cycle. Pre-project planning is defined as the "process for developing sufficient strategic information with which owners can address risk and decide to commit resources to maximize the chance for a successful project" (CII 1995). It begins when a validated project concept is developed during the business planning phase and ends with the decision to proceed with detailed design and construction. This decision is generally referred to as final authorization, at which time the appropriate funding is granted for execution of the project.

Figure 2 shows an overlap diagram of the major phases in the project life cycle. Pre-project planning encompasses the conceptual planning and detailed scope definition phases. The overlapping regions signify critical junctures where transitions are made and decisions to proceed typically occur. The increasing sizes of the phases are representative of the relative amounts of effort and resources expended during each phase.

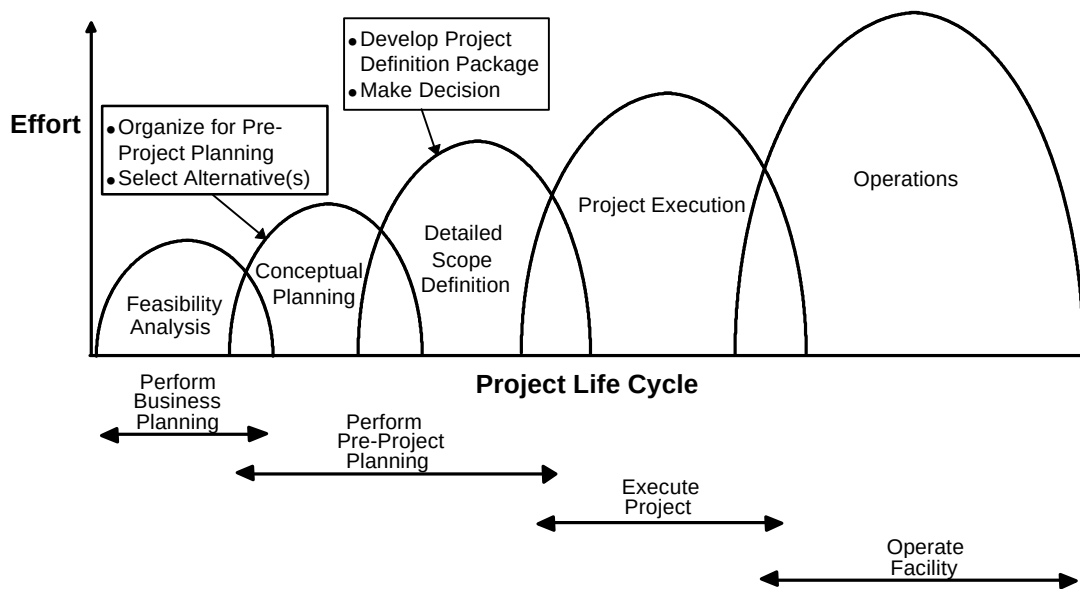


Figure 2. Project Life Cycle Overlap Diagram

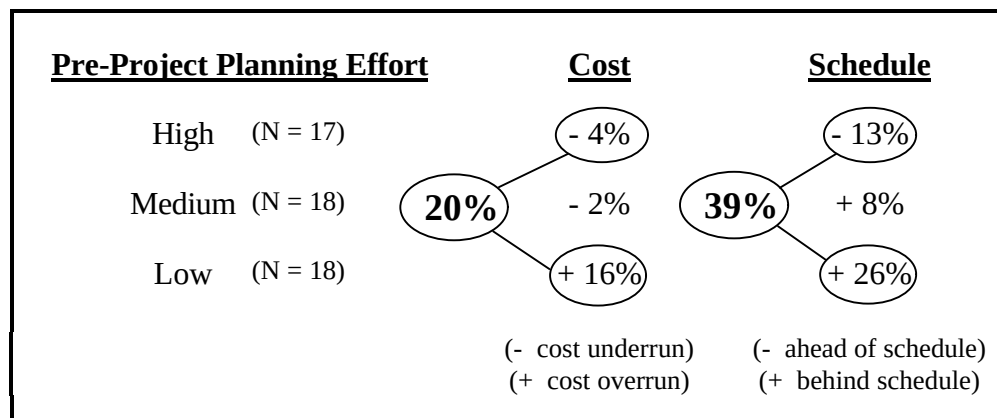
In its investigation, the Pre-Project Planning Research Team determined that project success, including cost performance, was greater when an increased level of pre-project planning effort is involved. The research indicated that increased levels of pre-project planning efforts yield greater project success with:

- Increased predictability of cost and schedule
- Reduced probability of financial disaster
- Improved operational performance

Specifically, this research team studied 53 capital facility projects, 17 of which had been executed with a high level of pre-project planning effort, 18 with a medium level of pre-project planning effort, and 18 with a low level of pre-project planning effort. Within these three effort categories, the average cost and schedule

performance for all projects was determined and is shown in Table 1. These data illustrate the savings, in terms of both time and money, that result from greater pre-project planning efforts (Gibson and Hamilton 1994).

Table 1. Cost and Schedule Performance for Varying Levels of Pre-Project Planning Effort



As proven, greater efforts expended during the pre-project planning phase of a project can improve overall project performance. However, the Pre-Project Planning Research Team found the industry lacking a practical, non-proprietary method for quantifying, rating, and assessing pre-project planning efforts. Tools for measuring both project scope definition and alignment between business, operational, and project objectives needed to be developed.

1.2. Purpose of This Research

The CII Front End Planning Research Team was formed 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.

1.2.1. The CII Front End Planning Research Team

CII chartered the Front End Planning Research Team in March 1994. This team, which is still actively researching the subject, consists of 16 individuals representing eight owner companies, seven contractors, and one member of academia. A list of the research team members and their companies is presented in Appendix A.

To accomplish the goal of developing pre-project planning tools, the research team established the following primary objectives:

1. Quantify pre-project planning efforts, specifically scope definition, 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 development 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 building, and one for infrastructure projects.
 - Ensure that the PDRI is easy to use and understand.

2. Analyze the impact of alignment between business, project management, and operations personnel of owner companies, as well as the alignment of owners and contractors with project objectives, and to produce alignment guidelines for pre-project planning. Secondary objectives included:
- Describe the functional process of project alignment during pre-project planning.
 - Further prove the need for and value of promoting alignment between business, operational, and project objectives as a part of the pre-project planning process. Types of projects that will be addressed include industrial, building, and infrastructure projects.
 - Identify the critical success factors, as well as the players, roles, and responsibilities required for alignment.
 - Develop a measurement approach for determining the degree of alignment attained on projects.

Early on, the research team realized that the most effective way to accomplish its objectives was to divide into two sub-teams. To date, the sub-teams have worked independently and coordinated their efforts within one master schedule. One sub-team has developed the Project Definition Rating Index while the other has examined alignment. This research report specifically addresses the activities of the PDRI sub-team and how it successfully accomplished the first primary objective discussed above. The report includes a description of the methodology employed in developing the PDRI and a detailed analysis of the research results.

1.2.2. The Importance of Project Scope Definition

Project scope definition is the process by which projects are defined and prepared for execution. The information identified during this process is usually presented in the form of a project definition package. A project definition package is a detailed formulation of a continuous and systematic strategy to be used during the execution phase of a project to accomplish the project objectives. This package should include sufficient supplemental information to permit effective and efficient detailed engineering to proceed (Gibson et al. 1993).

Success during the detailed design, construction, and start-up phases of a project is highly dependent upon the level of effort expended during the scope definition phase. Some construction industry officials consider lack of scope definition to be the most serious problem on construction projects (Smith and Tucker 1983). A poorly defined project can experience considerable changes that may result in cost overruns and a greater potential for disputes. Inadequate scope definition can lead to changes that may delay the project schedule, cause rework, disrupt project rhythm, and lower the productivity and morale of the work force.

In a study by the Rand Corporation, Myers studied the major factors causing schedule slippage in the detailed design, construction, and start-up of process plants. He found that poor scope definition is one of the primary causes of cost growth and schedule slippage on these projects. The management decision to invest more time

and effort in scope definition prior to authorization will usually result in more accurate construction scheduling (Myers and Shangraw 1986).

Another study by the Rand Corporation confirmed that poor project definition was a major factor contributing to inaccurate estimations and cost growth on process plants. Considerably more accurate estimates will result from efforts to define a plant in detail with specific regard to its proposed site, addressing items such as local labor and material costs, hydrology, and regulatory requirements. This study found that management's attempts to save time and money in the early planning and definition stages of a project are almost universally unsuccessful. It also concluded that the firms that appear to estimate better than others have established criteria for what constitutes an acceptable level of definition prior to project authorization (Merrow et al. 1981).

In a study of megaprojects (projects whose capital cost for completed construction exceeds \$1 billion), which often experience significant cost growth and schedule slippage due to their sheer magnitude and complexity, poor definition was found to be the most important source of faulty estimates (Merrow 1988). A primary recommendation resulting from this study was that the definition phase for megaprojects should be broadened substantially both in scope and detail to reduce project risk.

In addition to these studies, previous CII research has shown that scope definition is the highest ranking design input for construction projects on an industry-wide basis (Broaddus 1995). As shown in Table 2, scope definition was found to be the most important variable affecting the quality of design and overall project success.

Table 2. Ten Highest Ranking Inputs to Design for Project Success

<u>Input Variable</u>	<u>CII Rank</u>
Scope definition	1
Customer participation	2
Project objectives and priorities	3
Acquisition strategy	4
Basic design data	5
Designer selection and qualification	6
Project management team	7
Construction input	8
A/E contracting	9
Equipment sources	10

Due to its importance, preparing a quality scope definition package should receive a level of management attention commensurate with its potential for impacting project performance.

1.2.3. The Need for Project Scope Definition Tools

Apparently the majority of industry officials recognize the importance of scope definition and its potential impact on project success. The Front End Planning Research Team, however, found the industry lacking in a practical, non-proprietary method for determining the degree of scope development on a project. Further, the industry lacks documentation defining the differences between the scope development 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 development that, at a minimum, would provide the following benefits to the U.S. construction industry:

- 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 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.

This tool, called the Project Definition Rating Index (PDRI), identifies and precisely describes each critical element in a scope definition package and allows a project team to predict risk factors impacting the project quickly.

In a recent study by Merrow (1994), he reported that the construction industry needs to increase the predictability of performance and improve the accuracy of its estimates. The industry has shown very little improvement in the reliability of estimates over the past 20 years. Although cost overruns have declined significantly since the mid-1970s, variability in estimating remains a problem. Today, roughly half of all major projects actually underrun (Merrow and Yarossi 1994). An underrun signifies that unused capital was tied up on a project and could not be invested elsewhere for generating additional revenue.

One reason for this poor reliability is that in today's industry, it is becoming increasingly important to reduce project cycle times in order to get products to the market sooner. Although it is not the ideal situation, owners often feel that market demand or other pressures warrant authorization of projects with underdeveloped definition. Pushing a project into the field prematurely can adversely affect the

accuracy of cost and schedule estimates. However, if owners decide to proceed with projects that have poorly defined scopes, it is critical to have the ability to predict factors that may impact project risk quickly and accurately.

Another trend emerging in the industry is the downsizing of owner companies and the elimination of in-house detailed design capabilities. Much of the responsibility for detailed design is now being assumed by contractors. Contractor-led project definition is now prevalent on roughly one-third of all projects today, whereas 20 years ago, it rarely occurred (Merrow and Yarossi 1994). However, contractors are often not capable of taking on the responsibility of effectively leading the definition phase of a project. This often results in projects with poor cost, schedule, or operational performance. It is apparent that contractors could benefit from a tool that would provide a detailed checklist for determining the necessary steps to follow in defining a project scope as well as a means to evaluate their performance periodically throughout the process.

1.2.4. Previous Attempts at Defining Scope Definition Elements

Although numerous research efforts have identified the importance of scope definition on industrial projects, few attempts have been made to outline and define the process. An extensive literature search revealed only two previous attempts at identifying specific areas critical to a good scope definition package. The first

attempt was published by the late John W. Hackney in the mid 1960s and the other by the Rand Corporation in the early 1980s.

1.2.4.1. John W. Hackney's Definition Rating Checklist

John W. Hackney, a founder and past president of the American Association of Cost Engineers (AACE), was known by many as a pioneer of cost estimating and cost control. During the 1950s, 60s, and 70s, he worked for numerous industrial companies developing computerized systems for cost estimating, cost control, and scheduling. In 1965, he published the first Definition Rating Checklist, a tool for quantifying the degree to which the scope definition packages of industrial projects were defined at a given stage of planning development.

Hackney categorized the items that comprise a good scope definition package under six main headings. These headings along with their expanded list of items are contained in the Definition Rating Checklist. According to Hackney, these are the most important items in a project definition package that, if well-defined, will minimize the potential for cost growth on a project. This checklist was revised in 1990 and modifications to the checklist reflect additional experience with project estimates and changes in economic, political, and engineering conditions. The Revised Definition Rating Checklist is summarized in Figure 3 (Hackney 1992). The major headings and sub-headings are included. The individual items, however, are not included due to their length.

Hackney arbitrarily assigned maximum weights to each of the items in his checklist. The weights shown in Figure 3 pertain to process projects. The magnitude of the weights reflect an estimate of the percentage overrun that might be expected in the overall project if information for the item was completely unknown. In general, the weights represent the relative ability of an item to affect the degree of uncertainty in the project estimate. The intent of the checklist was for each item to be scored prior to estimating the cost of the project. Scores were to be assigned as follows: complete and full definition was to be indicated by a score of zero and the scores were to increase up to the maximum possible weight as the level of definition for the item decreased. If information for an item had not yet been established, it was to receive the maximum weight in the checklist. This scoring scheme was compared to that of the sport of golf, where lower scores were considered better. Lower scores corresponded to well-defined projects, while higher scores corresponded to poorly defined projects.

<u>Items</u>	<u>Maximum Weight</u>
<i>General Project Basis</i>	
Products and By-Products	100
Process Background	200
Raw Materials	100
Utilities & Services	50
Ownership Factor (multiplier)	----
<i>Process Design Status</i>	
Flow Balances	70
Major Equipment, type and size	80
Materials of Construction	50
Review of Process Design	70
<i>Site Information</i>	
Surveys	85
Climatological Information	25
Ordinances & Regulations	146
Reusable Equipment	25
Reusable Supports, Piping, & Electrical	25
Buildings Available	30
Utilities Available	25
Yard Improvements Available	40
Review with Operations	25
Review with Construction	25
<i>Engineering Design Status</i>	
Layouts	35
Line Diagrams	50
Auxiliary Equipment, type and size	70
Buildings, type and size	35
Yard Improvements, type and size	55
Hazard Control Specifications	30
Coating Specifications	20
Review of Engineering Design	100
<i>Detailed Design</i>	
Drawings and Bills of Materials	45
Drawing Reviews	35
<i>Field Performance Status</i>	50

Figure 3. John W. Hackney's Revised (1990) Definition Rating Checklist

Not only did Hackney intend for his definition checklist to be used as a means for identifying which items needed further attention in the planning process, but he also established criteria for computing contingency allowances based upon checklist scores. Contingency allowances are generally established on projects to compensate for deviations in the cost estimate due to unfavorable conditions such as (Hackney 1992):

- Deviations of the actual project from the project as contemplated at the time of the estimate
- Variations in effectiveness of project performance
- Changes in economic and other environmental conditions
- Accidental events during construction
- Imperfections in estimating methods
- Estimating errors and oversights

By scoring 29 projects and plotting their definition ratings versus their cost performance, he was able to show a correlation between high definition ratings and poor cost performance. From this correlation, he concluded that approximately 85 percent of the projects built would not overrun if a contingency allowance of $0.14D^*$ were added to their original authorized cost estimates. He also concluded that approximately 90 percent of projects built should include a percentage-contingency allowance of $0.03D$ to cover normal contingencies for items not listed in the original scope (Hackney 1992).

* D = Definition rating as computed using Hackney's Definition Rating Checklist.

Hackney's Definition Rating Checklist has not been widely accepted, perhaps due to its complexity. For this reason, the research team set as one of its priorities the goal of creating a simple and easy-to-use scope definition tool that both mirrored and expanded upon Hackney's work. Despite its complexity, however, the research team found Hackney's work to be the most comprehensive and detailed attempt at quantifying project scope definition to date. The team decided to adopt his "low score = good score" rating scheme and to compare its scope definition findings to his for the purpose of validating the PDRI. The results of this comparison are presented in Chapter 4.

1.2.4.2. The Rand Corporation's Pioneer Plants Study

Between the years of 1978 and 1981, the Rand Corporation performed a study of cost growth and performance shortfalls in first-of-a-kind process plants. This study, called the Pioneer Plants Study, analyzed 44 chemical process plants which were new at the time of the study and which represented a total capital investment of \$7.5 billion.* The plants were solicited from a diverse sample of thirty-four companies in the chemical, oil, minerals, and architectural design-services industries. This study concluded that the capital costs for first-of-a-kind chemical process facilities are frequently underestimated and performance predictions for these

* In 1980 dollars.

facilities are frequently overestimated by designers. Given these findings, researchers sought to determine the primary causes of cost growth and poor plant performance. Two models were developed, one identifying the variables affecting cost growth and one identifying the variables affecting plant performance. The cost growth model consisted of six variables (Horvath 1983):

PCTNEW: The percent of the estimate incorporating technology unproven in commercial use

IMPURITIES: The extent to which the impurity build-up in the process stream was a significant source of design and development problems

COMPLEXITY: A block count of all process steps in the plant

PROJECT DEFINITION: The extent to which the cost estimate used site-specific information, and the level of detailed engineering accomplished by the date of the cost estimate

PROCESS DEVELOPMENT: The stage of the process's technical development, ranging from being fairly well understood to having significant research and development issues remaining

INCLUSIVENESS: The completeness and amount of detail of the cost estimate

The PROJECT DEFINITION variable was found to have a potential impact of approximately 30 percent on the ratio of estimated to actual costs (i.e. the accuracy of the estimate) for the pioneer plants investigated (Merrow et al. 1981). This variable consisted of five parameters representing site specific information and

the degree of engineering definition accomplished at the date of the project evaluation. The equation required each parameter to be rated on a numerical scale according its completeness of definition. Similar to the scheme used by Hackney, lower scores were to be assigned for well-defined or complete parameters while higher scores represented lower levels of knowledge of the parameters. The five parameters were defined as follows (Milanese 1987):

SITE 1: Inclusiveness of on-site and off-site data

SITE 2: Completeness of soils and hydrological data

SITE 3: Incorporation of health and safety requirements

SITE 4: Incorporation of environmental requirements

ENGINEERING LEVEL: Amount of engineering design performed to date

A statistical analysis of the cost growth model showed it to be extremely accurate in explaining the effect of each variable on cost growth. It highlighted major problem areas affecting the accuracy of cost estimates. A primary conclusion of the Pioneer Plants Study was that poor project definition results in higher cost growth, both separately and in combination with the use of unproven process technologies (Merrow et al. 1981).

2. RESEARCH METHODOLOGY

The previous chapter presented background information regarding the CII Front End Planning Research Team and specific objectives for providing the U.S. construction industry with simple and easy-to-use project scope definition tools. This chapter describes how the research team developed the Project Definition Rating Index. It discusses the detailed procedures of data collection including the characteristics and amount of input obtained.

As mentioned in the previous chapter, the research team sought to create three versions of the PDRI -- one for industrial, one for building, and one for infrastructure projects. The research team decided to develop the industrial projects version of the PDRI first, as it best aligned with the majority of the members' expertise. The building projects and infrastructure projects versions were scheduled for future development.

For the purposes of this study, the research team considered industrial projects to 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

2.1. Identifying and Categorizing the Elements Comprising the PDRI

To accomplish its objective of producing a simple and easy-to-use tool for measuring project scope development on industrial projects, the research team sought to identify and categorize the critical elements that should be included in an industrial project's scope definition package. To develop a detailed list of these required elements, the research team utilized four primary resources:

- A literature review of previous scope definition research
- Documentation from a variety of owner and contractor companies
- The expertise of the research team members
- A separate workshop of project managers and estimators

A preliminary list of items to be included in the PDRI was obtained using documentation from both previous work and current industry practices. Rough topic categories were obtained from Hackney's Definition Rating Checklist, previous CII research findings, and scope development documentation from fourteen owner and contractor companies. This list, which began with approximately 150 elements, was refined to a list of 69 using the research team's internal expertise. During the team's monthly meetings, brainstorming, nominal group techniques, and affinity diagramming were all used to categorize and refine the list of elements.

The research team felt it was important to describe each of the 69 elements in detail to ensure consistent understanding by all people using the PDRI, both within a particular company and throughout the industry. The team expended great effort in

describing the elements and in reaching agreement on the exact terms and nomenclature for each.

Once the elements were identified and described to the best of the research team's abilities, a separate workshop was held on January 30, 1995, to "fine tune" the list of elements and their descriptions. Six individuals representing one owner and three engineering/construction companies were invited to this workshop. The participants, who had not seen the approach previously, were asked to critique the list of elements and their descriptions in detail and provide the research team with suggestions for improvement. They recommended several changes which were incorporated into the PDRI and used to create the final list of elements and descriptions. This list formed the basis for the final version of the PDRI and is presented in Figure 4. The PDRI now consisted of 70 elements grouped into fifteen categories and further grouped into three main sections.

At this workshop, the participants were also asked to weight each element in order of importance. However, since the suggestions provided by the participants led to changes in the PDRI after the workshop, their weighting information could not be used for final data analysis. To ensure statistical validity, all input used for computing final element weights had to be obtained from consistent evaluations of the final version of the PDRI.

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 4. PDRI SECTIONS, Categories, and Elements

2.2. Weighting the PDRI Elements According to Relative Importance

Early in development, the research team hypothesized that all of the elements within the PDRI were not equally important with respect to their potential impact on overall project success. Thus, it was apparent that each needed to be weighted relative to one another. For background on how to weight the elements, the research team referred to Hackney's Definition Rating Checklist in which he weighted each of the items relative to their potential for creating uncertainty in the project estimate. His weights, which were based on a "low score = good score" philosophy, indicated the degree of uncertainty produced in a project if information for an item was completely unknown. The research team felt that a similar weighting scheme should be adopted for the PDRI.

2.2.1. Interactive Workshops With Industry Representatives

To develop credible weights, the research team felt that a broad range of industry expertise would provide the best input. They hosted two workshops, one on March 16, 1995 and one on March 20, 1995, at which a total of 54 experienced project managers and estimators were invited to evaluate and weight the elements in the PDRI. These individuals represented a mix of 31 owner and contractor companies from the process industry. One workshop was held in the Northeast and the other in the Southwest to obtain an equitable representation from different geographic regions. The workshops provided an interactive forum for explanation

and discussion of the weighting methodology. A list of the companies who participated in the weighting workshops is given in Appendix A. Note that this list also includes the names of the companies represented by the research team members present.

A summary of the number of people who attended the March workshops as well as the number of weighted PDRI documents obtained is given in Figure 5. Each participant was asked to submit information regarding the number of years of experience they had working in industry. They were also asked to specify how much of their experience had been spent working in project management roles and how much had been spent working in estimating positions.

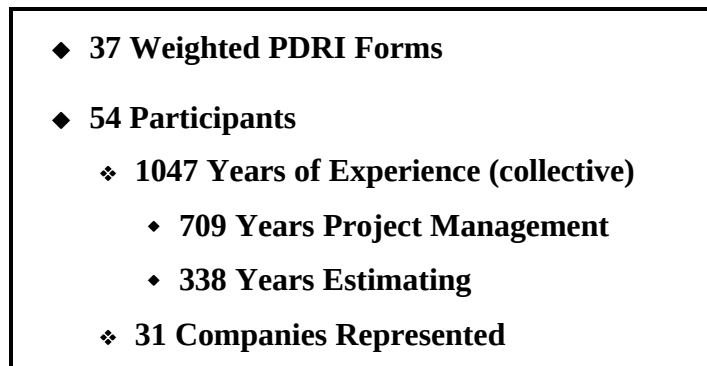


Figure 5. Summary of Input Obtained From Weighting Workshops

2.2.1.1. Instructions for Weighting the Seventy PDRI Elements

At the two workshops, the participants were provided with a detailed explanation of the PDRI including instructions for weighting the 70 elements. Participants were first asked to form small teams of one, two, or three individuals, depending on the experience of the team members. The goal was to obtain an equitable representation of individuals with experience in both project management and estimating on each of the teams. The teams were provided with the following information:

- Brief explanation of the PDRI
- Instructions for evaluating the PDRI
- PDRI Weighting Factor Evaluation form
- Descriptions of the 70 PDRI Elements
- Background Information sheets
- Suggestions for Improvement sheets

The workshop participants were asked to complete three of the above forms; the PDRI Weighting Factor Evaluation form (see Appendix D), the Background Information sheets (see Appendix E), and the Suggestions for Improvement sheets (see Appendix F). The other three forms, a Brief Explanation of the PDRI (see Appendix B), Instructions for Evaluating the PDRI (see Appendix C), and the Descriptions of the Seventy PDRI Elements document (see Appendix K), were to be used as reference material in completing the first three. The descriptions document shown in Appendix K is the final revised version of the PDRI element descriptions. The workshop participants were given a copy of an earlier version of these element

descriptions which was current at the time of the workshops. The final version, however, is very similar to the earlier one with only a few slight modifications. For the purpose of brevity, the earlier version has not been included as reference material.

When filling out the PDRI Weighting Factor Evaluation form, the workshop teams were asked to first consider a project that they typically managed for their company and which was familiar to each team member. They were to complete the PDRI Weighting Factor Evaluation form based on the requirements for this particular project type and size. The team was asked to assume that they were evaluating a scope definition package for their project immediately prior to authorization for detailed design and construction. They were instructed to consider each element one at a time and assess its potential effect on the overall accuracy of the project's total installed cost (TIC) estimate. Depending on how well the element was defined in the scope definition package, ranging from being completely defined to incomplete or poor definition, participants were asked to determine the potential impact of that element on the TIC estimate stated as a percentage of the overall cost.

The element's state of definition was to be evaluated using the following scale:

- 1 = Complete Definition
- 2 = Minor Deficiencies
- 3 = Some Deficiencies
- 4 = Major Deficiencies
- 5 = Incomplete or Poor Definition

It is important to note that the workshop participants were originally asked to weight the elements based upon the premise of assigning contingency allowances

rather than estimates of the elements' potential impact on the TIC estimate. However, after extensive discussion at the first weighting workshop, before weighting took place, the participants and the research team members present agreed that this was not the best approach and that the weighting should be performed as previously mentioned. In the Instructions for Evaluating the PDRI document given in Appendix C, the “contingency” term is used since this is a copy of the original document presented to the workshop participants.

The five levels of definition are listed across the top of the PDRI Weighting Factor Evaluation form creating a matrix with the 70 elements. Participants were asked to state their weighting percentages in the available boxes for each element. In short, they provided approximately 350 weights, five for each of the 70 elements based on their perception of cost impact versus completeness.

Theoretically, if an element was completely defined in the project definition package, it would have a minimal effect on the accuracy of the estimate and would be represented by a low percentage, perhaps zero percent. On the other hand, if the element was not included in the project definition package or was poorly defined, it could have a much larger effect on the accuracy of the estimate and, therefore, would be represented by a higher percentage. No upper or lower limits were placed on the allowable percentages that could be assigned to any of the elements.

The workshop participants were instructed that the magnitude of the percentages they assigned to each element in column 5 (incomplete or poor definition) would indicate to the research team the relative importance of each element in the scope definition package. Higher weights would represent the most important elements that, if completely undefined, would have the greatest effect on the accuracy of the TIC estimate at authorization.

An interactive question and answer period followed the explanation of the weighting instructions. During this time, the research team fielded questions from the workshop participants and attempted to clarify any confusion regarding the weighting instructions. The goal was to ensure that all participants shared a common understanding of the methodology for weighting the PDRI. The workshop participants then weighted the elements. Additional questions were answered on an individual basis until the workshops were completed. At the end of the workshops, participants submitted their weighting input directly to the research team.

2.2.1.2. Instructions for Weighting the Y/N Elements

Early in the process of defining each element in the Descriptions of the 70 PDRI Elements document, the research team decided that some should be evaluated on a simple YES or NO basis indicating that the element either existed or did not exist in the project scope definition package. In the descriptions document, these elements are indicated by a “Y/N” icon. In the PDRI Weighting Factor Evaluation form, these elements have the boxes corresponding to definition levels 2, 3, and 4 darkened. A total of 20 elements were designated for evaluation on a YES or NO basis.

Workshop participants were asked to weight these elements in the following manner. First, consider that at the time of authorization for detailed design and construction, the element existed within the project definition package and weight it under definition level 1. Then, consider that it did not exist within the project definition package and weight it under definition level 5. They were to apply percentages using the same criteria as they had with the non-Y/N elements regarding an element’s potential impact on the TIC estimate. The Y/N elements, therefore, only received two weighting percentages, rather than five as with all of the other elements.

2.2.1.3. An Example of Element Weighting

A portion of the PDRI Weighting Factor Evaluation form that was completed during the workshops is shown in Figure 6. This is an example of Category J, one of the fifteen categories within the entire form. Elements J1 and J2 are typical elements evaluated on a scale including all five levels of definition. Element J3 is an example of an element evaluated on a Y/N basis. Sample percentages are included in the columns representing the five (or two) levels of definition to demonstrate the type of input obtained during the workshops.

SECTION II - FRONT END DEFINITION					
CATEGORY Element	1	2	3	4	5
J. INFRASTRUCTURE					
J1. Water Treatment Requirements	0%	5%	10%	15%	20%
J2. Loading / Unloading / Storage Facilities Requirements	1%	4%	8%	12%	14%
J3. Transportation Requirements	0%				10%

1 = Complete Definition 2 = Minor Deficiencies 3 = Some Deficiencies
4 = Major Deficiencies 5 = Incomplete or Poor Definition

Figure 6. Sample Weighting of Category J in the Weighting Factor Evaluation Form

2.2.2. Benefits of Using Weighting Workshops for Data Collection

The workshops provided a favorable forum for weighting the PDRI using industry input. This method was chosen over others, such as solicitation through mail-out surveys, since it provided immediate feedback to the research team. Also,

representatives from the research team were present to verbally explain the weighting instructions in detail and answer any questions from the workshop participants. The participants were able to reach a common understanding regarding the weighting instructions prior to completing the PDRI Weighting Factor Evaluation form. Thus, the research team felt that the data obtained using this method was of a higher quality than if it had been obtained through a mail-out solicitation coupled with follow-up telephone calls.

2.2.3. Summary of the PDRI Weighting Workshops

A sample of a completed PDRI Weighting Factor Evaluation form obtained during the workshops is presented in Appendix G. Only one of these completed forms is included due to the large volume of data collected. However, a complete list of the maximum weights assigned to each element in all of the completed PDRI Weighting Factor Evaluation forms is included in Appendix H. These maximum weights, obtained from column 5 of each form, represent the participants' opinions regarding the hierarchy of most important to least important elements.

In addition to the 54 individuals invited to the two weighting workshops held in March, three of the six individuals who attended the earlier "fine tuning" workshop in January were also asked to weight the PDRI again. These individuals were mailed identical copies of all materials presented and filled out at the two weighting workshops. Although the research team was skeptical regarding the

quality of input obtained from a mail-out solicitation, the three individuals contacted were already familiar with the PDRI and the weighting instructions. As previously mentioned, they had completed a preliminary version of the PDRI Weighting Factor Evaluation form at the January workshop. Upon examining the weighting information resubmitted by these three individuals, the research team felt it was reliable and of similar quality to the input obtained from the two weighting workshops. The addition of these three PDRI Weighting Factor Evaluation forms brought the total number of completed forms up to forty.

All of the weighting information in the PDRI Weighting Factor Evaluation forms was then analyzed by the research team. These data were used to compute final weights for all of the PDRI elements. The next chapter discusses the methodology for analyzing the data and computing final element weights.

3. DATA ANALYSIS

The previous chapter described how the CII Front End Planning Research Team obtained the input required for weighting each element in the PDRI. This chapter discusses the methods used for analyzing this input and computing the final PDRI element weights. Although a total of 40 completed PDRI Weighting Factor Evaluation forms were collected from the two weighting workshops and the mail-out survey, 38 were used for computing the final element weights. Upon examining each form in detail, the research team discarded two of them. These two had a significant amount of missing data which could not be reasonably collected through follow-up inquiries.

3.1. Characteristics of the Projects Used for Weighting the PDRI

When workshop participants completed the PDRI Weighting Factor Evaluation form, they were asked to consider a project that they typically managed for their company and weight the elements based upon the requirements for this project. Figures 7 and 8 categorize the projects used for weighting the PDRI by type and size, respectively. The research team felt that these projects comprised a representative sample of projects in the industrial construction sector.

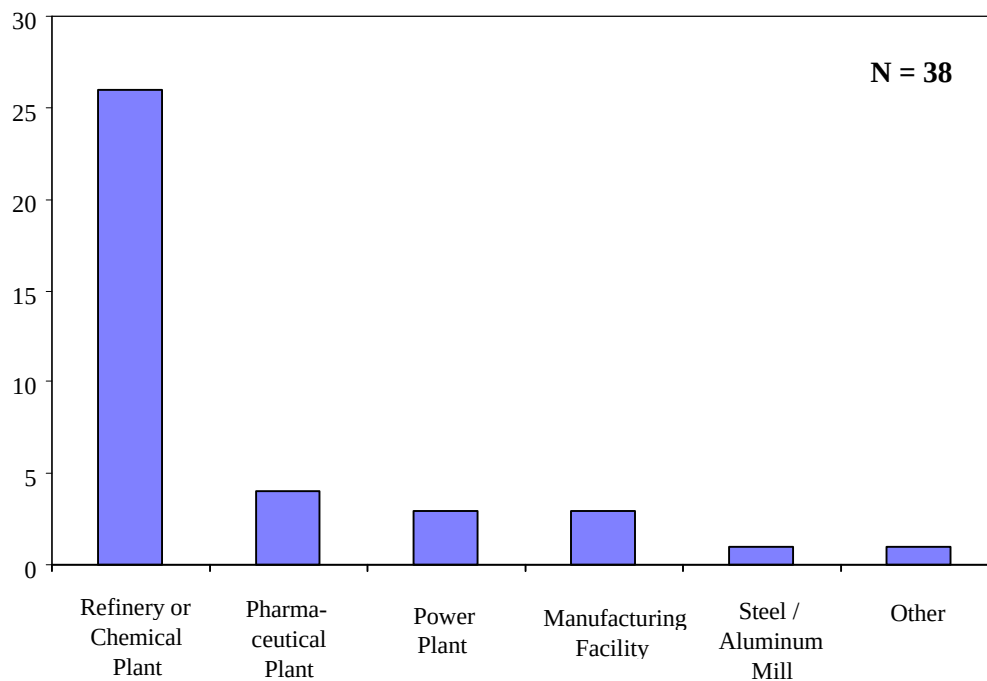


Figure 7. Project Types Used in Weighting the PDRI

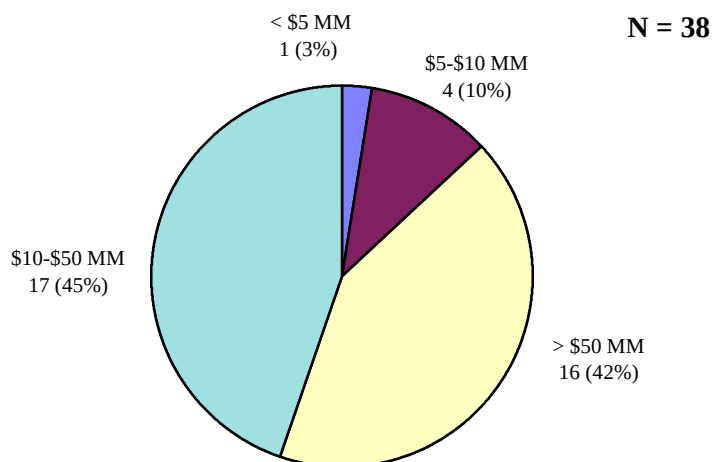


Figure 8. Project Sizes Used in Weighting the PDRI

3.2. Handling Missing Data

Of the 38 PDRI Weighting Factor Evaluation forms used by the research team in computing the final element weights, 13 contained some missing data. The most frequent case of missing data involved forms where a few of the seventy elements were left blank or partially blank. Three primary causes led to the incidents of missing data. These were as follows:

- The element(s) were simply overlooked
- The participant(s) felt that the element(s) were not applicable for the project being considered
- The participant(s) did not possess adequate knowledge or experience to properly address the element(s)

In 11 of the 13 incomplete forms, the research team later obtained the missing data. In cases where the workshop participant(s) could be contacted, these data were collected through follow-up telephone interviews and facsimile correspondence. In some cases, however, the missing data were filled in using the expertise of the research team. An example of this situation was where the low and high definition levels (levels 1 and 5) for an element were completed, but the three intermediate levels (levels 2, 3, and 4) were left blank. The values for these three blanks were then interpolated linearly between the low and high values for that element. In situations where an element was left blank and the values could not be filled in through either of the above means, it remained incomplete and was not included in the final weighting calculations. Once all obtainable missing data were

collected, each PDRI Weighting Factor Evaluation form was normalized to a 1000-point scale in preparation for computing the final element weights.

3.3. Software Used for Data Analysis

Two Microsoft® Windows™-based computer programs were used to perform all data analysis. Raw data from each of the thirty-eight PDRI Weighting Factor Evaluation forms was compiled and sorted in Microsoft Access™ Version 2.0, a relational database management system. This software was chosen for its ease of data entry, its ability to efficiently sort large volumes of data, and its availability. All calculations were performed in Microsoft Excel™ Version 5.0, a spreadsheet program. This software was selected due to its ease of use, computing capabilities, and its availability.

3.4. Normalizing the PDRI Weights Based on a 1000-Point Scale

In order for the PDRI Weighting Factor Evaluation forms to be compared and used in the final weighting calculations, each had to be converted to a similar scale. Since the weights for all elements were based on subjective responses from industry representatives, they covered a broad range of values. As stated earlier, the research team set no limit on the maximum value that could be assigned to an element. Thus, the weights in some forms varied by as much as an order of magnitude.

All of the forms, therefore, were normalized to the same 1000-point scale. Normalizing allowed the research team to capture information specifically regarding the relative importance of the elements despite the varying magnitudes of weights from document to document.

3.4.1. Benefits of Using a 1000-Point Scale

A scale of 1000 points was chosen for normalizing each PDRI Weighting Factor Evaluation form. As mentioned in Chapter 1, the research team referred to previous scope definition work by John Hackney. The scoring scheme used in his Definition Rating Checklist, however, was very complicated, with no clear instructions for using it provided in the supporting text (Hackney 1992). The complicated nature of Hackney's checklist may be a reason why it is not widely used and accepted. Therefore, the research team felt that a simple, straightforward scoring scheme should be used for the PDRI. A 0 to 1000 point scheme was chosen, as it was an easily comprehensible range of values, yet it provided enough detail to differentiate between projects of similar definition levels.

As mentioned earlier, the research team adopted Hackney's "low score = good score" philosophy. When evaluating scope definition packages with the PDRI, a score close to 0 represents a well-defined project while a score close to 1000 signifies one that is poorly defined. This scheme was chosen for two reasons. The first reason is that the research team felt it is easy to understand. More