

CONSTRUCTION  
INDUSTRY  
INSTITUTE

# **DEVELOPMENT OF THE PROJECT DEFINITION RATING INDEX (PDRI) FOR BUILDING PROJECTS**

by  
**Chung-Suk Cho**  
**Jeffrey C. Furman**  
and  
**G. Edward Gibson, Jr.**

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

**Under the Guidance of the**  
**PDRI for Building Projects Research Team**  
**Number 155**

**from**  
**The University of Texas at Austin**  
**Austin, Texas**

**December 1999**

*Reviewed by CII 23Feb05*

© 1999 Construction Industry Institute™.

The University of Texas at Austin.

CII members may reproduce and distribute this work internally in any medium at no cost to internal recipients. CII members are permitted to revise and adapt this work for the internal use provided an informational copy is furnished to CII.

Available to non-members by purchase; however, no copies may be made or distributed and no modifications made without prior written permission from CII. Contact CII at <http://construction-institute.org/catalog.htm> to purchase copies. Volume discounts may be available.

All CII members, current students, and faculty at a college or university are eligible to purchase CII products at member prices. Faculty and students at a college or university may reproduce and distribute this work without modification for educational use.

Printed in the United States of America.

## Table of Contents

|                                                          |     |
|----------------------------------------------------------|-----|
| List of Tables .....                                     | ix  |
| List of Figures .....                                    | x   |
| Executive Summary .....                                  | xii |
| Chapter 1 INTRODUCTION .....                             | 1   |
| 1.1. Research Team Objectives .....                      | 2   |
| 1.2. Project Domain .....                                | 3   |
| 1.3. Research Hypothesis .....                           | 4   |
| 1.4. Research Objectives .....                           | 4   |
| 1.5. Organization of the Research Report .....           | 5   |
| Chapter 2 BACKGROUND .....                               | 7   |
| 2.1. Construction Industry Institute (CII) .....         | 7   |
| 2.2. Project Life Cycle .....                            | 8   |
| 2.3. Pre-Project Planning .....                          | 13  |
| 2.4. Project Scope Definition .....                      | 17  |
| 2.5. PDRI for Industrial Projects .....                  | 21  |
| 2.6. Building Project Life Cycle .....                   | 25  |
| 2.7. Facility Programming .....                          | 27  |
| 2.8. Team Alignment .....                                | 29  |
| 2.9. Process Map of Planning Steps .....                 | 30  |
| 2.10. Project Success and Critical Success Factors ..... | 32  |
| 2.11. Summary of the Literature Review .....             | 37  |

|                                                          |    |
|----------------------------------------------------------|----|
| Chapter 3 PROBLEM STATEMENT AND RESEARCH HYPOTHESES..... | 39 |
| 3.1. Problem Statement.....                              | 39 |
| 3.2. Research Hypotheses.....                            | 40 |
| 3.3. Summary.....                                        | 42 |
| Chapter 4 METHODOLOGY.....                               | 43 |
| 4.1. Scoresheet Development .....                        | 45 |
| 4.2. Weighting Workshops .....                           | 45 |
| 4.3. Data Collection.....                                | 46 |
| 4.4. Survey Research .....                               | 47 |
| 4.4.1. Survey Mode Selection.....                        | 48 |
| 4.4.2. Survey Administration.....                        | 49 |
| 4.4.3. Sample Selection .....                            | 50 |
| 4.4.4. Survey Instrument Development.....                | 50 |
| 4.5. Unit of Analysis.....                               | 51 |
| 4.6. Measures.....                                       | 52 |
| 4.6.1. Schedule Information.....                         | 52 |
| 4.6.2. Cost Information.....                             | 53 |
| 4.6.3. Change Information .....                          | 53 |
| 4.6.4. Operating Information .....                       | 53 |
| 4.6.5. Customer Satisfaction.....                        | 54 |
| 4.6.6. Project Rating with the PDRI.....                 | 54 |
| 4.7. Statistical Tests .....                             | 55 |
| 4.7.1. The Boxplot .....                                 | 55 |
| 4.7.2. Regression Analysis.....                          | 57 |
| 4.7.3. Independent-Samples <i>t</i> Test.....            | 59 |
| 4.8. Limitations of the Data Analysis .....              | 61 |

|                                                                           |           |
|---------------------------------------------------------------------------|-----------|
| 4.9. Summary.....                                                         | 62        |
| <b>Chapter 5 PDRI DEVELOPMENT PROCESS.....</b>                            | <b>63</b> |
| 5.1. Background of the PDRI for Building Projects.....                    | 63        |
| 5.2. Weighting the PDRI Elements.....                                     | 66        |
| 5.3. PDRI Weighting Workshops .....                                       | 67        |
| 5.3.1. Information on Weighting Workshops Participants .....              | 70        |
| 5.3.2. Characteristics of the Projects used for the PDRI Weighting.....   | 72        |
| 5.3.3. Weighting Workshop Packet.....                                     | 74        |
| 5.4. Weighting Methodology.....                                           | 74        |
| 5.4.1. Example of Element Weighting Process .....                         | 77        |
| 5.4.2. Not Applicable Elements.....                                       | 78        |
| 5.4.3. Summary of the Weighting Methodology .....                         | 79        |
| 5.5. Developing the PDRI Element Weights.....                             | 80        |
| 5.5.1. Normalizing Process.....                                           | 80        |
| 5.5.2. Preliminary PDRI Element Weights.....                              | 84        |
| 5.5.3. Data Screening with Boxplots .....                                 | 84        |
| 5.5.4. Element Mean Weights for Definition Level 5 and 1.....             | 89        |
| 5.5.5. Interpolating the Weights for Definition Level 2, 3, and 4 ...     | 91        |
| 5.6. Finalizing the PDRI Project Score Sheet.....                         | 93        |
| 5.7. Analyzing the Weighted PDRI.....                                     | 97        |
| 5.7.1. Comparison of Owners and Contractors' Perception<br>on PDRI .....  | 101       |
| 5.7.2. Comparison of Architects and Engineers' Perception<br>on PDRI..... | 103       |
| 5.8. Instructions for Scoring a Project.....                              | 105       |
| 5.8.1. Philosophy of Use.....                                             | 110       |
| 5.9. Summary.....                                                         | 112       |

|                                                                     |     |
|---------------------------------------------------------------------|-----|
| <b>Chapter 6 PDRI VALIDATION</b> .....                              | 113 |
| 6.1. Validation Project Domain .....                                | 114 |
| 6.2. Validation Questionnaire Development .....                     | 114 |
| 6.3. Sample Project Selection .....                                 | 115 |
| 6.3.1. Sample Characteristics.....                                  | 117 |
| 6.4. Questionnaire Responses and Analyses.....                      | 120 |
| 6.4.1. Project Rating Information .....                             | 120 |
| 6.4.2. Project Performance Analyses.....                            | 122 |
| 6.5. Summary of Performance Evaluation.....                         | 134 |
| 6.6. PDRI Validation Using In-Progress Projects .....               | 136 |
| 6.7. Summary.....                                                   | 139 |
| <b>Chapter 7 PROJECT SUCCESS AND PDRI</b> .....                     | 141 |
| 7.1. Correlations between PDRI and Four Performance Variables ..... | 142 |
| 7.2. Project Success Computation Using the Top Two Variables.....   | 144 |
| 7.3. Project Success Computation Using the Top Three Variables..... | 146 |
| 7.4. Project Success Computation Using All Four Variables.....      | 147 |
| 7.5. PDRI and Project Success Index .....                           | 148 |
| 7.6. Summary.....                                                   | 152 |
| <b>Chapter 8 LOGIC FLOW DIAGRAMS</b> .....                          | 153 |
| 8.1. Introduction .....                                             | 153 |
| 8.2. Validation.....                                                | 154 |
| 8.2.1. Interview Development .....                                  | 155 |
| 8.2.2. Interview Summary .....                                      | 156 |
| 8.3. Logic Flow Diagrams Description.....                           | 160 |
| 8.3.1. Section Diagram .....                                        | 161 |
| 8.3.2. Category Diagram.....                                        | 162 |

|                                                                                                                                |            |
|--------------------------------------------------------------------------------------------------------------------------------|------------|
| 8.3.3. Element Diagram.....                                                                                                    | 164        |
| 8.4. Summary of the LFD Development .....                                                                                      | 169        |
| <b>Chapter 9 CONCLUSIONS AND RECOMMENDATIONS .....</b>                                                                         | <b>171</b> |
| 9.1. Review of Research Objectives.....                                                                                        | 171        |
| 9.1.1. Development of Project Scope Definition Measurement<br>Tool.....                                                        | 171        |
| 9.1.2. Validation of the PDRI.....                                                                                             | 172        |
| 9.2. Findings Related to the Research Hypothesis .....                                                                         | 174        |
| 9.3. Conclusions.....                                                                                                          | 175        |
| 9.4. Recommendations to PDRI Users .....                                                                                       | 179        |
| 9.5. Recommendations for Future Research.....                                                                                  | 181        |
| <b>Appendix A Participating Organizations.....</b>                                                                             | <b>183</b> |
| PDRI for Building Projects Research Team Membership.....                                                                       | 184        |
| Organizations Participating in the Weighting Workshops .....                                                                   | 185        |
| Organizations Providing Validation Projects .....                                                                              | 186        |
| <b>Appendix B PDRI for Building Projects Documents.....</b>                                                                    | <b>187</b> |
| Unweighted PDRI Score Sheet.....                                                                                               | 188        |
| Weighted PDRI Score Sheet.....                                                                                                 | 192        |
| PDRI Element Descriptions.....                                                                                                 | 196        |
| <b>Appendix C Weighting Workshops Information Packet.....</b>                                                                  | <b>233</b> |
| <b>Appendix D Sample of a Completed “PDRI Weighting Factor Evaluation<br/>Form” Obtained from the Weighting Workshops.....</b> | <b>245</b> |
| <b>Appendix E Descriptive Statistics of the Element Weights .....</b>                                                          | <b>249</b> |
| <b>Appendix F PDRI Validation Projects Questionnaire .....</b>                                                                 | <b>257</b> |

Appendix G Example of a Project Evaluation Using the PDRI for Building Projects .....279

Appendix H Validation Projects Characteristics .....285

Appendix I Performance Results For Validation Projects Using PDRI Cutoff Point of 200.....287

Bibliography .....291

## List of Tables

|            |                                                                                                         |     |
|------------|---------------------------------------------------------------------------------------------------------|-----|
| Table 2.1. | Evaluation of Performance by Pre-Project Planning Groups .....                                          | 16  |
| Table 5.1. | Summary of Weighting Workshops .....                                                                    | 69  |
| Table 5.2. | Data Screening Variables and Weights .....                                                              | 87  |
| Table 5.3. | The Result of Frequency Score Calculations as Part of the Data<br>Screening Process.....                | 88  |
| Table 5.4. | The PDRI Element Weights After Interpolations.....                                                      | 92  |
| Table 5.5. | Twelve Highest Weighted Elements from Each Category.....                                                | 99  |
| Table 6.1. | Sample Projects Classification and Complexity.....                                                      | 118 |
| Table 6.2. | Independent Samples Test Results for Schedule Performance .....                                         | 124 |
| Table 6.3. | Independent Samples Test Results for Cost Performance.....                                              | 126 |
| Table 6.4. | Independent Samples Test Results for Average Number of<br>Change Orders .....                           | 128 |
| Table 6.5. | Independent Samples Test Results for Design Size Changes.....                                           | 131 |
| Table 6.6. | Independent Samples Test Results for Project Success.....                                               | 134 |
| Table 6.7. | In-Progress PDRI Validation Projects.....                                                               | 137 |
| Table 7.1. | Determination of Relative Importance of the Four Variables .....                                        | 143 |
| Table 7.2. | Regression Analysis Results for the PDRI and the Project<br>Success Computed with Two Variables .....   | 145 |
| Table 7.3. | Regression Analysis Results for the PDRI and the Project<br>Success Computed with Three Variables ..... | 146 |
| Table 7.4. | Regression Analysis Results for the PDRI and the Project<br>Success Computed with Four Variables .....  | 148 |
| Table 8.1. | Key Strengths of Building Industry Professionals.....                                                   | 155 |
| Table 8.2. | Specialty Breakout of Interviews .....                                                                  | 156 |
| Table 8.3. | Interviewee's Uses of the LFDs .....                                                                    | 159 |

## List of Figures

|              |                                                                                                                     |     |
|--------------|---------------------------------------------------------------------------------------------------------------------|-----|
| Figure 2.1.  | Influence and Expenditures Curves for the Project Life Cycle.....                                                   | 9   |
| Figure 2.2.  | Project Life Cycle Overlap Diagram.....                                                                             | 12  |
| Figure 2.3.  | PDRI Ten Highest Weighted Elements.....                                                                             | 22  |
| Figure 2.4.  | PDRI Section and Category Weights.....                                                                              | 24  |
| Figure 2.5.  | Project Performance Comparison Using a 200 Point Cutoff .....                                                       | 25  |
| Figure 2.6.  | Success Index Variables and Weights.....                                                                            | 35  |
| Figure 2.7.  | Equation for Measuring Project Success.....                                                                         | 36  |
| Figure 4.1.  | Research Methodology Flow Diagram.....                                                                              | 44  |
| Figure 4.2.  | Annotated Sketch of the Boxplot .....                                                                               | 56  |
| Figure 5.1.  | PDRI Sections, Categories, and Elements .....                                                                       | 65  |
| Figure 5.2.  | PDRI Elements Weighting Process.....                                                                                | 68  |
| Figure 5.3.  | Summary of Input Obtained from Weighting Workshops.....                                                             | 71  |
| Figure 5.4.  | Project Types used in Weighting the PDRI .....                                                                      | 72  |
| Figure 5.5.  | Project Sizes used in Weighting the PDRI.....                                                                       | 73  |
| Figure 5.6.  | An Example of Weighting Category G .....                                                                            | 77  |
| Figure 5.7.  | Example of Normalizing Level 5 and Level 1 for a Sample<br>PDRI Weighting Factor Evaluation Form – DA1 .....        | 82  |
| Figure 5.8.  | Identifying Extremes and Outliers from 67 Data Sets for<br>Definition Level 5, Category B using Boxplot Option..... | 86  |
| Figure 5.9.  | PDRI Project Score Sheet .....                                                                                      | 94  |
| Figure 5.10. | PDRI Section and Category Weights.....                                                                              | 97  |
| Figure 5.11. | Fourteen Highest Weighted PDRI Elements.....                                                                        | 98  |
| Figure 5.12. | Ten Highest Ranking Business Elements.....                                                                          | 100 |
| Figure 5.13. | Ten Highest Ranking Technical Elements .....                                                                        | 101 |
| Figure 5.14. | PDRI Sections and Category Weights by Owners and<br>Contractors .....                                               | 102 |

|                                                                                                                                        |     |
|----------------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 5.15. PDRI Sections and Category Weights by Architects and Engineers .....                                                      | 104 |
| Figure 5.16. Applicability of PDRI in Project Lifecycle.....                                                                           | 106 |
| Figure 6.1. Specifications for the Validation Project .....                                                                            | 114 |
| Figure 6.2. Sample Projects Categorized by Type .....                                                                                  | 117 |
| Figure 6.3. Sample Projects Categorized by Contract Type.....                                                                          | 119 |
| Figure 6.4. Schedule Performance versus the PDRI .....                                                                                 | 123 |
| Figure 6.5. Cost Performance versus the PDRI.....                                                                                      | 126 |
| Figure 6.6. Change Performance versus the PDRI.....                                                                                    | 128 |
| Figure 6.7. Financial Performance of Sample Projects .....                                                                             | 129 |
| Figure 6.8. Design Size Changes versus the PDRI.....                                                                                   | 131 |
| Figure 6.9. Facility Utilization versus the PDRI .....                                                                                 | 132 |
| Figure 6.10. Project Success versus PDRI.....                                                                                          | 133 |
| Figure 6.11. Summary of Cost, Schedule, and Change Order Performance<br>for the PDRI Validation Projects Using a 200 Point Cutoff..... | 135 |
| Figure 6.12. Summary of Other Performance Data for the PDRI Validation<br>Projects Using a 200 Point Cutoff .....                      | 136 |
| Figure 7.1. Scoring Criteria for the Project Success Variables .....                                                                   | 142 |
| Figure 7.2. Equation for Computing the Project Success Rating.....                                                                     | 149 |
| Figure 7.3. Project Success Ratings vs. PDRI Scores .....                                                                              | 150 |
| Figure 8.1. Section Diagram.....                                                                                                       | 161 |
| Figure 8.2. Category Diagram .....                                                                                                     | 163 |
| Figure 8.3. Element Diagram.....                                                                                                       | 165 |

## Executive Summary

Recent research studies have proven the importance of the pre-project planning phase of the construction life cycle. Specifically, a complete scope definition improves project performance in the area of cost, schedule, and operational characteristics. Unfortunately, until now, the building sector has lacked non-proprietary tools to assist in performing this critical stage of the project. In order to address this need, the Construction Industry Institute (CII) formed the Project Definition Rating Index (PDRI) for Building Projects Research Team (RT 155) to produce an effective and user-friendly scope definition tool for building projects.

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 building construction industry.

Specifically, the research team developed the PDRI for building projects, which consists of 64 scope definition elements in a weighted checklist format and provides a method for measuring the completeness of project scope development. The PDRI for building projects, a weighted index based on industry “best practices”, allows its users to measure the level of scope definition and to compare scope definition to anticipated project success. This tool should help

owners and contractors better achieve business, operational, and project objectives.

The 64 scope definition elements of the PDRI for building projects were weighted in order of importance using input from 69 experienced project managers, architects, and engineers. The result of this weighting process revealed the critical elements in building projects that are imperative to project success.

When using the PDRI tool, the weighted score of a project can range up to 1000 points, with a lower score being better. Based on an analysis of 33 completed projects during the validation process, the research team found that projects scoring less than 200 (out of 1000 total points) were significantly more successful than those that scored greater than 200.

The PDRI for building projects was used on several projects that were in-progress during the research. Lessons learned are presented to provide a better understanding of how to use the PDRI tool in planning a project. Logic flow diagrams, developed to provide time-sequenced logic to project planning activities, are also included.



## CHAPTER 1 INTRODUCTION

Over the past several years, the Construction Industry Institute (CII) has funded a number of research projects focused on pre-project planning. Findings from these investigations have dramatically changed the awareness of project management professionals within CII toward the importance of the process and the benefits of pre-project planning. Research results show that greater pre-project planning efforts lead to improved performance on industrial projects in the areas of cost, schedule, and operational characteristics.

Crystallizing these efforts was the development of the Project Definition Rating Index, a scope definition tool for Industrial Projects. This tool is comprised of a comprehensive checklist of 70 scope definition elements presented in a scoresheet 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 (Gibson and Dumont 1996).

Results from usage of the industrial version of the PDRI have indicated an increase in project budget predictability of almost 20 percent on average versus authorization estimate, with similar results for schedule, change orders, and operability. Included in these benefits are real cost savings of greater than 10 percent per project (Gibson and Dumont 1996).

The building industry is obviously different from the industrial sector in various ways such as, approach to planning, design, construction of facilities, owner perspective, architectural focus, and so on. Nonetheless, there are many more similarities than differences. Like the industrial sector, the building industry suffers from poor or incomplete project scope definition. However, a quantitative understanding of scope definition issues during the pre-project planning phase has not been studied. Consequently, early planning is typically not performed well in this sector which results in significant overruns of budgets and schedules.

In order to produce an effective and easy-to-use scope definition tool for building projects, CII commissioned Research Team 155, the PDRI for Building Projects Research Team in 1998. This team consisted of representatives from seven owner organizations, nine contractors, and one academic member and was dedicated to developing a nonproprietary tool that could help owners and contractors better achieve business, operational, and project objectives.

### **1.1. Research Team Objectives**

The primary objective of the PDRI for Building Projects Research Team was to develop a user-friendly tool to support adequate scope development for building projects that is widely accepted in the industry. Sub-objectives include:

1. Help gain a better understanding of scope development for building projects, including logic flow.

2. Finalize the building projects PDRI that should:
  - Be simplistic, easy to use, yet detailed enough to be effective
  - Reduce total project costs as well as schedule through better scope definition
  - Serve as a communication tool with customers, within project team, for owner project managers to users, or for contractors to developers
  - Be a decision support tool
  - Be flexible among facility types
  - Be a reliable predictor of costs and schedule
3. Verify the viability of the PDRI as a predictor of project success.
4. Develop publications and deploy to industry.

## **1.2. Project Domain**

This research investigation is limited to developing a scope definition tool for building projects, excluding residential houses, performed in both the public and private sector. Therefore, the findings from this research are most applicable to the multi-story or single story commercial, institutional, or light industrial facilities such as:

- |                                      |                                       |
|--------------------------------------|---------------------------------------|
| • Offices                            | • Schools (classrooms)                |
| • Banks                              | • Research & laboratory facilities    |
| • Medical facilities                 | • Nursing homes                       |
| • Institutional buildings            | • Stores / shopping centers           |
| • Dormitories                        | • Apartments                          |
| • Hotels / motels                    | • Parking structures                  |
| • Warehouses                         | • Light assembly / manufacturing      |
| • Churches                           | • Airport terminals                   |
| • Recreational / athletic facilities | • Public assembly / performance halls |
| • Industrial control buildings       |                                       |

The PDRI for building projects has limited applicability to the infrastructure sector. Infrastructure projects involve different scope elements and thus should remain as a subsequent research topic.

### **1.3. Research Hypothesis**

The primary research hypothesis of this study is that the successful completion of a building construction project is positively correlated with the level of the scope definition during the pre-project planning phase. That is, a well-defined scope definition package would correspond to a higher probability of project success. How well the project scope is defined will be measured by the PDRI.

### **1.4. Research Objectives**

The purpose of this research effort is to improve the probability that projects involving the construction of general building facilities will be successful. This objective will be met by developing an effective scope definition tool. The three primary objectives as well as secondary objectives of this research are:

1. To produce a user-friendly and generic tool for measuring project scope development based on industry best practices and a methodology for benchmarking the degree of scope development.
  - Identify a critical few success elements in building projects PDRI.

2. To validate the PDRI through testing on sample projects and measuring the level of project scope definition during the pre-project planning phase as well as the degree of project success.
  - Identify the relationship that exists between PDRI and project success.
  - Identify significant project success variables.
  - Identify measures for project success.
3. To develop a *generic* logic flow diagram for pre-project planning of buildings.
  - Tie the diagrams to the quantitative score of the PDRI for buildings. This chart shows the project's PDRI score as the user progresses through the planning process.
  - Validate the logic flow diagram's usefulness and accuracy.

The main focus of this research report is to verify the viability of the PDRI as a predictor of project success. Because one use of the PDRI is as a prediction tool, identifying the relationship between PDRI and project success is imperative to the success of this research effort.

### **1.5. Organization of the Research Report**

This research report is organized into nine chapters and several appendices containing supporting information and results of data collection and analysis. Following this introduction chapter, background information regarding CII, the project life cycle, pre-project planning, project scope definition, PDRI for industrial projects, building project life cycle and facility programming, team alignment, and project success and critical success factors, are presented in

Chapter Two. Chapter Three presents the research problem statement and research hypotheses. Research methodology is presented in Chapter Four, including data collection methods employed using the survey instruments and statistical analysis procedures used. Chapter Five provides detailed descriptions of the PDRI development process including the weighting workshops, PDRI element weighting process, analysis performed on the weighted PDRI, and instructions on how to use the PDRI. Chapter Six discusses the validation process and analysis of results. In Chapter Seven, mechanics of measuring building project success are presented and significant relationships found between the PDRI and project performance measured with the success rating index are discussed. An outline of the Logic Flow Diagram development process is provided in Chapter Eight. Lastly, Chapter Nine reviews the achievement of research objectives, as well as conclusions, recommendations, and suggestions for follow-up research.

## **CHAPTER 2 BACKGROUND**

As a starting point, an extensive literature review was conducted into research related to the project life cycle, pre-project planning, scope definition, programming, and project success. The results of this literature review are presented in this chapter to provide background and support in developing the problem statement, research hypotheses, and methodologies used to test those hypotheses.

### **2.1. Construction Industry Institute (CII)**

CII is a research organization established in 1983 with a mission to improve the safety, quality, schedule, and cost effectiveness and to support the competitive advantage to its members in the global marketplace. It is a consortium of approximately 85 leading owner and contractor organizations that have joined together to find better ways of planning and executing capital construction programs. Member organizations staff CII Research Teams to provide guidance for specific research activities which are conducted at a number of different universities.

Since its first formal publication in May 1986, CII has produced over 110 different publications. These publications summarize the findings of the detailed research, which is contained in the CII research documents. The publications are

offered to the construction industry as a contribution with the intent of disseminating the results of the research conducted.

## **2.2. Project Life Cycle**

A number of recent research studies conducted and published by CII have investigated the importance of the pre-project planning phase of the construction life cycle. These studies have defined the pre-project planning process for the construction of capital facilities and evaluated the relationship between overall project success and the level of pre-project planning effort (Gibson et al. 1993; Gibson and Hamilton 1994). These studies based their research hypotheses on the concept that the early stages in the project life cycle can have a much greater influence on a project's outcome than later stages, as conceptually shown in Figure 2.1.

The influence versus expenditures curve is presented in this report to emphasize the important concept that it represents. The diagram illustrates that it is much easier to influence a project's final outcome during the planning stage when expenditures are relatively minimal than it is to affect the outcome during later stages when expenditures are more significant (Gibson et al. 1994).

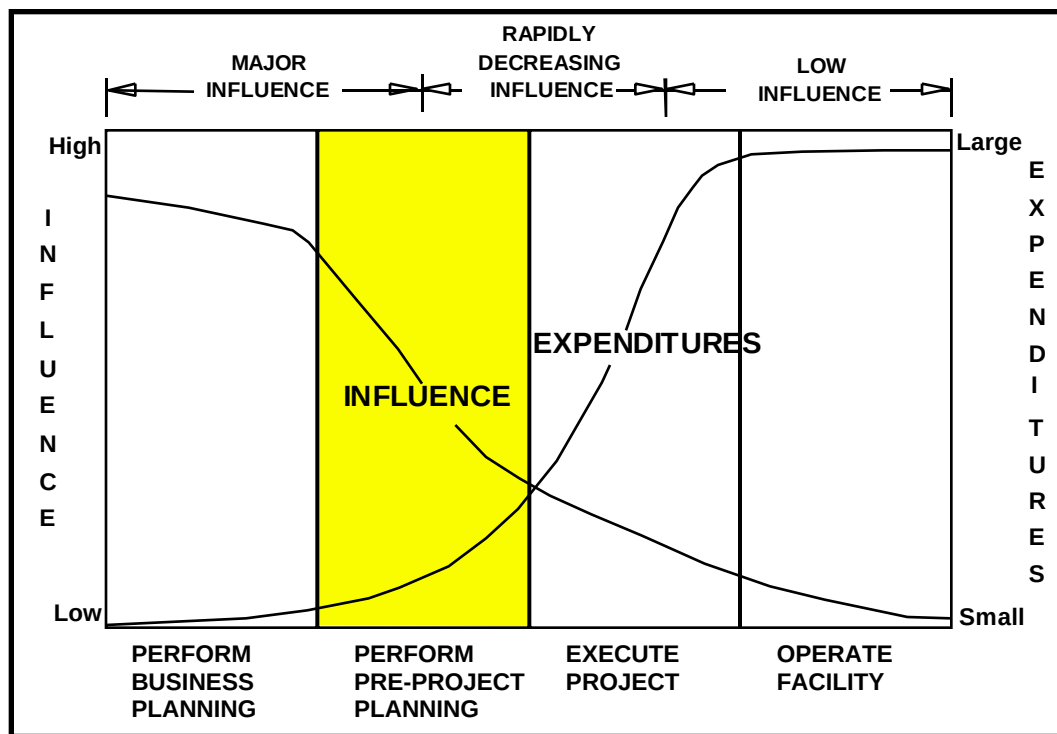


**Figure 2.1. Influence and Expenditures Curves for the Project Life Cycle**

As shown in Figure 2.1, the project life can be broken into four distinct phases: business planning, pre-project planning, project execution, and facility operation. The first function in the project life cycle, perform business planning, is the strategic planning which focuses on the goals and objectives of the organization as they relate to the project. The project concept is the initial idea which sets the project in motion. It may involve new profit opportunity or it may involve compliance with regulations or reduction of liability exposure. This project concept typically includes information relating to the preliminary project objectives.

The second function in the project life cycle is pre-project planning which is the main focus of this research. Pre-project planning is defined as *the process of developing sufficient strategic information for owners to address risk and decide to commit resources to maximize the chance for a successful project* (CII 1994). This process begins with an identification and validation of the project concept during the business planning phase and ends with the decision to proceed with detailed engineering design and facility construction. Normally, a decision on whether or not to authorize funding for the execution of the project is made at this stage.

During pre-project planning, the validated project concept is transformed into outputs in the form of a decision and a project definition package. The first output of the pre-project planning process is a decision which is a formal determination as to whether or not to provide the resources necessary to proceed with the execution of a project. The second output of the process is the project definition package which is the detailed formulation of a continuous and systematic strategy to be used during the execution phase of the project to accomplish the project objectives.

The third function in the project life cycle is the execution of the project which encompasses the detailed design, procurement, construction, and startup for a facility. During project execution, the decision to proceed is transformed into a

completed project which typically encompasses a facility that has no missing or deficient systems or components.

The fourth and final function in the project life cycle is operation of the facility. In this function, the completed project is operated to produce a product during the economic life of the facility. This function may also include renovation and decommissioning. Figure 2.2 shows an overlap diagram of the major phases in the project life cycle (Gibson and Hamilton 1994).

Pre-project planning encompasses the feasibility analysis, conceptual planning and detailed scope definition phases. The overlapping regions signify critical junctures where transitions are made and a decision to proceed typically occur. The increasing sizes of the phases are representative of the relative amounts of effort and resources expended during each phase (CII 1994).

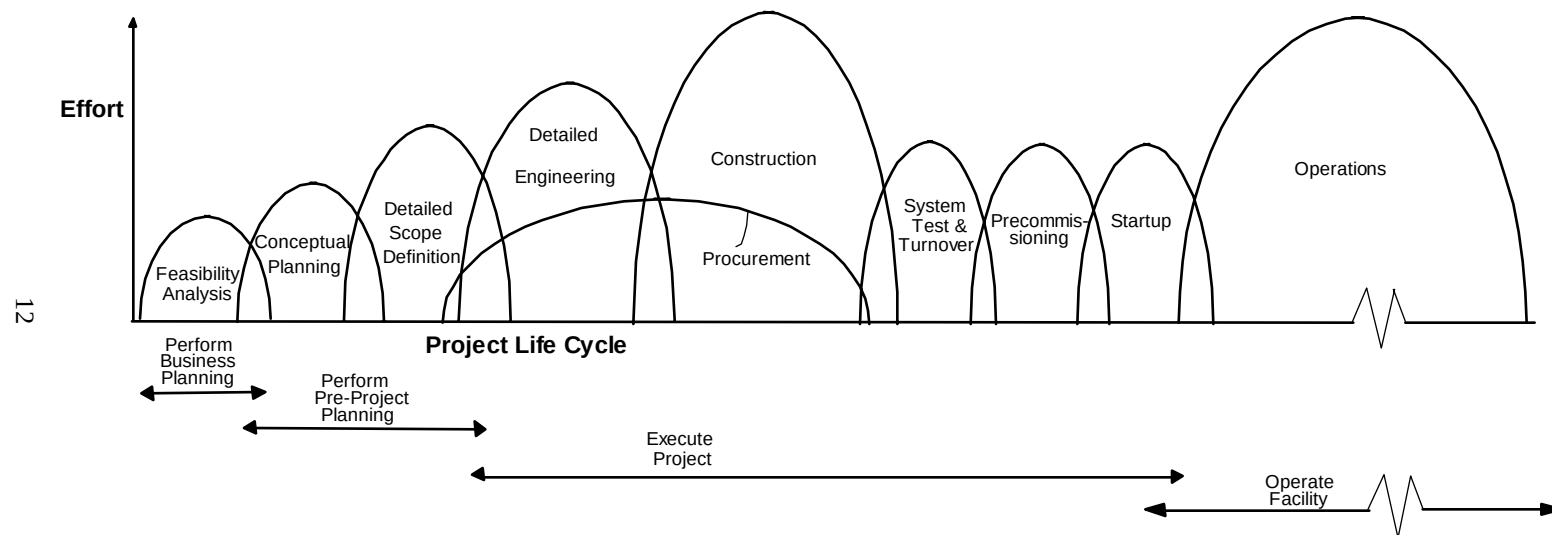


**Figure 2.2. Project Life Cycle Overlap Diagram**

### **2.3. Pre-Project Planning**

Pre-project planning of capital facilities is an extremely important function in determining the ultimate outcome of a project. How well it is performed will affect cost and schedule performance, operating characteristics of the facility, as well as the overall financial success of the project. When a high level of effort is put forth in this early phase, the project is likely to experience fewer scope changes during project execution. Overall, proficient pre-project planning is vital to the success of a project (Gibson and Hamilton 1994).

It is during this critical phase of the project cycle when the project team is aligned and major decisions regarding project scope are made. These early decisions regarding the project's scope and specific project information are compiled into a project definition package that allows the decision maker to determine the viability of the overall project and further provides the basis for project execution. The central premise of the PDRI for Building Projects Research Team effort has therefore been that "teams must be working on the right project in a collaborative manner (alignment), and performing the right work (scope definition) during pre-project planning."

It was not until recently that the topic of pre-project planning received significant research effort. Although substantial effort has been expended on understanding and improving the execution phase of capital projects, little

attention was given on the phases involving pre-project planning. Before CII investigated this topic, there have been few definitive studies in the literature that have identified the important factors for measuring pre-project planning effort and the impact it has on the project success.

In his study of capital costs estimating and controls, Hackney (1992) categorized items that are most important in a project definition package and proposed a detailed checklist for project planning. He assigned maximum weights to each of the items in his checklist which the weights represented the relative ability of an item to affect the degree of uncertainty in the project estimate. This definition checklist was intended to be used as a means for improving areas of uncertainty and predicting project performance. Hackney's Definition Rating Checklist was found to be the most comprehensive and detailed attempt at quantifying project scope definition and became a prototype model for the development of the PDRI for industrial projects.

A study by the Rand Corporation, called the Pioneer Plants Study, investigated the reasons for inaccurate estimates of plant capital costs and performance difficulties on first-of-a-kind process plants. The study provided factors responsible for inaccurate cost estimates and poor plant performance. According to results from the study, both performance problems and inaccurate

cost estimations were associated with the technical and site characteristics of the project (Merrow et al. 1981).

The CII Pre-Project Planning Research Team was chartered to determine the impact of pre-project planning on the success of industrial projects (1994). Using data from 53 capital facility projects, the research team discovered high correlation between the project success index and pre-project planning effort index. That is, the more effort made during pre-project planning, the higher the chance of project success. In its investigation, the research team divided the 53 projects into three groups according to the level of pre-project planning effort as shown in Table 2.1 and analyzed the performance in the area of cost, schedule, percent attainment of nameplate capacity at six months, and utilization of the facility at six months. The values shown in the table represent deviation versus estimates at the time of project authorization for execution.

**Table 2.1. Evaluation of Performance by Pre-Project Planning Groups**

| Pre-Project Planning Effort | Category      | Range        | Average | Std. Dev.    |
|-----------------------------|---------------|--------------|---------|--------------|
| High                        | Cost          | -19 to +13%  | -4%     | 7%           |
|                             | Schedule      | -57 to +17%  | -13%    | 17%          |
|                             | % Attainment  | 50 to 140%   | 102%    | 20%          |
|                             | % Utilization | 52 to 140%   | 103%    | 19%          |
|                             | Financial     | 6 Exceeded   | 7 Met   | 3 Fell Short |
| Medium                      | Cost          | -28 to +9%   | -2%     | 10%          |
|                             | Schedule      | -57 to +45%  | +8%     | 24%          |
|                             | % Attainment  | 42 to 101%   | 93%     | 16%          |
|                             | % Utilization | 42 to 102%   | 94%     | 15%          |
|                             | Financial     | 6 Exceeded   | 6 Met   | 5 Fell Short |
| Low                         | Cost          | -34 to +142% | +16%    | 45%          |
|                             | Schedule      | -55 to +125% | +26%    | 44%          |
|                             | % Attainment  | 20 to 100%   | 87%     | 20%          |
|                             | % Utilization | 46 to 107%   | 85%     | 20%          |
|                             | Financial     | 5 Exceeded   | 6 Met   | 6 Fell Short |

From this analysis, the investigation showed that well-performed pre-project planning can:

- reduce total project design and construction costs by an average of 20 percent
- reduce total project design and construction schedule by an average of 39 percent
- improve project predictability in terms of cost, schedule, and operating performance
- increase the chance of the project meeting environmental and social goals

Furthermore, the research team discovered that more highly planned facilities experienced fewer scope-based change order costs than projects with low pre-project planning effort (Gibson and Hamilton 1994).

#### **2.4. Project Scope Definition**

Project scope definition is a process by which projects are defined and prepared for execution and is a *key component of pre-project planning*. During this process, information such as general project requirements, necessary equipment and materials, and construction methods or procedures are identified and compiled in the form of a project definition package. This package includes sufficient supplemental information to permit effective and efficient detailed design to proceed (Gibson et al. 1993).

Inadequate or poor scope definition, which negatively correlates to the project performance, is recognized as the most serious problem on a construction project (Smith and Tucker 1983). Due to poor scope definition, final project costs can be expected to be higher because of the inevitable changes which interrupt project rhythm, cause rework, increase project time, and lower the productivity as well as the morale of the work force (O'Connor and Vickroy 1986). Therefore, success during the detailed design, construction, and startup phases of a project highly depends on the level of effort expended during the scope definition phase

as well as the integrity of the project definition package (Gibson and Dumont 1996).

The University of Texas System (UT System) conducted study on 37 capital projects (mostly general buildings) completed during 1990 to 1995 focusing on the scope definition and early planning. From this study, the UT System found that change orders, which normally occurred due to inadequate scope definition, totaled approximately \$33 million of the \$425 million of projects constructed. The study also found that scope changes, which typically are a result of incomplete planning, led to cost increases on 26 percent of the construction contracts and 64 percent of design contracts during that same period. During the same time interval, total project schedules for the entire sample increased an average of approximately 52 percent. Analysis on subjective input regarding the schedule increase showed that scope definition/design changes were the most common factor affecting the project schedule. By the same token, the total project cost variations of positive 9.59 percent for all projects were explained by the inadequate scope definition and cost estimates at official project authorization (Gibson et al. 1997).

The UT System research investigation of capital project performance (1997) identified several issues as critical success factors that are key to providing

better pre-project planning and better projects in the future. The followings is the summary of their findings (Gibson et al. 1997).

- Develop a more **realistic overall project schedule**.
- Have the **proper technical expertise involved during pre-project planning** and the subsequent design phase of the projects to prevent costly budget increases and schedule slippage from occurring.
- **Perform programming on projects prior to schematic design** – comprehensive programming increases the likelihood of meeting schedules and provides a more realistic project cost estimate due to a more well-defined project scope.
- Have the **appropriate individuals and end-users involved** in the programming, schematic design, and design development phases to minimize costly scope changes from occurring during construction.
- **Perform adequate site investigations** on all projects.
- **Standardize the pre-project planning approach, adequately train individuals** in pre-project planning, and **communicate** requirements.

Although intended for UT System component institutions, these recommendations can be adopted by the general building sectors as a guideline to improve capital project performance.

Several studies focusing on the project performance and success identified the major factors that cause project failure. These studies suggest that poor scope definition is one of the primary causes of unsuccessful projects (Morrow et al. 1981; Myers and Shangraw 1986; Morrow 1988; and Broaddus 1995). According

to these studies, cost growth and inaccurate estimates, as well as schedule slippage on most process plant projects are due to inadequate scope definition. These studies further conclude that the more time and effort invested in scope definition prior to authorization to move forward with detailed design, the more accurate the construction cost and schedule estimate.

Several factors were identified as explanations for inadequate scope definition. The most important variable considered by owners and contractors is the market demand or other pressures that force the organizations to reduce project cycle times and warrant the authorization of projects with underdeveloped definition (O'Connor and Vickroy, 1986). Although this study was focused primarily on the process industries, the same can be said for the general building projects. Owners may want to see the early startup and occupation of the end-facility for the maximum return of the investment thereby (incorrectly) justifying the reduction of time spent in the scope definition phase.

Lack of sufficient design labor within organizations also contributes to the commitment of underdeveloped scope definition. Organizations consider the costs of adding or reassigning personnel to outweigh the benefits of increased scope definition. Moreover, organizations misperceive that the better definition of scope requires higher commitment of funds before the authorization of entire projects (O'Connor and Vickroy, 1986).

A study by the CII Design Task Force (1987) particularly emphasized the responsibilities of the owner in a joint effort with the project team in providing a good scope definition. Not only allowing adequate time to define an all inclusive scope, the owner should also expect to spend as much as 10 percent of the total engineering cost to develop a good scope definition at the front-end of a project. Based on expert consensus, the study articulated that poorly defined scopes can increase project costs as much as 25 percent. The study pointed the necessity to establish a minimum level of scope definition for the industry and define what constitutes good, acceptable, and inadequate scope definition (Chalabi et al. 1987). Further work by Gibson et al. (1994) statistically concluded that greater than 10 percent of design effort should be expended to adequately define scope.

## **2.5. PDRI for Industrial Projects**

Many CII member organizations as well as other engineering and contracting companies in large industrial projects are currently using the Project Definition Rating Index (PDRI) for industrial projects. This scope definition tool is intended to help project teams identify risk factors that may impact their project (Gibson and Dumont 1996).

The PDRI consists of three main sections, which are broken down into 15 categories which, in turn, are further broken down into 70 elements. These 70 weighted scope definition elements are presented as a checklist in a scoresheet

format. Elements are defined with 33 pages of detailed description with specific examples. The total possible scoring range of the PDRI is from 70 to 1000 where a score of 70 indicates a project that is very well-defined. That is, the lower the PDRI score the higher the probability for project success. A project with a score greater than 200 usually indicates that scope definition is lacking in certain areas which may impact on the project outcome. As the score moves closer to 1000, the project scope definition becomes increasingly less defined (Gibson and Dumont 1996).

The research team sorted the 70 PDRI weighted elements in order of importance to find the critical success factors for industrial projects. A list of the 10 highest weighted elements is shown in Figure 2.3.

| Element                                         | Weights    |
|-------------------------------------------------|------------|
| B1. Products                                    | 56         |
| B5. Capacities                                  | 55         |
| C1. Technology                                  | 54         |
| C2. Processes                                   | 40         |
| G1. Process Flow Sheets                         | 36         |
| F1. Site Location                               | 32         |
| G3. Piping & Instr. Diagrams (P&ID's)           | 31         |
| D3. Site Characteristics Available vs. Required | 29         |
| B2. Market Strategy                             | 26         |
| D1. Project Objectives Statement                | 25         |
|                                                 | 384 / 1000 |

**Figure 2.3. PDRI Ten Highest Weighted Elements**

These are the elements that have the greatest potential to negatively affect project performance if poorly defined during pre-project planning. Of the potential of 1000 points, these 10 elements comprise 384 points, approximately 38 percent (Gibson and Dumont 1996). These 10 highest weighted elements are the most important issues that, if only a short amount of time can be spent on project scope definition prior to authorization, are the critical few that should be addressed.

Similarly, the three sections and 15 categories of the PDRI were weighted in order of importance as shown in Figure 2.4. Section I, Basis of Project Decision, was the most important receiving roughly half of the 1000 total points. Of the 15 categories, B and G, the business objectives and process/mechanical information, were found to be the most important (Gibson and Dumont 1996).

| Section Weights           |        | Category Weights                  |        |
|---------------------------|--------|-----------------------------------|--------|
| Section                   | Weight | Category                          | Weight |
| Basis of Project Decision | 499    | Business Objectives               | 213    |
| Front End Definition      | 423    | Process / Mechanical              | 196    |
| Execution Approach        | 78     | Project Scope                     | 120    |
|                           | 1000   | Site Information                  | 104    |
|                           |        | Basic Data Research & Development | 94     |
|                           |        | Manufacturing Objectives Criteria | 46     |
|                           |        | Instrument & Electrical           | 45     |
|                           |        | Project Execution Plan            | 36     |
|                           |        | Equipment Scope                   | 33     |
|                           |        | Value Engineering                 | 27     |
|                           |        | Infrastructure                    | 25     |
|                           |        | Civil, Structural & Archetectural | 19     |
|                           |        | Project Control                   | 17     |
|                           |        | Procurement Strategy              | 16     |
|                           |        | Deliverables                      | 9      |
|                           |        |                                   | 1000   |

**Figure 2.4. PDRI Section and Category Weights**

Once finalized, the PDRI was tested on 40 sample projects for its validation as a scope definition tool. The validation process correlated PDRI scores with a project success rating obtained from each sample project. Comparison was made for projects with PDRI scores above and below 200 points as evaluation cutoff for a well-defined scope definition. 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 2.5. Projects scoring below 200, on average outperformed those scoring above 200 in cost, schedule, and change orders by approximately 19 percent, 13 percent, and 6 percent, respectively versus their authorization estimates for this sample (Gibson and Dumont 1996).

| Performance   | PDRI Score    |               | $\Delta$ |
|---------------|---------------|---------------|----------|
|               | < 200         | > 200         |          |
| Cost          | -5%           | +14%          | 19%      |
| Schedule      | -1%           | +12%          | 13%      |
| Change Orders | +2%<br>(N=20) | +8%<br>(N=20) | 6%       |

**Figure 2.5. Project Performance Comparison Using a 200 Point Cutoff**

## 2.6. Building Project Life Cycle

Peña et al., in Problem Seeking - an Architectural Programming Primer (1987), defined in detail the various processes involved in the building project life cycle. They discussed the total project delivery system as a complete series of operations leading to the occupancy of a completed building. This total project delivery system encompasses the pre-project planning, design, and construction phases of project life cycle and is comprised of programming (P), schematic design (SD), design development (DD), construction documents (CD), bidding, and construction (Peña et al. 1987).

The first three phases in architectural practice, called the total design process, includes programming, schematic design, and design development. Programming, which is a part of the total design process, is separate from schematic design. The total design process less the programming phase is the design process. They further defined each of these sub-processes as follows (Peña et al. 1987):

- **Programming:** A process leading to the statement of an architectural problem and the requirements to be met in offering a solution.
- **Schematic Design:** Interpretation of the owner's project requirements by studies and drawings which illustrate basic architectural concepts, circulation, scale, massing, use of site, general appearance and scope of the project. Included is a statement of adequacy of the stipulated project budget.
- **Design Development:** Following approval of schematic design, development includes determination, design and coordination of architectural, structural, mechanical, electrical systems; equipment layouts, and all related site development. This phase insures that all significant design questions and/or problems have been answered.
- **Construction Documents:** This phase transforms the preceding approved "DD Package" into a set of detailed, legal, bidding documents which relate to the construction industry. These documents control and direct the construction process via construction drawings and detail materials/building systems specifications.

The ability to influence the project outcome rapidly diminishes as the schematic design and design development phases end, whereas the expenditures

start to dramatically increase as the development of construction documents is completed and construction begins. Therefore, preparing well-developed design documents based on complete scope definition is indispensable to project success.

## **2.7. Facility Programming**

Architectural programming is a relatively new trend in architecture and engineering, yet an increasingly accepted step in the facility delivery process due to the positive impact it has on the project outcome. It is defined as the *research and decision-making process that defines the problem to be solved by design* (Cherry 1999). As presented earlier, architectural programming is *a process leading to the statement of an architectural problem and the requirements to be met in offering a solution* (Peña et al. 1987). Regardless of how it is defined, the architectural programming process provides the client and designer with a clear definition of the scope of a project and the criteria for a successful solution (Cherry 1999).

Programming is a simple, yet comprehensive approach that influences the design of buildings. It involves simple and repeatable processes of establishing goals, collecting and analyzing facts, uncovering and testing concepts, determining needs, and stating the problem. This five-step process of programming increase the chances of a building project being a successful one when properly coupled with four major concerns as design determinants during

the design. These considerations – function, form, economy, and time – indicate the types of information needed. Therefore, good programming is the prelude to a good design (Peña et al. 1987).

The UT System Office of Facilities Planning and Construction (OFPC) developed a document called *Facilities Programming Guidelines* (1995) as a tool to help its component institutions program the requirements for their capital improvement projects. Facility programming, similar to architectural programming, is defined as *the process of collecting, analyzing, synthesizing, and documenting all (or most) of the requirements for a capital improvement project prior to beginning design* (UT System 1995). This document was written by UT System because of its desire to improve facility programming in order to have less change and cost increase during the life of a project. Some of the benefits identified from having complete facility programming are (UT System 1995):

- Early opportunity for all interested parties to provide input and discuss issues – programming provides a forum to debate what should be included in a project
- Obtain consensus and convert project needs into hard requirements before design begins – a facility program builds concurrence and causes decisions to be made in a logical sequence
- Test different concepts and evaluate options inexpensively during programming
- Clearly define the needs before architects and engineers design a project – the facility program is the road map for the architects

and engineers who will design the project and keep the designers from deviating from the actual requirements and produce a building that does not meet the needs

- Collect all necessary information at the beginning of a project to be available for everyone involved with the project to use

Thus, it is clear that the facility program contains the information needed to begin design of a project. It is also apparent that well-developed facility programming coupled with good schematic design and design development results in less project variability in terms of cost, schedule, and operating characteristics. Moreover, it increases the probability of the project meeting desired goals. Therefore, programming should be thoroughly considered during the pre-project planning phase of buildings and effectively incorporated into the scope definition development process.

## **2.8. Team Alignment**

One of the sub-objectives that the CII Front-End Planning Research Team selected to investigate was the alignment issue during pre-project planning. In its study, the research team identified the factors that significantly contribute to alignment and demonstrated the effect that the level of alignment has on project success. For the study, the team defined the alignment as (Griffith and Gibson 1997):

*The condition where project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objectives.*

The research team used workshops, mail surveys, telephone interviews and personal interviews to collect data related to alignment during pre-project planning. The critical alignment issues identified were:

1. Stakeholders are appropriately represented on the project team.
2. Project leadership is defined, effective, and accountable.
3. The priority between cost, schedule, and required project features is clear.
4. Communication within the team and with stakeholders is open and effective.
5. Team meetings are timely and productive.
6. The project team culture fosters trust, honesty, and shared values.
7. The pre-project planning process includes sufficient funding, schedule, and scope to meet our objectives.
8. Reward and recognition systems promote meeting project objectives.
9. Team work and team building programs are effective.
10. Planning tools (e.g., checklists, simulations, and work flow diagrams) are effectively used.

The research also demonstrated that the level of team alignment during pre-project planning positively contributes to the ultimate success of the project (Griffith and Gibson 1997). In this study, the research team found a significant level of correlation between project alignment as measured by the PDRI and a series of Likert Scale statements, and project success as measured by the success index described in a later section.

## **2.9. Process Map of Planning Steps**

Griffin (1972) presented a project model in three phases; decision, design, and delivery. He also shown a critical path network of the steps required to

prepare a proposal. These individual steps contained logic and terminology that can be applied to developing the logic flow diagram.

Billings (1993) described the four main stages of the planning process as:

1. Needs or program formulation
2. Physical data collection
3. Designing process
4. Evaluation

These steps proved to be particularly useful when trying to analyze the parts of the building process that typically belong to the architect. He presented a generic list of the activities for reengineering an organization's capital facilities processes and stated that the activities could be assembled in the form of a bar chart but they likely overlap. This bar chart can be adopted as a high level representation of an logic flow diagram without much detail.

CII and others have published numerous books and other literature relating to pre-project planning (CII 1993). However, reviewing the majority of these publications, the lack of a detailed pre-project planning process map for generic building projects is apparent. Many authors have drafted checklists but assembling a detailed pre-project planning map is beyond the scope of any list the authors have observed (Billings 1993, Cherry 1999, Griffin 1972, Preiser 1993, Thornburn 1994). Perhaps the majority of organizations that use pre-project planning maps view them as proprietary. Thus, the work pursued in this

investigation in developing a series of logic flow diagrams is exploratory in nature.

## **2.10. Project Success and Critical Success Factors**

An extensive review of the relevant literature has revealed that project success has been the focus of many recent studies (Griffith et al. 1999). Several studies have focused on identifying the critical factors that contribute to project success while others have concentrated on measuring and defining project success. Throughout all the research effort, there is a general agreement that success criteria or definition of project success varies over projects. Definitions may differ depending on participants, scope of services, project size, sophistication of the owner related to the design of facilities, technological implications, and many other factors (Parfitt and Sanvido 1993). Moreover, the basic view of project success is different for the various organizations involved in the planning, design, construction, and operation of capital facilities (Rowings et al. 1987).

One study (Ashley et al. 1987) using objective measures considered 46 factors as relevant to project success. The study identified planning efforts, scope and work definition, project team motivation, and project objectives as the most significant factors that contribute to project success. In this study, Ashley et al. defined project success as “results much better than expected or normally

observed in terms of cost, schedule, quality, safety, and participant satisfaction” and measured the project success in terms of these variables.

Another study conducted by the CII Project Organization Task Force emphasized the objective-setting process as a critical element to the success of projects. Through case studies, the research team identified that problem projects exhibit difficulties due to lack of clear owner-objective definition, internal inconsistency of objectives, and the lack of clearly communicated project objectives. In order to avoid these, a clear definition of the owner’s objectives must be made and effectively communicated to the project team including design and construction contractors (Rowings et al. 1987).

Mainly focusing on building construction, Sanvido et al. (1992) defined the critical success factors, those that predict success on projects, valid for building projects. Combining the established theoretical work in construction process modeling and field research, the team identified four factors that can be deemed the critical project success factors. These four factors, identified as critical success factors, are as follows (Sanvido et al. 1992):

- Facility team
- Contracts, obligations, and changes
- Facility experience
- Optimization information

By predicting the probability of success using these factors, the project participants can avoid unsuccessful projects, identify good projects to pursue, and identify problems on current projects and take corrective action (Sanvido et al. 1992).

In addition to the issue of success factors, measuring and defining project success has been a heated subject of discussion for many studies. Objectively measuring project success is a difficult proposition. Much research has been addressed at improving the knowledge of what makes a project successful, but most of these studies rely on subjective assessments to distinguish more successful projects from less successful projects (Rowings and Behling 1993). Based on the published literature and articles, there seems to be no universally accepted definition or measurement of project success.

Thamhain (1992) identified some of the characteristics of a successful project by surveying experienced engineering and project managers. Among these characteristics, over 60 percent of participants agreed on the top three characteristics of a successful project as follows (Thamhain 1992):

- Technical project success, measured according to agreed-upon objectives
- On-time performance
- On-budget performance

These results are consistent with more recent research by CII into the relationship between pre-project planning and project success.

In its study of the relationship between pre-project planning effort and project success, the CII Pre-Project Planning Research Team developed an index for measuring project success of industrial projects based on four performance variables. Through interviewing 131 industry representatives, the team determined the relative importance of each variable in the success index and gave weights as shown in Figure 2.6 (Gibson and Hamilton 1994).

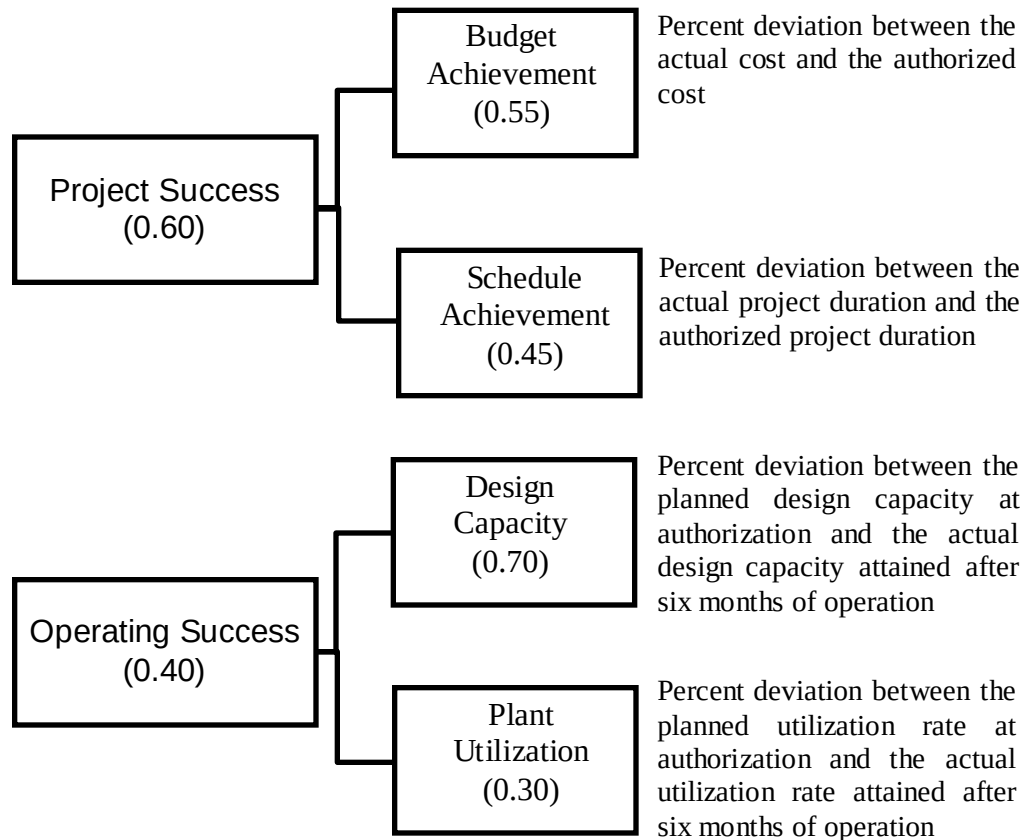


**Figure 2.6. Success Index Variables and Weights**

Combining the four variables and their corresponding weights yielded the equation for computing the project success index presented in Figure 2.7 (Gibson and Hamilton 1994).

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

**Figure 2.7. Equation for Measuring Project Success**

Griffith et al. (1999) summarized the validation results of the success index (Figure 2.7) on three separate research investigations where it was used as the dependent variable. The first research project involved the study of the effect that pre-project planning effort has on project success. Having the pre-project planning effort as an independent variable, the bivariate regression analysis showed positive correlation between two variables. That is, as the pre-project planning effort level increases so does the level of success attained (Gibson and Hamilton 1996). In the second research project, the correlation between the PDRI (Industrial version) score and the success index, calculated from 40 sample projects, was measured using bivariate regression analysis. The  $R^2$  for this analysis was 0.39 (Gibson and Dumont 1996; Dumont et al. 1997). From 20 sample projects and 54 telephone interviews, the third research investigation analyzed the alignment effort and project success. Similarly, bivariate regression