Development of the Project Definition Rating Index (PDRI)

for Small Industrial Projects

by

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ABSTRACT

Project teams expend substantial effort to develop scope definition during the front end planning phase of large, complex projects, but oftentimes neglect to sufficiently plan for small projects. An industry survey administered by the author showed that small projects make up 70-90 percent (by count) of all projects in the industrial construction sector, the planning of these project varies greatly, and that a consistent definition of "small industrial project" did not exist. This dissertation summarizes the motivations and efforts to develop a non-proprietary front end planning tool specifically for small industrial projects, namely the Project Definition Rating Index (PDRI) for Small Industrial Projects. The author was a member of Construction Industry Institute (CII) Research Team 314, who was tasked with developing the tool in May of 2013. The author, together with the research team, reviewed, scrutinized and adapted an existing industrial-focused FEP tool, the PDRI for Industrial Projects, and other resources to develop a set of 41 specific elements relevant to the planning of small industrial projects. The author supported the facilitation of five separate industry workshops where 65 industry professionals evaluated the element descriptions, and provided element prioritization data that was statistically analyzed and used to develop a weighted score sheet that corresponds to the element descriptions. The tool was tested on 54 completed and in-progress projects, the author's analysis of which showed that small industrial projects with greater scope definition (based on the tool's scoring scheme) outperformed projects with lesser scope definition regarding cost performance, schedule performance, change performance, financial performance, and customer satisfaction. Moreover, the author found that users of the tool on in-progress projects overwhelmingly agreed that the tool added value to their projects in a timeframe and manner consistent with their needs, and that they would continue using the tool in the future. The author also developed an index-based selection guide to aid PDRI users in choosing the appropriate tool for use on an industrial project based on distinguishing project size with indicators of project complexity. The final results of the author's research provide several contributions to the front end planning, small projects, and project complexity bodies of knowledge.

TABLE OF CONTENTS

CHAPTER Page

CHAPTER Page

CHAPTER Page

CHAPTER Page

CHAPTER Page

LIST OF TABLES

LIST OF FIGURES

Figure Page

Figure Page

Figure Page

Figure | Page

CHAPTER 1. INTRODUCTION

Planning efforts conducted during the early stages of a construction project, known as pre-project planning or front end planning, have significantly more effect on project success than efforts undertaken after detailed design and construction has begun (Gibson et al. 1993). The Construction Industry Institute (CII), a research consortium based out of the University of Texas at Austin, has made project planning and scope definition a research focus area since the early 1990's. CII has funded the development of several front end planning decision support tools, namely the Project Definition Rating Index (PDRI) tools. Past CII research teams created PDRI tools to provide project teams with a structured approach for developing a good scope definition package, and measuring the level of project scope definition (Cho and Gibson, 2001). Three such PDRI tools were developed prior to 2013: PDRI-Industrial (Gibson and Dumont 1995), PDRI-Building (Cho et al. 2008), and PDRI-Infrastructure (Bingham et al. 2012). Researchers leveraged project performance data from more than 1,000 projects spanning more than 250 organizations and representing over US $88 Billion in expenditure to develop these tools. Use of the tools supported effective front end planning that in turn supported predictable project cost, schedule, and change performance outcomes (CII 2012).

CII desired to develop a front end planning tool for a long-overlooked and ubiquitous project type: small industrial projects. The research outlined in this dissertation describes the development of the PDRI for Small Industrial Projects (PDRI-Small Industrial). The objective of this dissertation is to outline the tool development methodology, tool testing, and conclusions in relation to the work done by this author in support of the research team developing the PDRI-Small Industrial. The methodologies, testing processes, and conclusions presented are corroborated in this dissertation by statistical analysis and supporting literature.

1.1. Research Team 314

CII tasked Research Team 314 (RT 314) with developing an effective, simple, and easy to use scope definition tool (i.e., PDRI tool) specifically for small industrial projects in May 2013. The team consisted of twenty industry professionals from CII member organizations who had experience with industrial construction activities, and three academic members. A list of research team members and their organizations is included in Appendix A.

The research team met every 8-10 weeks in various locations across the United States between March 2013 and June 2015, with meetings lasting approximately one and a half days each occurrence. The meetings were hosted by several of the research team members, and facilitated by the academic team members. The purpose of the initial team meetings was to clarify the objectives of the research effort, and outline a research strategy. The research was executed during subsequent meetings, as well as between meetings, through collaboration and individual efforts.

The author was one of the academic members of the research team, and served in many capacities actively participating in and supporting the research effort. The author's primary role was data collection, analysis, and interpretation, described in detail throughout this dissertation. The author also served as the primary author (or one of the primary authors) for several publications required by CII that summarized the research effort and implementation of the tool. The author further promoted the research through several administrative tasks, including team-member coordination, preparation for team meetings and industry workshops, and documentation of team meetings and industry workshops.

1.1.1. Research Objectives

The research team set forth the following objectives:

1. Produce a user-friendly tool for measuring project scope definition of small industrial projects with the following characteristics and functions:
    - Based upon the PDRI-Industrial, yet tailored specifically to small industrial projects
    - Less time-consuming than the PDRI-Industrial
    - Is easy to use, yet detailed enough to be effective
    - Helps reduce total project costs
    - Improves schedule performance
    - Serves as a communication and alignment tool
    - Supports decision-making
    - Identifies risks
    - Reliably predicts project performance
    - Is flexible among industrial facility types
2. Test the tool by comparing the level of project scope definition during the front end planning phase vs. corresponding project performance factors for a sample of completed small industrial projects

1.2. Project Domain

Defining "small industrial project" was imperative for the research team so that guidance could be provided to PDRI users as to which industrial-focused PDRI would be most appropriate for their projects: PDRI-Industrial or PDRI-Small Industrial. The author determined through literature review, discussions with the other research team members, and two industry questionnaires, that typical small industrial projects meet the following criteria:

1. A project completed within industrial facilities such as (or similar to):
    - Oil/gas production facilities
    - Refineries
    - Chemical plants
    - Pharmaceutical plants
    - Paper mills
    - Steel/aluminum mills
    - Power plants
    - Manufacturing facilities
    - Food-processing plants
    - Textiles mills
2. A project closely aligning with the following characteristics:
    - Total installed cost less than US $10 Million
    - Construction duration between 3 and 6 months
    - Project funding approval at a regional or corporate level
    - Moderate project visibility to owner management

- 7 to 9 core team members (i.e., project managers, project engineers, owner representatives)
- Part-time management availability of core team members
- None to minimal external permitting required
- None to local/state permits required
- 3 to 4 separate trade contractors

The author determined that these features are typical of small industrial projects, but not a strict definition. This is due to the vast variability in how small projects are defined across the industrial sector. It should also be noted that the PDRI is a general-use tool, and was developed to assess a wide range of small industrial projects. The project domain includes small industrial projects that are process and non-process related, new construction projects, renovation and revamp projects, small projects that are part of a program of many similar projects, and shutdown/turnaround projects. Detail is provided throughout this dissertation that support these assertions, along with the small industrial project criteria listed above.

1.3. Organization of the Dissertation

This dissertation is organized into ten chapters, and includes several appendices that provide important additional information including the PDRI-Small Industrial tool itself, detailed statistical analysis, and examples of documents utilized for gaining industry involvement during development of the tool. Chapter 1 provides an introduction to the research team, research objectives, project domain, and the research report structure itself. Chapter 2 provides the problem statement of the research, and the hypotheses developed by the research team. Chapter 3 provides the research methodology and framework utilized by the research team in developing the PDRI-Small Industrial. Chapter 4 provides a summary of the CII front end planning research thread, previous PDRI research projects and tools, research projects and tools that support the PDRI, and previous research regarding small projects. Chapter 5 details the results of an industry survey regarding the prevalence of small industrial projects, the planning practices used for small industrial projects, and potential differentiators of small and large industrial projects. Chapter 6 details the development process of the PDRI element descriptions and weighted score sheet. Chapter 7 details the testing process completed by the research team to test the efficacy of the tool. Chapter 8 provides a detailed comparison of the PDRI-Industrial and the PDRI-Small Industrial. Chapter 9 details the development of the Industrial Project Definition Rating Index (PDRI) Selection Guide for Industrial Projects. Chapter 10 provides the conclusions of the research, and offers recommendations for using the PDRI-Small Industrial.

CHAPTER 2. PROBLEM STATEMENT AND RESEARCH HYPOTHESES

The findings from the literature review (presented in Chapter 4) showed a need for research into the front end planning of small industrial projects. There has been little research work to date in this area, especially in studying the effects of front end planning on small project success. The lack of research led the author to develop a set of hypotheses. This chapter establishes a problem statement, which can be answered by proving these research hypotheses

2.1. Problem Statement

Small projects are prevalent in the industrial sector, though the size and scope of small projects vary greatly. Individually, small projects may appear insignificant to an organization's yearly capital expenditure, but cumulatively, small projects can make up a majority of the projects completed and capital expensed. Oftentimes appropriate planning consideration is not given to small projects, consistently leading to cost and schedule overruns. CII developed a suite of PDRI tools (and several complementary tools) that have consistently been shown to improve project cost and schedule performance of large, complex projects through enhanced front end planning. Small project research studies have found that procedures or processes designed for large projects typically are not effective for use on small projects, as they are too cumbersome to be effective. The industrial construction sector could greatly benefit from a user-friendly, non-proprietary tool to assist in defining project scope to maximize project success on small projects.

2.2. Research Hypotheses

The PDRI-Small Industrial is modeled directly after the previously developed PDRI tools: industrial, building, and infrastructure. These PDRI tools all share the same basic research hypotheses. The author asserts that (as has been done by each of the preceding PDRI research teams) that the PDRI score indicates the current level of scope definition, and corresponds to project performance. Cost, schedule, and change performance differences between projects with high and low PDRI scores were tested to confirm this assertion. This testing methodology is described in detail in Chapter 7. The specific hypotheses are as follows:

> ***Hypothesis 1****: A finite and specific list of critical issues related to scope definition of small industrial projects can be developed.*

A draft tool was developed by the research team and shared with other industry experts to test this hypothesis. Their feedback was collected and incorporated into the list of scope definition elements. These elements comprise a finite and specific list of critical issues related to scope definition of small industrial projects.

> ***Hypothesis 2****: Projects with low PDRI scores outperform projects with high PDRI scores.*

A draft tool was provided to industry professionals experienced in completing small industrial projects to test this hypothesis. Specific project data regarding (1) scope definition (based on the PDRI tool) along with cost and schedule budgets at the beginning of detailed design, and (2) project cost, schedule, and change performance at the completion of the projects, was collected and analyzed. PDRI scores were calculated for each project and compared to the project performance data through statistical analysis.

***Hypothesis 3**: Project complexity indicators can be used to distinguish small projects from large projects.*

Commentary provided by the participants of an industry survey (described in Chapter 5) suggested that indicators of project complexity could be used to distinguish project size. Completed industrial-project data (described in Chapter 9) was collected, analyzed, and used to develop an indexed selection guide for the industrial PDRI tools to test this hypothesis. The index was statistically analyzed, and pilot tested amongst the industry team members of RT 314.

2.3. Summary

This chapter outlined the problem statement and research hypotheses. The research problem is derived from a need to develop a user-friendly, non-proprietary tool to assist in defining project scope and maximizing project success on small industrial projects. The research hypotheses test the validity that the PDRI-Small Industrial can effectively improve project performance in the same manner as previously developed PDRI tools, and that indicators of project complexity can be used to direct PDRI users to the appropriate tool for use on an industrial project. The following chapters detail the research methodology and testing procedures used in this study.

CHAPTER 3. RESEARCH METHODOLOGY

This chapter outlines the research methodology employed for producing and testing the PDRI-Small Industrial. This methodology was developed and proven in previous PDRI research (Gibson and Dumont 1995, Cho et al. 2008, Bingham et al. 2012) and chosen due to its reliability in achieving the research objectives and hypotheses confirmation. Specific research methods and concepts including content analysis, conceptualization, population sampling, data collection procedures, survey research, questionnaire development, and statistical data analysis procedures are described in this chapter.

Table 3-1 provides a summary of the research methods and data analysis techniques utilized to develop the PDRI-Small Industrial. Figure 3-1 provides a logic flow diagram of the research methodology, providing a visual representation of the steps undertaken by the author and the research team to test the research hypotheses described in Chapter 2. The following sections briefly describe the flowchart and the role of the author and research team in each step.

Table 3-1. Research and Data Analysis Methods

PDRI Development Phase	Research Method Employed	Data Analysis Method Employed
Develop PDRI Elements and Score Sheet	Conceptualization Content Analysis Focus Groups	
PDRI Element Prioritization	Focus Groups Purposive Sampling Snowball Sampling Field Research Statistical Analysis	Boxplots Skewness
Test PDRI Research Hypotheses	Survey Research Case Studies Statistical Analysis	Correlation Independent Sample t-test Mann-Whitney U Test Boxplots Regression Analysis
Small Project Definition	Survey Research Purposive Sampling Snowball Sampling Focus Groups Field Research Statistical Analysis	Mann-Whitney U Test

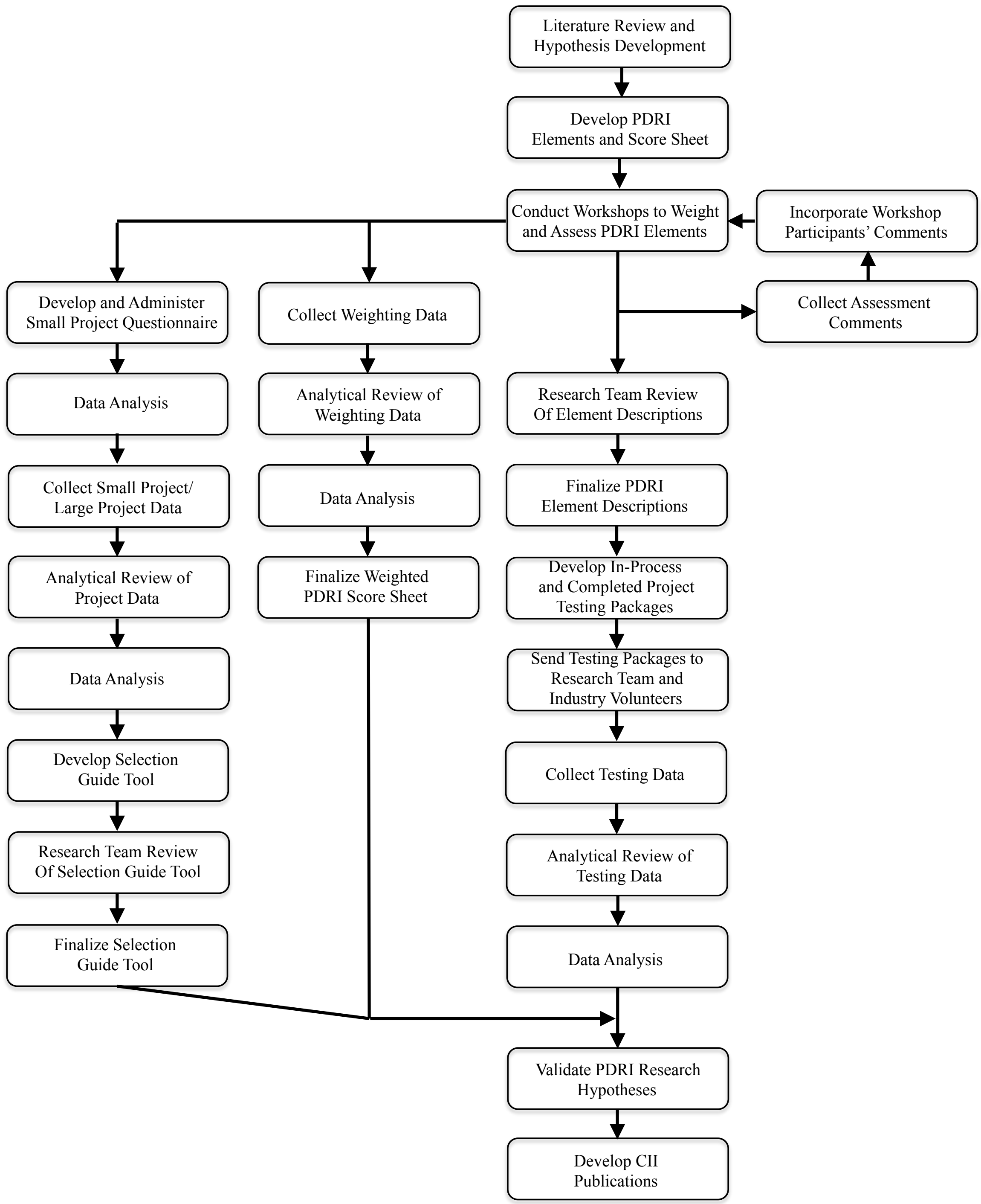


Figure 3-1. Research Methodology Flow Chart

3.1. Data Collection

Data collection was necessary to develop the PDRI elements, PDRI score sheet, prioritization of the PDRI elements, testing of the research hypotheses, and defining small project in the industrial construction sector. The following sections provide an overview of the data collection processes and associated research methods utilized.

3.1.1. Developing the PDRI Elements and Score Sheet

Chapter 4 details the literature review completed by the author regarding front end planning, previously completed PDRI research projects, and small projects. The literature review is considered a form of content analysis, defined as a study of recorded human communications (Babbie 2011). Reviewing the documents provided a basis or starting point for the research team to conceptualize the PDRI-Small Industrial. Conceptualization is defined as the process whereby imprecise notions or concepts are made more specific and precise (Babbie 2011). The initial intent was to create a tool with the same "look and feel" of the other PDRIs. The research team developed the PDRI-Small Industrial element descriptions and associated score sheet through rigorous discussion and debate after the tool was initially conceptualized, using the PDRI-Industrial as a baseline. Individuals that participated in the PDRI weighting focus groups (described in the next section) also reviewed the PDRI element descriptions and provided feedback regarding suggestions for improvement. Detailed explanation of the PDRI development process is provided in Chapter 6.

3.1.2. PDRI Element Prioritization

A basic tenet of front end planning is that not all items to be assessed (i.e., elements) are equally critical to project success. Therefore, each element must be prioritized relative to the total set of elements. Collecting input from all stakeholders involved with small industrial projects regarding element prioritization would be impossible. The research team utilized focus groups to gain prioritization data from a subset of the total industrial construction stakeholder population, as had been done by the previous PDRI research teams. Focus groups are simply a group of subjects interviewed together, prompting a discussion (Babbie 2011). Five such focus groups were convened to weight the PDRI elements. Purposive and snowball sampling techniques were used to empanel the focus groups. Purposive sampling, also referred to as judgmental sampling, is a method in which individuals are selected to be part of the sample based on the researcher's judgment as to which individuals would be the most useful or representative of the entire population (Babbie 2011). Industry experts with substantial experience in the management and/or design of small industrial projects were targeted to participate in the weighting workshops (i.e., focus groups). Snowball sampling, or requesting that targeted individuals suggest other individuals with similar expertise (Babbie 2011) was used to increase workshop attendance. A detailed description of the workshop procedures is provided in Chapter 6.

3.1.3. Test PDRI Research Hypotheses

Chapter 2 details three hypotheses the research team sought to test. Hypothesis 1 - that a finite list of critical issues relating to scope definition of small industrial projects could be developed - was tested through the focus group sessions described in the previous section, and detailed in Chapter 6. Hypothesis 2 - that project with low PDRI scores outperform projects with high PDRI scores - was tested through surveying industry professionals through the use of a detailed questionnaire. A questionnaire is a document containing questions designed to solicit information appropriate for analysis (Babbie 2011). The author developed a multi-part questionnaire that solicited information regarding PDRI Score, cost, schedule, change, and operating performance of recently completed small industrial projects through a series of open-ended and closed-ended questions. The author used statistical techniques (described later in this chapter) to test the value of the tool through comparison of PDRI scores and project performance.

The author also developed a questionnaire for in-progress projects; projects currently in the front end planning phase during the PDRI-Small Industrial testing timeframe. Data collected on the in-progress projects were used as case studies, or an in-depth examination of a single instance (Babbie 2011). The author collected data on in-progress projects to discern the various types of small industrial projects that the PDRI could be used to assess, typical gap-lists generated, and to determine if value was added to the in-progress projects during the assessments. Chapter 7 details the PDRI testing progress of both completed and in-progress projects.

3.1.4. Small Project Definition

Defining "small project" as it relates to industrial projects was necessary to distinguish the PDRI-Small Industrial from the PDRI-Industrial. The research team developed a questionnaire (administered, analyzed, and interpreted by the author) to gain industry perspective regarding this definition. Open and closed-ended questions and a matrix of 14 separate potential small and large project differentiators were generated based on the small project research previously completed by CII and others, described in Chapter 4. The questionnaire also included a set of closed-ended questions regarding the prevalence of small projects, and typical front end planning practices employed for small projects. Purposive and snowball sampling was used to elicit responses, mainly through targeting CII data liaisons and individuals associated with the research team members. Results from the completed questionnaires were mixed. The questionnaire respondents agreed with few of the metrics identified by the research team as being differentiators between small and large projects. Many of the respondents noted that measures of “project complexity” might be a better way to differentiate between small and large projects.

The author developed a separate questionnaire based on indicators of project complexity, consisting of twenty-one open and closed-ended questions to test Hypothesis 3 - that indicators of project complexity can be used to distinguish small projects from large projects. The questionnaires were distributed to the focus group (i.e., weighting workshop) participants, again using purposive sampling. The data collected from these individuals provided clarity to characterizing small and large industrial projects, and was used to develop an industrial PDRI selection guide. Chapter 5 details the results of the initial questionnaire, and Chapter 9 details the results of the second questionnaire and the development of the selection guide.

3.2. Data Analysis

The author used several statistical methods to analyze the data collected from the questionnaires and weighting workshops. Statistical analysis allowed the author to interpret the data, and provided a basis for the author to offer recommendations to the research team. The next few sections describe the statistical methods employed by the author, including boxplots, regression analysis, t-tests, and Mann-Whitney U-tests. These methods were chosen due to their successful usage on the previously developed PDRIs, all except for Mann Whitney U-tests, which had not been used during statistical data analysis of the other PDRI tools. Microsoft Excel™ and SPSS™ were the two primary software platforms used to aggregate and analyze data.

It should be noted that the author made every effort to keep confidential any personal or proprietary information collected from individuals that provided data to support the research effort. Responses were coded during the analysis as to make anonymous all individual, organization, project, or client names or indicators.

3.2.1. The Boxplot

Boxplots are a commonly used method for graphically summarizing the distribution of a data set (Morrison 2009). The author utilized boxplots to analyze element-weighting data collected during the industry workshops (described in Chapter 6), and completed project data collected to test the tool (described in Chapter 7).

Figure 3-2 (developed by the author) details the typical values provided by a boxplot. The "box" highlights the interquartile range of the dataset; values between the 25^{th} and 75^{th} percentile (Morrison 2009). Fifty percent of the dataset falls within this range. The median value is also shown as a horizontal line. If the median does not fall at the center point of the interquartile range, this denotes skewness to the dataset (Morrison 2009), described further in the next section. The boxplot will also indicate values that fall outside of the interquartile range, namely outlier and extreme values. Outlier and extreme values can skew the statistics of a dataset, specifically causing mean and/or median values to shift away from the central point (Morrison 2009). The largest and smallest observes-values not considered an outlier or extreme are indicated on the boxplot by a "whisker", or lines extending above and below the box.

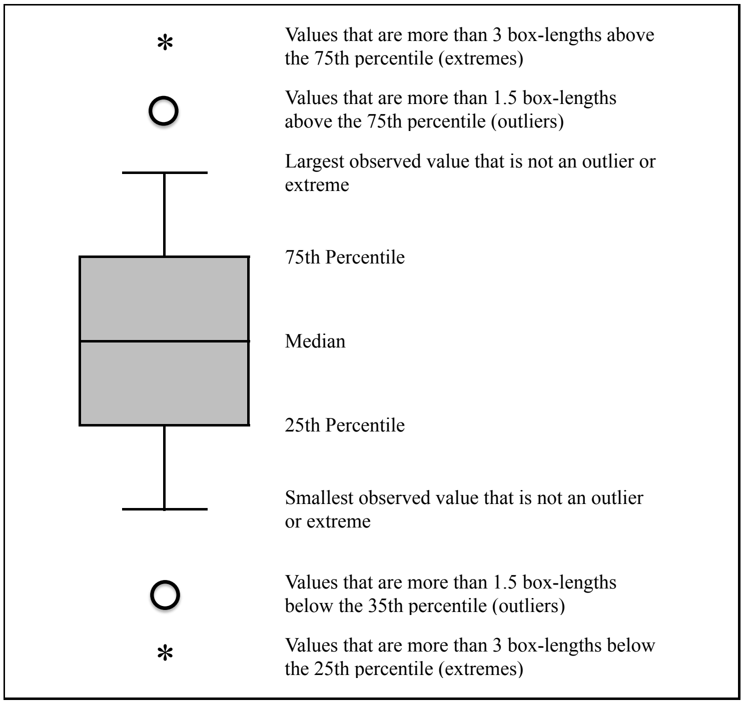


Figure 3-2. Typical Boxplot

A data point is considered an outlier value (X) if:

X < (Q1 – 1.5 IQR) or X > (Q3 + 1.5 IQR)

Where:

Q1 = 25^{th} percentile value

Q3 = 75^{th} percentile value

IQR = Interquartile range = Q1 – Q3

A data point is considered an extreme value (Y) if:

Y < (Q1 – 3 IQR) or Y > (Q3 + 3 IQR)

Where:

Q1 = 25th percentile value

Q3 = 75th percentile value

IQR = Interquartile range = Q1 – Q3

3.2.2. Skewness

Statistical analysis methods, such as independent-sample t-tests, assume that a dataset is normally distributed, or symmetric around some central value such as the mean or median of the dataset (Morrison 2009). If a dataset is highly skewed, mean and median calculations will also be skewed (Morrison 2009). Outlier and extreme values described in the previous section can lead to skewness. Figure 3-3 highlights positively and negatively skewed distribution.

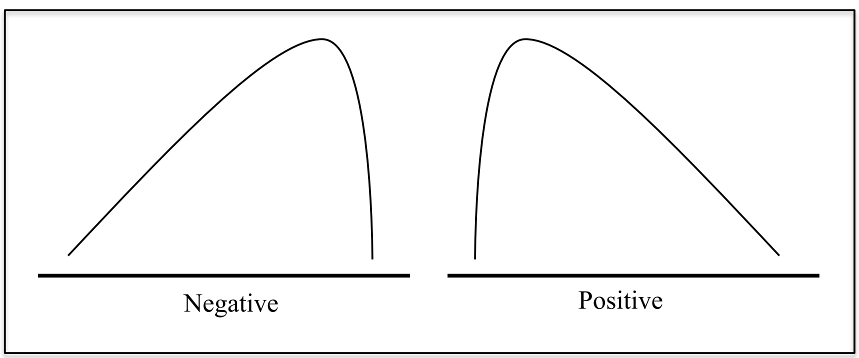


Figure 3-3. Negative and Positive Skewness

3.2.3. Independent Samples t-tests

In theory, two groups may have the same mean, but the data within those groups may be dispersed differently (Morrison 2009.) Groups with a tighter clustering of data points around the mean value will have a higher statistical significance than those groups where the data points are more dispersed (Morrison 2009.) Independent sample t-tests are used to determine if the means of two groups are statistically different from one another (Morrison 2009.) The author utilized independent sample t-tests to compare projects at various PDRI score levels vs. project cost, schedule and performance values (described in Chapter 7).

The t-statistic is calculated as:

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Where:

n_1 and n_2 = sample sizes

$\bar{x}_1$ and $\bar{x}_2$ = sample means

s_1 and s_2 = sample standard deviations

The null hypothesis, or H_O, is that the mean values of the two groups being tested against each other are equal, or nearly equal (Morrison 2009). The alternate hypothesis, or H_1, is that the mean values of the two groups being tested against each other are not equal, or nearly equal (Morrison 2009). The t-value derived from the t-statistic equation is tested against a critical t-value, to test of the null hypothesis is to be accepted or rejected (Morrison 2009). The critical t-value is dependent on the degrees of freedom of the samples (Morrison 2009.) Values derived from the t-tests also have an associated p-value, or probability, which is used to determine if the difference between mean values of the groups are statistically significant (Morrison 2009). A confidence interval for the test is stated; the typical confidence interval being 95 percent, which corresponds to an alpha level (or rejection level) of 5 percent (Morrison 2009). If the associated p-value from the t-test is greater than .05 (i.e., 5 percent), then there is a greater than 5 percent chance that the mean values of the two groups being compared are equal, or nearly equal, and the null hypothesis is accepted. If the associated p-value from the t-test is less than or equal to .05 (i.e., 5 percent), then there is a les than 5 percent chance that the mean values of the two groups being compared are equal, or nearly equal, and the null hypothesis is rejected.

An assumption of the t-test is that the two groups being compared have equal variance (Morrison 2009.) The Levene's test for Equality of Variance is used to determine if two groups being compared have equal variance, if the sample size is small (i.e., total sample size is less than 100 and if either group in the sample is less than 30). Levene's test is also an hypothesis test, where the null hypothesis, or H_O, is that the variances of the two groups being tested against each other are not equal, or nearly equal (Morrison 2009). The alternate hypothesis, or H_1, is that the variances of the two groups being tested against each other are equal, or nearly equal (Morrison 2009). Levene's test also uses a p-value to determine statistical significance. If the associated p-value from the test is greater than .05 (i.e., 5 percent), then there is a greater than 5 percent chance that the variances of the two groups being compared are equal, or nearly equal, and the null hypothesis is accepted. If the associated p-value from the t-test is less than or equal to .05 (i.e., 5 percent), then there is a les than 5 percent chance that the variances of the two groups being compared are not equal, or nearly equal, and the null hypothesis is rejected.

Statistical tools such as SPSS™ can be utilized to perform t-tests. Figure 3-6 provides a sample SPSS™ output. As shown, the variances between the two groups have equal variance (i.e., the p-value is .874, which is greater than .05), and the two groups have a statistically significant difference (i.e., the p-value is .010, which is less than .05).

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Performance	Equal variances assumed	.025	.874	2.744	31	.010	6.09821	2.22233	1.56575	10.63068
	Equal variances not assumed			2.704	22.039	.013	6.09821	2.25491	1.42230	10.77413

Figure 3-6. Sample t-test Output from SPSS™

3.2.4. Mann-Whitney U Test

Mann-Whitney U Tests are used when comparing mean values of two groups where data within the groups are based on a ranked order-scale (Wilcox 2009). An example of a ranked-order scale is a Likert scale. The Mann-Whitney U Test is similar to t-tests, but is used for comparing means where equal variance cannot be assumed, referred to as being nonparametric (Wilcox 2009). The author utilized Mann-Whitney U Tests to compare financial performance and customer satisfaction scores of completed projects used to test the PDRI (described in Chapter 7), and also to compare a set of completed industrial projects that were scored with the Industrial PDRI Selection Guide (described in Chapter 9).

The Mann-Whitney U statistic is calculated as:

$$U = N_1 N_2 + \frac{N_1(N_1 + 1)}{2} - R_1$$

Where:

N_1 and N_2 = Sample sizes

R_1 = Sum total of ranks for Sample 1

The sampling distribution of U has a mean, μ_U, calculated as:

$$\mu_U = \frac{N_1 N_2}{2}$$

The sampling distribution has a variance calculated as:

$$\sigma_U^2 = \frac{N_1 N_2 (N_1 + N_2 + 1)}{12}$$

The distribution of U is assumed to be a normal, or Z distribution. The Z value to compare against the critical Z value of 1.96 is calculated as:

$$U = \frac{U - \mu_U}{\sigma_U}$$

Statistical tools such as SPSS™ can be utilized to perform Mann-Whitney U tests. Figure 3-7 provides a sample SPSS™ output. The test statistics table is used to determine if the there is a statistical difference between the two groups through the calculation of a probability, or p-value. A confidence level for the statistical significance is stated; the typical confidence level being 95 percent, which corresponds to an alpha level (or rejection level) of 5 percent (Wilcox 2009). If the p-value of the test is greater than .05 (i.e., 5 percent), then there is not a statistical difference between rank-order of the two groups (Wilcox 2009). If the p-value of the test is less than .05 (i.e., 5 percent), then there is a statistical difference between rank-order of the two groups (Wilcox 2009). As shown, the test shown in Figure 3-7 is not show a statistically significant difference between the two groups (i.e., the p-value is .191, or greater than .05).

Mann-Whitney Test

Ranks

		N	Mean Rank	Sum of Ranks
Test Groups	1.00	19	17.63	335.00
	2.00	12	13.42	161.00
	Total	31		

Test Statistics[a]

	Group 1
Mann-Whitney U	83.000
Wilcoxon W	161.000
Z	-1.308
Asymp. Sig. (2-tailed)	.191

Figure 3-7. Sample Mann-Whitney U Test Output from SPSS™

3.2.5. Correlation

Correlation, commonly denoted as r, measures the strength of the linear relationship between a set of two quantitative variables (Moore et al. 2010). The author calculated correlation as part of the regression analysis performed to compare PDRI scores and project performance of completed projects (described in Chapter 7).

Aggregated data in the form of dependent (Y) and independent (X) variables are first graphed in the form of a scatterplot as shown in Figure 3-4. Independent variables, or response variables, are graphed based on their position along the Y-axis, and dependent variables, or explanatory variables, are graphed based on their position along the X-axis (Moore et al. 2010). Statistical tools such as Microsoft Excel™ and SPSS™ can be utilized to create scatterplots.

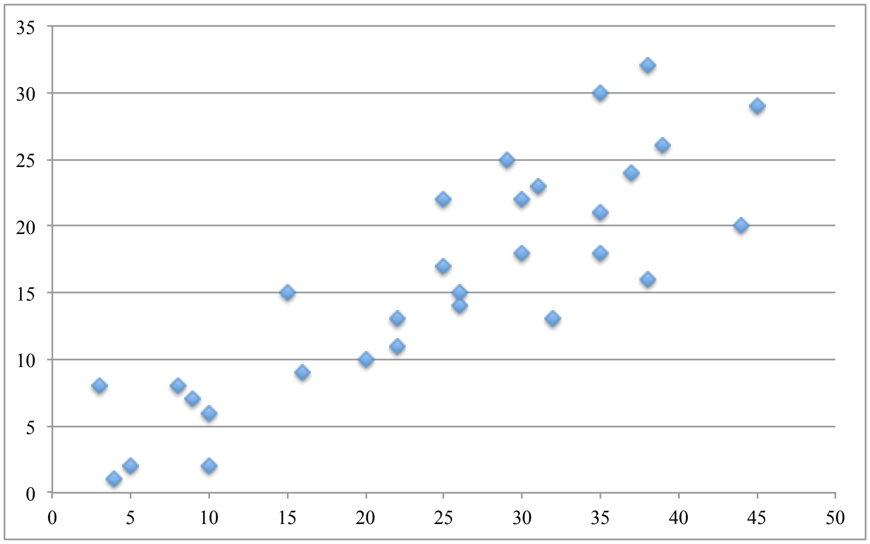


Figure 3-4. Sample Scatterplot from Microsoft Excel

The independent variable is assumed to predict behavior of the dependent variable (Moore et al. 2010.) The strength of the relationship is determined by how closely the points follow a clear form or direction. Calculating r provides this determination.

r is calculated as:

$$r = \frac{1}{n-1} \sum \left(\frac{x_i - \bar{x}}{s_x}\right)\left(\frac{y_i - \bar{y}}{s_y}\right)$$

Where:

n = total sample size

$\bar{x}$ = sample mean value of x

$\bar{y}$ = sample mean of y,

s_x = sample standard deviation of x

s_y = sample standard deviation of y

A positive r-value indicates a positive association between the variables, and a negative r value indicates a negative association. r-values will always be numbers between -1 and 1, where a value close to 0 indicates a weak correlation between the variables and a value closer to -1 or 1 indicates a strong correlation (Moore et al. 2010.) Outlier and extreme values in the data set can skew these values.

3.2.6. Regression Analysis

A simple linear regression model attempts to model the relationship between one independent (Y) and one dependent (X) variable, with the basic assumption that the relationship between the variables behaves in a linear fashion (Waissi 2015). The author performed regression analysis to compare PDRI scores and project performance of completed projects (described in Chapter 7).

Linear regression, also known as least squares estimation, uses formulas for finding the y-intercept and slope of a line such that the sum of squares distances of the data points from the line itself are kept to a minimum (Waissi 2015).

The equation used to generate a regression line for linear bivariate regression is:

$$Y = b_1X + b_0$$

Where:

b_1 = slope or regression coefficient, calculated as $b_1 = r \frac{s_y}{s_x}$

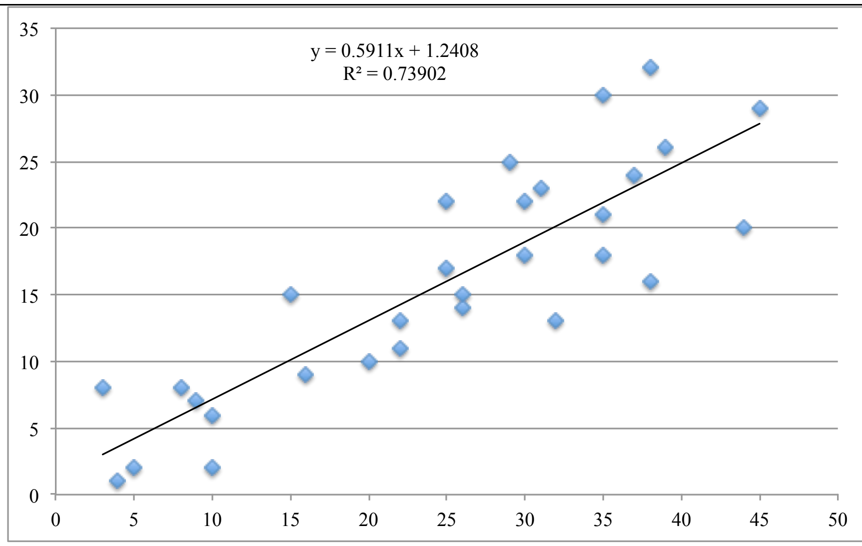
b_0 = Y Intercept, calculated as $b_0 = \bar{y} - b_1\bar{x}$

The strength of the regression model (i.e., fit) is calculated as r^2, where:

$$r^2 = \frac{Sum\ of\ Squares\ (Total)}{Sum\ of\ Squares\ (Regression)}$$

The r^2 value, denotes how well the regression equation explains the dependency between the X and Y variables. The r^2 value will always be positive, and between 0 and 1. The r^2 value denotes what percentage of the variation in the dependent variable (Y) is explained by the dependent variable (X) (Waissi 2015).

Statistical tools such as Microsoft Excel™ and SPSS™ can be utilized to perform regression modeling. Figure 3-5 shows the trendline, regression equation and r^2 value of the scatterplot provided in Figure 3-5. As shown, the dependent variable (X) explains approximately 74 percent of the variation in the independent variable (Y).



Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.860[a]	.739	.730	4.42072

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1549.503	1	1549.503	79.288	.000[b]
	Residual	547.197	28	19.543		
	Total	2096.700	29			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.241	1.833		.677	.504
	X	.591	.066	.860	8.904	.000

Figure 3-5. Sample Regression Model

Figure 3-5 also includes the SPSS™ regression modeling output, which includes the model summary, the analysis of variance (i.e., ANOVA) table, and the coefficients table. The ANOVA table is used to determine of the regression model is statistically significant through the calculation of a probability, or p-value (denoted as “Sig.” in SPSS™). A confidence level for the statistical significance is stated; the typical confidence level being 95 percent, which corresponds to an alpha level (or rejection level) of 5 percent (Waissi 2015). If the p-value of the regression model is greater than

.05 (i.e., 5 percent), then a significant portion of the total variability in the data is primarily due to randomness, or error in the model (Waissi 2015). If the p-value of the regression model is less than .05 (i.e., 5 percent), then a significant portion of the total variability in the data can be attributed to the relationship between the variables (Waissi 2015). As shown, the model given in Figure 3-5 is statistically significant (i.e., the p-value is .000, or less than .05).

The coefficients table is used to determine if the model parameters (i.e., the y-intercept and slope) are significantly different than zero. A confidence level for the statistical significance is stated; the typical confidence level being 95 percent, which corresponds to an alpha level (or rejection level) of 5 percent (Waissi 2015). If the p-value of the model parameter is greater than .05 (i.e., 5 percent), then the parameter is not statistically different than zero (Waissi 2015). If the p-value of the model parameter is less than .05 (i.e., 5 percent), then the parameter is statistically different than zero (Waissi 2015). As shown, the constant (i.e., y-intercept) in the model given in Figure 4-6 is not statistically significant (i.e., the p-value is .504, or greater than .05), but the slope (i.e., X) is statistically significant (i.e., the p-value is .000, or less than .05).

3.3. Limitations of the Data Analysis

Several limitations exist with this data analysis, as with any data analysis. Optimally, the projects utilized to weight the PDRI, and the projects used to test the PDRI would come from a random sample. In this case, the data collected came from individuals who volunteered to participate in the research study. The authors stressed to focus group members that both "good" and "bad" projects were desired. However, the final selection of projects used during the workshop sessions came from the focus group members themselves, and they may have chosen only "good" projects. As such, generalizing the results of this study to the entire population is not possible.

The second limitation to this study stems from data collected during the testing process. Collecting "after the fact" data required respondents to refer back to the point in time just prior to the start of detailed design on the chosen projects. This point may have been weeks, months, or even years prior to the volunteer completing the testing questionnaire. This method may have led to slightly inaccurate information due to memory lapse of the project participants during that time period. Having knowledge of the actual project outcomes may also have biased the respondent's answers to be more favorable. However, given the relatively short schedule of the research investigation, tracking projects from planning through completion was not possible.

3.4. Summary

This chapter outlined the research methodology employed for producing and testing the PDRI-Small Industrial. Five separate focus groups were empaneled to gain industry perspective on the PDRI tool itself, as well as prioritization of the elements. Questionnaires were developed to test the tool on both completed and in-progress projects. Questionnaires were also developed to gain industry perspective on small industrial projects. Various statistical methods were used to analyze the data received.

CHAPTER 4. LITERATURE REVIEW

The author performed a literature review to establish a theoretical baseline concerning previous research investigations into front end planning and small projects. The articles and studies detailed in this chapter served as the starting point for the research team to develop the PDRI-Small Industrial tool. This chapter introduces and discusses relevant organizations, terms, research, and existing tools central to the development of the tool.

4.1. Construction Industry Institute Research

This section details the literature review findings regarding The Construction Industry Institute, project definition rating index, and front end planning tools associated with the project definition rating index.

4.1.1. The Construction Industry Institute (CII)

The Construction Industry Institute (CII) is a unique knowledge creation organization and consortium of owner, engineering-contractor, and supplier firms that join together to enhance the business effectiveness and sustainability of the capital facility life cycle through research. The purpose of CII is to measurably improve the delivery of capital facilities. This purpose is achieved through the funding of a considerable amount of collaborative research where both academics and industry professionals unite to identify and address significant opportunities for construction industry improvement. CII's mission is stated as (CII Website 2015):

> *CII creates global, competitive, and market advantages for its members through its research-based, member-driven creation of knowledge and CII Best Practices. The institute's ability to disseminate this knowledge and assess its implementation gives members a decisive industry edge. Employees of CII member organizations cooperatively engage with*

leading academics to generate CII knowledge; this unprecedented partnering of industry and academia creates the perfect forum for identifying the most significant opportunities for industry improvement. These industry participants and academics also benefit from the professional development and career advancement the collaborative effort provides.

Front end planning has been considered by CII to be a Best Practice for over 15 years, which has led to a considerable amount of research into this area. The development of the PDRI-Small Industrial was sponsored by CII as a research investigation in 2013. Several key terms and definitions produced by previous CII research teams are provided in the next few sections.

4.1.2. Early CII Research into Project Planning

Research into the relationship between pre-project planning impacts and facility construction outcomes had not been conducted prior to 1991 (CII 1994). CII established the Pre-Project Planning Task Force in 1991 to outline the functions involved in the pre-project planning of capital facilities. The task force defined pre-project planning 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” (Gibson et al. 1993). Pre-project planning is considered an important subset of the overall project planning endeavor; it begins after the business leadership of an organization deems a project concept desirable, and continues until the beginning of detailed design and construction of a project (Gibson et al. 1995). Decisions made during the early stages of the project life cycle have a much greater influence on a project’s outcome than those made in later stages (CII 1994), illustrated in Figure 4-1.

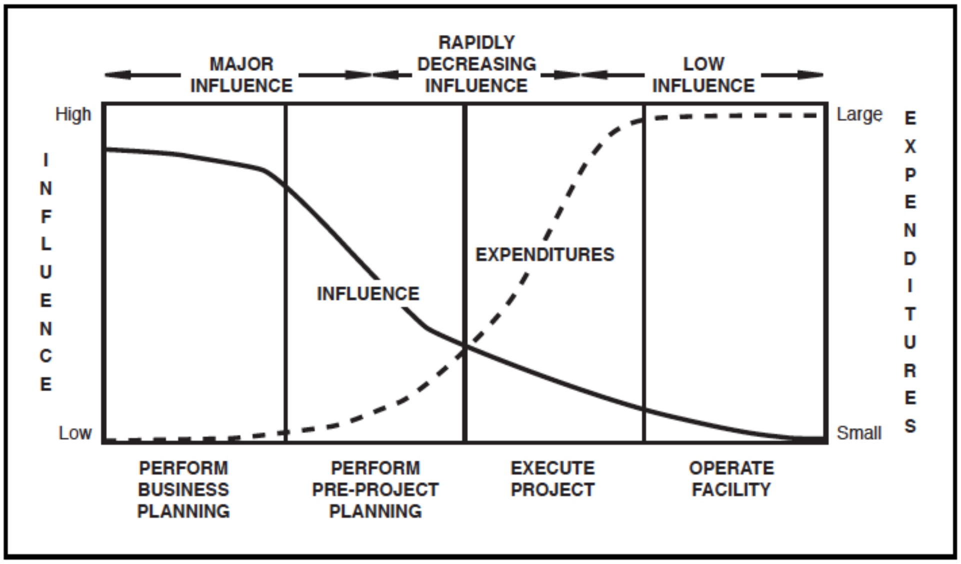


Figure 4-1. Influence and Expenditures Curve for the Project Life Cycle (CII 1994)

The Pre-Project Planning Task Force developed a generic model expressing the typical pre-project planning process (Gibson et al. 1993, CII 1995), a quantitative study comparing pre-project planning effort vs. project success factors (Gibson and Hamilton 1994, Hamilton and Gibson 1996), and culminated with a pre-project planning handbook that detailed specific steps typical in planning capital projects (CII 1995). The Task Force found that well performed pre-project planning could reduce the total project design and construction costs by as much as 20 percent, reduce the total project design and construction schedule by as much as 39 percent, improve project predictability in terms of cost, schedule, and operating performance, and increase the chance of a project meeting stated environmental and social goals (Gibson and Hamilton 1994, Hamilton and Gibson 1996, CII 1994).

4.1.3. Project Scope Definition Tools

CII initiated the development of three pre-project planning tools for quantifying, rating, and assessing project planning efforts based on the conclusions found by the Pre-Project Planning Task Force, namely the Project Definition Rating Index (i.e., PDRI) tools, between the years of 1994 and 2008. Separate research teams developed tools to specifically address industrial projects, building projects, and infrastructure projects. The purpose of the tools is three-fold: (1) to provide a structured planning process for use during the front end planning phase of a project, (2) to provide a quantitative measure (i.e., a score) of the level of scope definition of a project, and (3) to correlate the level of scope definition to typical project success factors so that project stakeholders can determine whether to move a project forward into detailed design and construction.

4.1.3.1. PDRI-Industrial

CII formed the Front End Planning Research Team in 1994 to "produce effective, simple, 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" (Gibson and Dumont 1995). The 16 individuals (from both industry and academia) that made up the research team were initially split into two separate sub-teams: one team tasked with developing a tool for measuring project scope development of industrial construction projects, and the other tasked with developing a guideline for measuring alignment within project teams. (The outcomes of the alignment research are provided in section 4.1.4.1).

The Front End Planning Research Team determined that, at a minimum, any tools developed for measuring project scope definition should provide (Gibson and Dumont 1995):

- 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.

The research team developed the Project Definition Rating Index-Industrial Projects (PDRI-Industrial) to address these challenges. The research team considered industrial projects to include the following types of facilities (Gibson and Dumont 1995):

- Oil/gas production facilities

- Chemical plants
- Paper mills
- Power plants
- Food processing plants
- Textile mills
- Pharmaceutical plants
- Steel/aluminum mills
- Manufacturing facilities
- Refineries

The PDRI-Industrial tool includes two main components: a structured list of descriptions detailing specific elements that should be addressed during the front end planning phase of industrial projects, and a weighted score sheet that corresponds to the element descriptions. The purpose of the weighted score sheet is to quantitatively gauge the scope definition of a project. The research team identified 70 elements critical to the planning of industrial construction projects. The research team divided the elements into three separate sections (Basis of Project Decision, Front End Definition, Execution Approach), and further divided the elements into 15 categories. This arrangement places similar elements together for ease of discussion during pre-project planning assessments. Each element also has a detailed narrative that provides description of the element, and certain additional items to consider when assessing a project. Figure 4-2 provides an example of element A.1 Reliability Philosophy from the PDRI-Industrial. The structure of each element in the PDRI is typical of Figure 4-2.

A.1 Reliability Philosophy

A list of general design principles to be considered to achieve dependable operating performance from the unit/facility or upgrades instituted for this project. Evaluation criteria should include:

- Justification of spare equipment
- Control, alarm, security and safety systems redundancy, and access control
- Extent of providing surge and intermediate storage capacity to permit independent shutdown of portions of the plant
- Mechanical/structural integrity of components (metallurgy, seals, types of couplings, bearing selection)
- Identify critical equipment and measures to be taken to prevent loss due to sabotage or natural disaster
- Other

Additional items to consider for Renovation & Revamp projects

- Potential impacts to existing operations

Figure 4-2. Sample Element Description from PDRI-Industrial

The research team hypothesized that all elements within the PDRI were not equally important regarding their potential impact to overall project success. The team convened two workshops where 54 project managers and estimators experienced with a variety of industrial construction projects provided input concerning the relative importance (i.e., weight) of each element included in the PDRI. The team developed the PDRI score sheet based on the element prioritization data provided by the workshop participants, deriving a scoring scheme for the score sheet such that a lower score indicates a project with a greater level of scope definition, while a higher score indicates a lesser amount of scope definition. Each element in the PDRI was given five potential levels of definition, ranging from complete definition (i.e., Level 1) to little to no definition (i.e., Level 5). The workshop participants provided weights for each element at each score level.

The typical PDRI scoring scheme is such that a project with all elements assessed as Level 1 totals 70, and a project with all elements assessed as Level 5 totals 1000. Level 2, 3, and 4 scores range between the Level 1 and Level 5 scores. Any elements deemed not applicable during a project assessment would lower the potential total project score on a pro-rata basis, depending on the weighting of non-applicable elements. Figure 4-3 provides a section and category breakdown of the finalized PDRI-Industrial score sheet, based on definition Level 5 weights of the elements in each section and category. Figure 4-3 also provides the top ten highest weighted elements in the PDRI-Industrial, based on the definition Level 5 weights. These ten elements were deemed to be the most critical to project success of all of the 70 elements included in the tool, hence the most critical to address during front end planning of an industrial project

Section		Weight
I.	Basis of Project Decision	499
II.	Basis of Design	423
III.	Execution Approach	78
		1000

Category		Weight
A.	Manufacturing Objectives Criteria	45
B.	Business Objectives	213
C.	Basic Data Research & Development	94
D.	Project Scope	120
E.	Value Engineering	27
F.	Site Information	104
G.	Process/Mechanical	196
H.	Equipment Scope	33
I.	Civil, Structural & Architectural	19
J.	Infrastructure	25
K.	Instrument & Electrical	46
L.	Procurement Strategy	16
M.	Deliverables	9
N.	Project Control	17
P.	Project Execution Plan	36
		1000

Element		Weight
B.1	Products	56
B.5	Capacities	55
C.1	Technology	54
C.2	Processes	40
G.1	Process Flow Sheets	36
F.1	Site Location	32
G.3	Piping & Inst. Diagrams (P&ID's)	31
D.3	Site Characteristics (Avail. Vs. Req)	29
B.2	Market Strategy	26
D.1	Project Objectives Statement	25
		384/1000

Figure 4-3. PDRI-Industrial Section and Category Weights, and Top 10 Highest Weighted Elements

The team confirmed the element weightings through testing of the PDRI-Industrial on 40 completed projects, totaling over $3.3 billion in expenditure (CII 1997). The research team determined through analyzing the 40 completed projects that projects with PDRI scores lower than 200 statistically outperformed projects with PDRI scores above 200 regarding cost, schedule, and change order performance. Figure 4-4 provides a summary of the PDRI-Industrial testing results at the 200-point PDRI score cutoff.

	PDRI Score		
Performance	**< 200**	**> 200**	**Δ**
Cost	5% below budget	14% above budget	19%
Schedule	1% behind schedule	12% behind schedule	11%
Change Orders	2% of total cost	8% of total cost	6%
	(n=20)	(n=20)	

Figure 4-4. PDRI-Industrial Cost, Schedule, and Change Order Performance based on 200-Point Cutoff

4.1.3.2. PDRI-Building

The Front End Planning Research Team concluded that separate PDRI tools should be developed for industrial, building, and infrastructure Projects. The success of the PDRI-Industrial tool to led CII to form Research Team 155 in 1998 for the purpose of developing a PDRI tool specifically for building projects. The PDRI-Building was developed for building projects, excluding residential houses, performed in both the public and private sector, and was most applicable to multi-story or single story commercial, institutional, or light industrial facilities such as (Cho et al. 1999):

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

Research Team 155 utilized the same development and testing procedure established by the Front End Planning Research Team (Gibson and Dumont 1995) when developing the PDRI-Building. The team identified 64 elements critical to the planning of building construction projects. The elements were broken into three separate sections (Basis of Project Decision, Basis of Design, Execution Approach), and further broken down into 11 categories. Each element had a detailed narrative providing description of the element, and certain additional items to consider when assessing a project. The element descriptions were structured similar to the PDRI-Industrial element descriptions, shown in Figure 4-2.

The team convened seven workshops in various locations across the United States where 69 project managers, architects and engineers experienced with a variety of building construction projects provided input concerning the relative importance (i.e., weight) of each element included in the PDRI. The team used the element prioritization data provided by the workshop participants to develop the weighted PDRI score sheet. The team used the same scoring scheme as the PDRI-Industrial, where scores range from 70-1000, and a lower score indicates a greater level of scope definition.

Figure 4-5 provides a section and category breakdown of the finalized PDRI score sheet, based on definition Level 5 weights of the elements in each section and category. The sections and categories are listed from highest total weight to lowest total weight. Figure 4-5 also provides the top ten highest weighted elements in the PDRI-Building, based on the definition Level 5 weights. These ten elements were deemed to be the most critical to project success of all of the 64 elements included in the tool, hence the most critical to completely address during front end planning of a building project.

Section		Weight
I.	Basis of Project Decision	413
II.	Basis of Design	428
III.	Execution Approach	159
		1000

Category		Weight
A.	Business Strategy	214
B.	Owner Philosophies	68
C.	Project Requirements	131
D.	Site Information	108
E.	Building Programming	162
F.	Building/Project Design Parameters	122
G.	Equipment	36
H.	Procurement Strategy	25
I.	Deliverables	11
J.	Project Control	63
K.	Project Execution Plan	60
		1000

Element		Weight
A.1	Building Use	44
A.5	Facility Requirements	31
A.7	Site Selection Considerations	28
A.2	Business Justification	27
C.6	Project Cost Estimate	27
A.3	Business Plan	26
C.2	Project Design Criteria	24
C.3	Evaluation of Existing Facilities	24
A.6	Future Expans./Alt. Considerations	22
F.2	Architectural Design	22
		275/1000

Figure 4-5. PDRI-Building Section and Category Weights, and Top 10 Highest Weighted Elements

The team confirmed the element weightings through testing of the PDRI tool on 33 completed building projects, totaling nearly $900 million in expenditure. The team determined through an analyzing the 33 completed projects that projects with PDRI scores lower than 200 statistically outperformed projects with PDRI scores above 200 regarding cost, schedule, and change order performance, the same as the PDRI-Industrial. Figure 4-6 provides a summary of the PDRI-Building testing results at the 200-point PDRI score cutoff.

Performance	PDRI Score < 200	PDRI Score > 200	Δ
Cost	1% above budget	6% above budget	5%
Schedule	2% behind schedule	12% behind schedule	10%
Change Orders	7% of budget	10% of budget	3%
	(n=16)	(n=17)	

Figure 4-6. PDRI-Building Cost, Schedule, and Change Order Performance based on 200-Point Cutoff

4.1.3.3. PDRI-Infrastructure

CII formed Research Team 268 in 2008 to develop a PDRI tool specifically for Infrastructure projects. The research team defined an infrastructure project as (Bingham et al. 2011):

> *An infrastructure project is defined as a project that provides transportation, transmission, distribution, collection or other capabilities supporting commerce or interaction of goods, service, or people. Infrastructure projects generally impact multiple jurisdictions, stakeholder groups and/or a wide area. They are characterized as projects with a primary purpose that is integral to the effective operation of a system. These collective capabilities provide a service and are made up of nodes and vectors into a grid system (e.g., pipelines (vectors) connected with a water treatment plant (node)).*

Research Team 268 utilized the same development and testing procedure established by the Front End Planning Research Team (Gibson and Dumont 1995) and Research Team 155 (Cho et al. 1999) when developing the PDRI-Infrastructure. The team identified 68 elements critical to the planning of infrastructure construction projects. The elements were broken into three separate sections (Basis of Project Decision, Basis of Design, Execution Approach), and further broken down into 13 categories. Each element had a detailed narrative providing a description of the element, and certain additional items to consider when assessing a project. The element descriptions were structured similar to the PDRI-Industrial and PDRI-Building element descriptions, shown in Figure 4-2.

The team convened six workshops in various locations across the United States and Great Britain where 64 industry professionals representing multiple owner and contractor organizations experienced with a variety of infrastructure construction projects provided input concerning the relative importance (i.e., weight) of each element included in the PDRI. The team used the element prioritization data provided by the workshop participants to develop the weighted PDRI score sheet. The team used the same scoring scheme as the PDRI-Industrial and PDRI-Building, where scores range from 70-1000, and a lower score indicates a greater level of scope definition.

Figure 4-7 provides a section and category breakdown of the finalized PDRI score sheet, based on definition Level 5 weights of the elements in each section and category. The sections and categories are listed from highest total weight to lowest total weight. Figure 4-7 also provides the top eight highest weighted elements in the PDRI-Infrastructure, based on the definition Level 5 weights. These eight elements were deemed to be the most critical to project success of all of the 68 elements included in the tool, hence the most critical to completely address during front end planning of an infrastructure project.

Section		Weight
I.	Basis of Project Decision	437
II.	Basis of Design	293
III.	Execution Approach	270
		1000

Category		Weight
A.	Project Strategy	112
B.	Owner/Operator Philosophies	67
C.	Project Funding and Timing	70
D.	Project Requirements	143
E.	Value Analysis	45
F.	Site Information	119
G.	Location and Geometry	47
H.	Associated Structures and Equipment	47
I.	Project Design Parameters	80
J.	Land Acquisition Strategy	60
K.	Procurement Strategy	47
L.	Project Control	80
M.	Project Execution Plan	83
		1000

Element		Weight
A.1	Need and Purpose Documentation	44
A.2	Investment Studies & Alternate Assess.	28
C.3	Contingencies	27
L.2	Design and Construction Cost Estimates	25
B.1	Design Philosophy	22
C.2	Preliminary Project Schedule	22
D.3	Evaluation of Compliance Requirements	22
D.4	Existing Environmental Conditions	22
		234/1000

Figure 4-7. PDRI-Infrastructure Section and Category Weights, and Top 8 Highest Weighted Elements

The team confirmed the element weightings through testing of the PDRI tool on 22 completed infrastructure projects, totaling over $6 billion in expenditure. The team determined through an analysis of the 22 completed projects that projects with PDRI scores lower than 200 statistically outperformed projects with PDRI scores above 200 regarding cost, schedule, and change order performance, the same as the PDRI-Industrial and PDRI-Building. Figure 4-8 provides a summary of the PDRI-Infrastructure testing results at the 200-point PDRI score cutoff.

	PDRI Score		
Performance	**< 200**	**> 200**	**Δ**
Cost	2% under budget	23% above budget	25%
Schedule	5% behind schedule	29% behind schedule	24%
Change Orders	3% of total cost	10% of total cost	7%
	(n=13)	(n=9)	

Figure 4-8. PDRI-Infrastructure Cost, Schedule, and Change Order Performance based on 200-Point Cutoff

4.1.4. Other CII Front End Planning Research Supporting the Process

CII has funded several research projects to further investigate aspects of front end planning that should be addressed along with project scope definition. These aspects include project team alignment, renovation and revamp projects, integrated project risk assessment, information flow to support front end planning, and optimizing construction input during front end planning.

4.1.4.1. Project Team Alignment

An objective of the CII Front End Planning Research Team was to investigate alignment during the pre-project planning phase. The team defined alignment as "The condition where appropriate project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objectives" (Griffith and Gibson 1997). The project objectives are formed in the early stages of project development, must meet the business requirements and overall corporate strategy of the project stakeholders, and have a critical impact on project success (CII 1997). Alignment in the project environment was found to exist in three dimensions, shown in Figure 4-9. Without commitment to the project objectives by all project stakeholders within the three dimensions, there is no alignment (CII 1997).

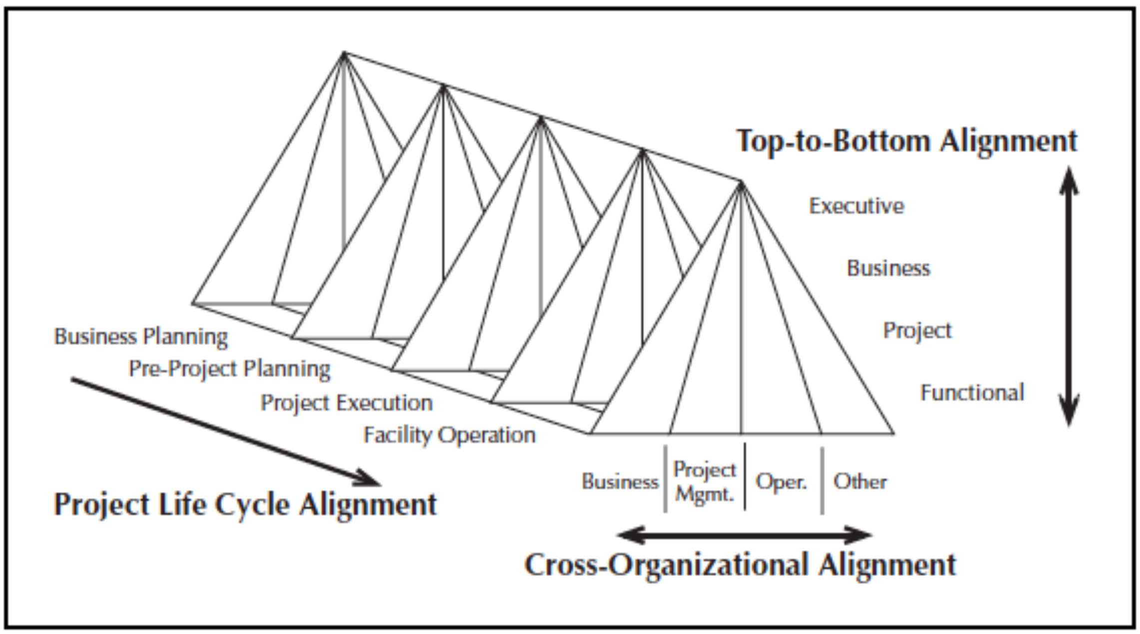


Figure 4-9. Three Dimensions of Alignment in the Project Environment (Taken from CII 1997)

The team developed a list of critical issues found to have the greatest effect on team alignment and project success through a series of three workshops and 54 structured interviews with industry professionals (Griffith and Gibson 1997). The team also developed a tool called the Alignment Thermometer used to assess how well a project team is aligned during front end planning. The ten most critical alignment issues are (CII 2009):

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 team culture fosters truth, honesty, and shared values
7. The pre-project planning process includes sufficient funding, schedule, and scope to meet objectives
8. The reward and recognition system promotes meeting project objectives
9. Teamwork and team building programs are effective
10. Planning tools (e.g., checklists, simulations, and work flow diagrams) are effectively used

4.1.4.2. Renovation and Revamp Projects

CII Research Team 242 studied renovation and revamp (R&R) projects for the purpose of offering support to the case for performing adequate front end planning on R&R projects. The team defined a R&R project as "one that is focused on and existing facility and includes the act, process, or work of replacing, restoring, repairing, or improving this facility with capital or non-capital funds. It may include additional structures and systems to achieve a more functional, serviceable, or desirable condition, including improvement in: profitability; reliability; efficiency; safety; security; environmental performance; and/or compliance with regulatory requirements" (CII

2009). The team completed a review of R&R projects through a survey of individuals employed by CII member organizations, and a case study of completed projects by these organizations. The team stated that some R&R projects may be small, while other may be hundreds of millions of dollars in cost, and that 30 percent of projects completed by CII member organizations were considered R&R projects at that time (CII 2009). The team found that the planning of R&R projects differs from greenfield projects in that such projects are fraught with the risk of unknown existing site conditions, and are oftentimes undertaken while a facility is still in operation (CII 2009). The absence of a proper planning approach can result in disputes, delays, and cost increases (CII 2009). The research team identified several unique characteristics to planning for R&R projects including:

- Safety and security issues of work force interfacing with existing conditions
- Unforeseen site conditions more prevalent
- Scope definition, estimating the amount of work more difficult
- Scheduling intensity, higher in many cases
- Shutdown issues occur on many projects
- Greater need to interface with operations/tenants, maintenance, and construction personnel
- Additional schedule constraints occur due to operational interfaces
- Different funding sources, including both local capital and non-capital funds

The team's study of R&R projects led to them updating certain elements within the PDRI-Industrial and the PDRI-Building with specific items to consider when planning a project that included an R&R component, or was completely an R&R project.

The team also developed a separate tool specifically for shutdown/turnaround/outage (STO) projects, called the Shutdown/Turnaround Alignment Review (STAR) tool, as STO projects were found to make up a significant portion of R&R projects completed by CII member organizations (CII 2014). Shutdown/turnaround/outage is defined as "A project or portion of a project that is executed during a planned disruption in normal use or operation where return to service is a business priority." STO projects were described as "a single point in time where multiple projects converge to a point of "time-constrained" integration and rapid schedule execution" (CII 2009). The STAR tool was developed to complement the PDRI, providing measurement of key planning attributes unique to STO's. The STAR tool tests the alignment or preparedness of these multiple projects to be completed during the STO so that associated risks can be identified and acted upon (CII 2009).

4.1.4.3. Integrated Project Risk Assessment

CII Project Team 181 developed a risk assessment tool in 2003 for the purpose of assessing risk on any project, but specifically complex projects in unfamiliar venues or locations. Initially named the International Project Risk Assessment tool, or IPRA tool, the title was updated in 2013 to Integrated Project Risk Assessment due to the wide applicability of the tool to domestic projects along with international projects.

The team found several definitions for risk as it relates to construction, such as "the potential for loss or injury", "the exposure to the chance occurrences of events that adversely or favorably affect project objectives as a consequence of uncertainty", and "the presence of potential or actual threats or opportunities that influence project objectives during project planning, construction, and commissioning; and these objectives are in the form of cost, schedule and quality" (CII 2013). Coordinating risk management between disparate project stakeholders is not typically done in a formalized manner on most construction projects. Risk comes from different viewpoints depending on the project stakeholder: engineers/contractors/designers see technical risks, owners and developers see economic and financial risk, safety and health professionals see hazard impact/mitigation risk (CII 2013). Several benefits to project success exist when project stakeholders collaboratively identify and manage risk, including:

- Allows for early identification or hazards and opportunities
- Communicates risks between project participants
- Identifies and manages uncertainty
- Identifies and considers worst case scenarios
- Established ownership of risks and risk mitigation actions
- Enhance risk-based decision-making

The IPRA tool is a structured risk identification and assessment process, designed for use as part of an overall risk assessment strategy. The IPRA was developed with participation from 113 industry professionals, including 26 structured interviews to help develop the element descriptions, four workshops in North America, and was tested on 15 completed projects, and seven in process projects. The IPRA consists of four sections (commercial, location, facilities, production/operations), 14 categories, and 82 elements, and is applicable to industrial, buildings, and infrastructure projects. Each element/risk item is ranked depending on two factors: the likelihood of occurrence of the risk, and the potential impact to the project if the risk were to materialize. Figure 4-10 provides the IPRA Risk Assessment Matrix used to visually summarize project risks. The IPRA tool is to be used three times during project planning: validation of the project feasibility, project definition, and decision to proceed. The tool provides a structure for project teams to develop mitigation strategies once risks are defined, and to continually assess identified risks throughout the planning and construction process.

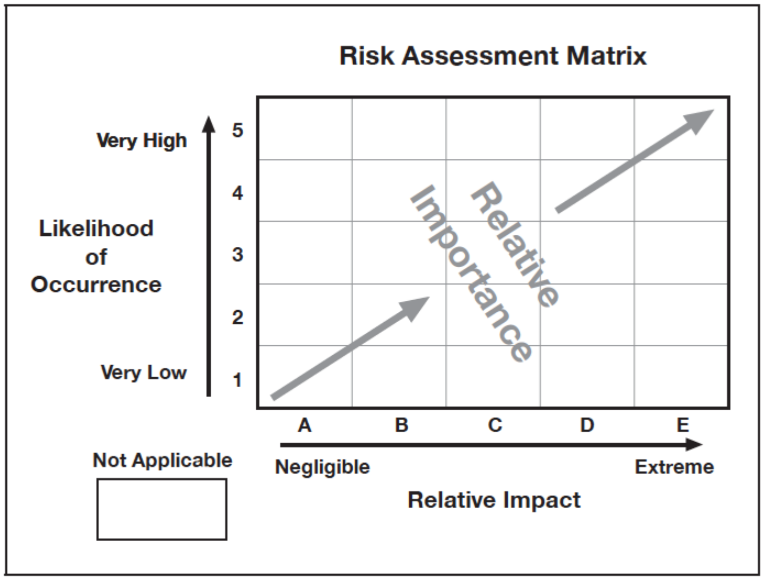


Figure 4-10. IPRA Element Risk Assessment Matrix (Taken from CII 2013)

4.1.4.4. Information Flow to Support Front End Planning (2007)

CII Research Team 221 studied information flow to support the front end planning process of engineer-procure-construct (EPC) projects. The objectives of the research were to identify the information flow activities in front end planning and their interrelationships, identify the information requirements for front end planning activities, and provide recommendations for improving information flow to support front end planning. The team found that "The quality of information and the manner in which information flows, with respect to its comprehensiveness, correctness, and completeness, can either enhance or hinder the successful execution of work" (George and Back 2007). Front end planning is both information intensive and information dependent, and successful front end planning is dependent on the utilization of information that is generated and/or managed both internally and externally to project organizations (George and Back 2007). It is important to identify when and what information is required within the planning process and how the generation or exchange of information can be improved within each individual phase of project delivery. The lack of availability or inadequacy of necessary information during front end planning will diminish the likelihood of successful project performance (George and Back 2007).

The team developed logic flow diagrams for 33 information flow activities showing the interrelationships between information flow tasks on typical EPC projects. The research team found that successful projects executed the information flow activities successfully and efficiently, devoted more time and resources to the execution of information flow activities, and the activities had all of the necessary information available when needed (George and Back 2007).

4.1.4.5. Optimizing Construction Input in Front End Planning (2009)

CII Research Team 241 studied how construction input during front end planning could improve project performance. The purpose of the research was to develop a CII best practice related to maximizing the value for construction input during front end planning to bring significant improvements in construction and commissioning phases of projects to improve project performance (Gokhale et al. 2009). The team found three principal barriers impeding on the involvement of construction input during front end planning:

1. Silos between design, construction and ownership, causing stakeholders to optimize their own interests rather than the overall project

2. Traditional contract models that institutionalize non-collaborative approaches
3. The lack of a decision tool to allow project managers to prioritize activities requiring construction input during front end planning

The team developed the Construction Input Assessment Tool (CIAT) through literature review, case studies, and industry questionnaires. The purpose of the tool is assist project decision makers in identifying and prioritizing key construction items and activities that require construction input during front end planning (Gokhale et al. 2009). The team used the PDRI-Industrial and PDRI-Building tools as a baseline, but utilized only those elements that required construction input during front end planning. Usage of the CIAT tool consists of four steps:

1. Assess the level of construction input necessary (on a scale of zero percent to 100 percent) for a project based on the element description within the tool, and determine if there is sufficient in-house expertise to successfully address the construction related issues.
2. A high-level assessment of the project concerning necessary construction input, comparing the current level of construction input versus the target level of construction input thought to be needed (from step one)
3. A detailed-level assessment of the project concerning necessary construction input, comparing the current level of construction input versus the target level of construction input thought to be needed (from step one)
4. Final result of the assessment, comparing the target level of construction input (taken from step one) and comparing that to the high level and detailed level assessments (from steps two and three) to highlight which elements have

sufficient construction input, and which elements need additional construction input.

4.1.5. Efficacy of the PDRI tools

CII twice sought to determine the efficacy of their front end planning research. The next section describes these two studies, and highlights several continuous improvement areas where the front end planning tools have been updated to meet the ever-changing field of construction.

4.1.5.1. Front End Planning: Break the Rules, Pay the Price (2006)

CII Research Team 213 investigated the importance and value of the front end planning process, the resources required to perform the front end planning process effectively, and to outline key "rules" to the front end planning process (CII 2006). The team utilized the CII Benchmarking and Metrics programs to collect project data regarding:

- The cost of front end planning
- Project performance (i.e., cost, schedule, change orders) based on assessing projects with the PDRI-Industrial and PDRI-Building tools
- Typical percentage of design completion at the end of scope definition
- Comparison of the Pre-Project Planning performance index vs. cost, schedule, and change performance
- Comparison of alignment during front end planning vs. cost, schedule, and change performance.

The research team found that (CII 2006):

- Four percent of total installed cost was spent on front end planning for all projects. This percentage was slightly higher for small projects
- Projects scoring below 200 (with the PDRI-Industrial and PDRI-Building) performed better than those scoring above 200 regarding cost, schedule, and change performance
- Projects with 20 percent of design completed at the end of frond end planning performed better than projects with a lesser amount of design completed at the end of front end planning
- Projects with Pre-Project Planning Index scores above the median mark (i.e., 7.9 out of 10) performed better than projects scoring below the median mark regarding cost, schedule, and change performance. Higher Pre-Project Planning Index scores (i.e., closer to 10) equate to more intensive front end planning. (Note: the Pre-Project Planning Index was developed by the CII Benchmarking and Metrics group to determine the relative level of front end planning at project authorization to expend funds for design and construction.)
- Projects with Alignment Index scores above the median mark (i.e., 7.8 out of 10) performed better than projects scoring below the median mark regarding cost and schedule performance. Higher Alignment Index scores (i.e., closer to 10) equate to more aligned projects

The team completed several other tasks, including replacing the term pre-project planning with front end planning, believing that the planning process includes efforts performed during the project, not just before as pre-project planning implied, and to better relate to industry specific terminology. The team also updated the PDRI-Industrial and PDRI-Building tools, and also developed an html based tool/process map to replace the pre-project planning handbook that had been developed by the Pre-Project Planning Task Force in 1991. The team concluded with developing a set of critical success factors, or "rules", for front end planning (CII 2006):

- Develop and consistently follow a defined front end planning process
- Ensure adequate scope definition prior to moving forward with design and construction; use front end planning tools
- Define existing conditions thoroughly
- Select the proper contracting strategy early
- Align the project team, including key stakeholders
- Build the project team, including owner stakeholders and consultants
- Include involvement from both owners and contractors
- Staff critical project scoping and design areas with capable and experienced personnel
- Identify and understand risks of new project types
- Address labor force skill and availability early in planning because this issue can effect project success
- Provide leadership at all levels for the front end planning process, including executive and project, owner, and contractor

4.1.5.2. Adding Value through Front End Planning (2012)

The second objective of CII Research Team 268 (beyond developing PDRI-Infrastructure tool) was to study how organizations have utilized the CII front end planning tools since the time of the 2006 study. The team was also tasked with updating the front end planning toolkit, and developing an overarching front end planning publication titled " Adding Value Through Front End Planning" that pulled together the 20 years of front end planning research completed by CII.

The team found that front end planning products sold by CII had been downloaded 39,585 times between the years of 1985 to 2011 (Bosfield and Gibson 2012). The team also surveyed the 116 CII member organizations to determine specifically what tools were CII members currently using. Fifty-nine responses were received to their survey, and the team completed 15 in-depth follow-up interviews. The team found that (Bosfield and Gibson 2012):

- Seventy-eight percent of respondents used at least one CII front end planning tool, mainly the PDRI-Industrial
- The overall usage of front end planning tools was higher for owners than contractors.
- Forty-two percent of respondents stated that the PDRI was included in their organization's budgetary approval process
- Ninety percent of respondents felt that the PDRI tools had a positive impact in their planning process effectiveness
- The PDRI tools were mainly used on medium to large projects, but sometimes for small projects.

- The most prevalent reason cited by respondents for not using CII front end planning tools included not being familiar with the tools, or using different tools. One respondent stated (regarding the difficulty of tool usage): "We do small projects, $1 million to $50 million and the PDRIs are too complex. When we get time we're going to simplify the PDRI Industrial for our use."

4.2. Small Project Research

Research Team 314 felt it imperative to review previous research studies into small projects to ensure the PDRI-Small Industrial tool addressed and conformed with any significant research findings in the area. The next sub-sections describe handbooks, manuals, and research studies that provided the research team background into the various definitions of "small project," as well as small project characteristics, suggestions for effective management, and success factors for small projects.

4.2.1. Managing the Engineering and Construction of Small Projects (1985)

The *Managing the Engineering and Construction of Small Projects* handbook was developed for the purpose of providing a practical management method for project engineers tasked with managing small industrial projects, but not experienced with project management. Small projects can include maintenance, upgrading, revamps, turnarounds and outages, research, engineering, plant improvements, light construction, or environmental work, and can be capital or non-capital expensed projects. Westney (1985) defines small projects as having one or more of the following characteristics:

- Cost levels from $5,000 to $50,000,000
- Cost levels less than 5 percent of annual budget for projects

- Numerous other similar projects take place concurrently
- Labor and equipment resources shared with other projects
- The company doing the project is, itself, small

Westney (1985) states that small projects can be just as important as large projects, and sometimes even more important. The value of successfully competing a small project can be far greater than the project itself, an example being a turnaround project being completed on an essential manufacturing process. The plant's profitability can be significantly reduced if the project takes too long, causing valuable production to be lost. Westney (1985) also states that the total cost of small projects is not small at all; the aggregate cost of all small projects in a facility may be substantial.

Westney (1985) asserts that one of the most difficult aspects of managing small projects is dealing with multiple projects at once, which is typically not an issue with large projects. The projects will also all be at various stages (i.e., design and procurement, under construction, start-up) of completion, causing project engineers to constantly change their priorities. Other typical issues with small projects include (Westney 1985):

- Many small projects occur in an active production environment
- Organizations are not designed for projects (i.e., project being managed by production engineers not project managers). Management lacks formal procedures, methods, and data to properly plan, estimate, and manage projects
- Standard approaches used for large projects don't work for small projects.
- Many small projects are revamps within active production facilities, which imposes many constraints such as restricted access to project sites, hot work

permits, construction personnel working around production personnel, (where production takes priority over construction), unpredictable nature of plant operations causes frequent changes to scheduled work site access, and access to knowledgeable plant personnel.

- Projects in manufacturing plants often experience significant increases to the scope of work due to specific scope items not being apparent until work has progressed to a certain point.

4.2.2. Manual for ~~Small~~ Special Project Management (1991)

The CII Small Projects Action Team was tasked with developing a comprehensive manual for managing small projects that was based on adapting generally accepted management techniques developed for large projects to small projects. The action team focused on small projects in four categories: engineering only, construction only, Engineer-Procure-Construct (EPC), and revamp (a term encompassing rebuild, retrofit, shutdown, add-on, and upgrade, but not maintenance).

The team found many problems and characteristics typical of small projects, including (CII 1991):

- The word “small” – dictionary definition is little, puny, meager, insignificant, unimportant. Using the word small may cause such projects to be seen as unimportant, hence undeserving of traditional management attention.
- Inexperienced Management – least experienced project managers used for small projects. The best management personnel are saved for large projects

- Combined Operating/Construction Responsibilities – operations or maintenance personnel tasked with managing small projects, even though they are seldom adequately prepared to do so
- Multiple Project Responsibilities – Project managers have simultaneous responsibility for multiple projects, taxing the manager's ability to give each project its due attention
- Multiple Individual Responsibilities – individuals assigned small projects are responsible for multiple functions. There is less attention paid to comprehensive look-ahead planning as the "squeaky wheel gets the grease."
- Safety and Quality Easily Compromised – Adequate attention not given to safety and quality due to lack of time and dedicated functional staff
- Short Duration – The typical short project duration provides insufficient time for detailed planning and in-process correction of problems. Personnel are still climbing the learning curve when the project is completed.
- Poor Career Attractiveness – Individuals tend to seek the stability of large projects as opposed to small projects, which are seen as having low visibility, questionable job security, involving frequent movement, and being non-career enhancing.
- Lost Expertise – Many experienced engineers and constructors that have traditionally served as mentors to younger personnel have left the workforce due to economic conditions, creating a lost generation of valuable experience
- High Loss Potential – Economic risks vs. project value (and profit) are much higher proportionately on small projects than large projects

- Poor Scope Definition – Poor scope definition effects both small and large projects, but can be devastating to small projects due to limited response time available for scope changes
- Poor Basis for Control – Limited availability of project managers and limited time leads to lack of established baselines for project control
- Inapplicability of Company Standard Control Systems – Robust control systems design for large projects may be overwhelming to small projects if not simplified and adapted
- Contractor Competence – Contractors accustomed to large projects tend to avoid small projects. If they do undertake them, they tend to overkill them. Some small contractors are excellent, while others lack the necessary skills and resources.
- Lack of Computer Literacy – Small contractors sometimes lack experience with or appreciation of the potential for computerization or automation of project management functions
- Regulatory Requirements Applicability – Safety, health, environmental, and government regulations apply with equal force to large and small projects
- Subcontracting vs. Direct Hire – Subcontractors may be necessary to obtain desired skills, but the project schedule may be extended due to the time needed to select an appropriate subcontractor, and addressing any scope changes. The use of direct-hires involves problems with timely recruitment of properly skilled personnel.

- Remote Location – Problems of remoteness: logistics, personnel availability, communication, are more challenging for small projects than large projects due to the limited number of project management staff

The team developed a detailed manual for addressing the typical problems and characteristics related to managing small projects, with nine focus areas including organizational structure and guidelines, planning, in-process management, revamp projects, contracts and contract administration, project controls, total quality management, safety and health, and environmental protection. Each focus area in the manual includes a description of the issue, and ways that organizations can plan, structure, and manage small projects to address the issue. The team also chose to refer to "small" projects as "special" projects in an attempt to remove the negative stigma associated with the project type.

One of team's the most significant findings was that due to the wide variations in relative size, complexity, schedule duration and cost of projects executed by an even less homogeneous cross section of owners, architects, engineers and constructors, it was impossible to clearly define "small project." The team asserted, "If the project is felt to be small relative to the culture and available resources within an executing entity, then it is indeed a small project. " The team suggested that one possible method for differentiating between small and large projects might be to list the typical characteristics of large projects, and if a project lacks several of these characteristics, then it would be considered small. The characteristics commonly associated with large projects were identified as (CII 1991):

- Has full-time staff

- Staff large enough to have functional specialists
- Company standard procedures are applicable (i.e., small project may need their own)
- Standard company control systems and reporting procedures are used (i.e., small projects may need their own)
- Duration is long enough to permit personnel to progress comfortably up the learning curve and to have time to adjust to in-process problems and mistakes
- Receives considerable management attention
- Takes a significant percentage of company resources or capabilities

The team ultimately concluded that the boundary between large and small projects could not be strictly defined, after much debate amongst the team members. The team chose to instead provide (in an appendix to the manual) a listing of possible small project parameters, including:

- Length of project: 1-15 months engineering only, 1-14 months for construction only, 2-30 months for EPC
- Personnel hours: 200-65,000 work hours for engineering only, 2,500 – 500,000 for construction only, 1,500 – 750,000 for EPC
- Cost: less than 5 percent of an organizations annual construction budget, cost under $50,000,000, $2,000 - $3,500,000 for engineering, $100,000 - $25,000,000 for construction only, $100,000 - $100,000,000 for EPC
- Management Approach: part-time management
- Controls Involved: simpler controls than large projects due to compressed time and multiple responsibilities of the management team

- Other: one or a few design disciplines, very few crafts, project execution completely within the control of an operating plant manager, ratio of engineering to construction higher than normal, ratio of manual to non-manual personnel costs in the construction phase higher than normal

4.2.3. Developing an Effective Approach to the Procurement and Management of Small Building Works within Large Client Organizations (1995)

Griffith and Headley (1995) summarized a major research study into the procurement and management of small building "works" (i.e., projects) within large owner-organizations in the United Kingdom. Griffith and Headley (1995) found that little previous research had been undertaken regarding small projects, and that the level of commitment needed to undertake small projects successfully is underestimated in many organizations. Griffith and Headley (1995) asserted that small projects require thorough and dedicated procurement, organization, and management if they are to be efficient and cost effective and that the specific tools, techniques, and procedures required must be appropriate to the nature and scale of projects.

Data from interviews and case studies highlighted two common problems the exist in small project procurement and management: the failure to recognize the fundamental characteristics of small projects and how these influence procurement and management approach, and from the misconceptions regarding the significance, composition, and value of small project loading within organizations (Griffith and Headley 1995). The study also found that small projects are not managed as efficiently and effectively as they might be, and that no recognized procedure or practice existed for the management of small projects. Ineffective management of small projects was found to be due to project managers becoming organizationally consumed in reacting to events, the need to authorize each and every job and inevitably lack sufficient time to manage the organizational small projects workload and each individual job in the sense that modern management techniques are applied to other processes in different industries.

Griffith and Headley (1995) defined small projects as featuring certain characteristics that make them discernable from other types of building projects, including:

- Limited cost
- Low complexity
- Short duration
- Limited inputs (materials and labor)
- Harbor practical and financial uncertainty due to lack of scope definition
- Utilize limited formal documentation
- Diverse in basic characteristics (size, value, complexity)
- Occur in active environments

Griffith and Headley asserted that these categorizations are oftentimes arbitrary, typically done with a level of cost as the differentiator. They contended that using a level of cost or type of work alone to different between project classes is insufficient and that projects should be looked at holistically through an appreciation of their particular characteristics within the core business and operation of the client organization. Griffith and Headley also asserted that small works fall along a spectrum that takes in to consideration their characteristics and classes, as shown in Figure 4-11.

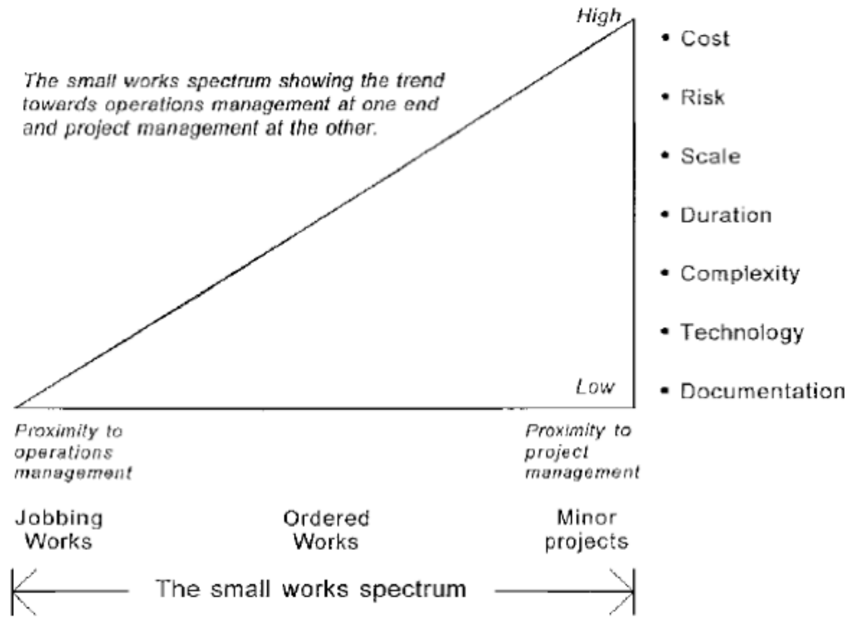


Figure 4-11. Small Works Spectrum (Taken from Griffith and Headley 1998)

4.2.4. Small Projects Toolkit (2001)

The CII Executing Small Capital Projects research team (RT 161) developed the Small Projects Toolkit in 2001 to assist project managers in improving small project programs and small project execution. The team asserted that small project execution is important due to 40-50 percent of capital budgets being spent on small projects for the purpose of increasing production capacities, improving product quality, improving efficiencies, and maintaining functionality of a plant for continued operation and production (CII 2001). The team defined small projects at projects having a total installed cost range between $100,000 and $2,000,000 (CII 2001).

The toolkit outlines small project best practices in the areas of front end planning, design, procurement, construction, start-up and commissioning, people, small projects organizations, processes, small projects controls, contracting, safety, health and environment, and technology and information systems. Regarding front end planning, the research team found that the planning of small projects must be completed in an environment with a compressed timeframe, few dedicated project resources, and a variable funding process. Having an owner representative/leader with profound knowledge of a facility and plant personnel to facilitate scope definition and plant input and approval, a clear, succinct, detailed identification of project scope prior to funding to avoid continued design improvements to the end, and funding processes that are clear, dependable, and make sense are the front end planning issues that can have the strongest impact on small project success. The team suggested several best practices for small project design and management, including (CII 2001b):

- Standardization of equipment and designs
- Larger project contingencies
- Project checklists
- Small project program team, providing consistency and continual improvement from quarter to quarter
- Separate funding for front end planning of small projects
- Dependable project funding
- Modified PDRI, even though the tools were not specifically design for small projects where many of the elements may be not applicable

4.2.5. Budget and Schedule Success for Small Capital-Facility Projects (2002)

Gao et al. (2002) provides the results of a literature review and industry survey (completed by 36 respondents) to determine what constitutes success on small projects, specifically if there was a difference between success factors for large and small projects.

Small projects used in the survey were "theoretically limited" to those projects not less than $100,000, and no more than $2,000,000. Gao et al. (2002) found that the most frequently noted project success factors (from both the literature and survey) were cost, schedule, technical performance, client satisfaction, and that these factors did not differ between small and large projects. Gao et al. (2002) highlighted several attributes of small projects and small project execution within project organizations, including:

- The significance of front end planning for small projects should not be underestimated. Scope changes, schedule slippage, delayed work, communication issues, and shifting priorities were the most frequently noted by survey respondents regarding problems encountered on small projects. Enhanced project scope definition can best address these issues. The front end planning process in many organizations was not well defined.
- When large project processes are imposed on small project programs, they may likely contribute to bureaucratic inefficiency in the small project delivery system. Those attempting to use large project procedures on small projects had less project success.
- Small projects consisted of 16% of total capital project budgets for survey respondents, but were 80% of the work volume (based on the number of projects)
- Firms with capital budgets below $20 million, or had a ratio of small to large projects at or above 20 percent, were classified as having a small project focus. Firms with a small project focus had more projects complete five percent below budget, and completed on or before the target date

- Contractors with binding agreements to provide maintenance work in addition to small capital project work were able to maintain a consistent workforce, the primary advantage being better budget performance. However, maintenance work must be concurrently scheduled with small projects, possibly producing more delays for project sites where maintenance and capital projects are performed at the same time.
- The projects that used a core management group for small capital facility projects showed a benefit in schedule performance due to improved communication processes and reduced potential for conflicts.

4.2.6. Is a Small Project Really Different? (2005)

Liang et al. (2005) sought to outline the differences between the project performance of small and large projects. Small projects were defined as projects having:

- Total installed cost between $100,000 and $5,000,000
- Duration of 14 months or less
- Site work hours up to 100,000
- Project does not require full-time project management resources or significant percentage of company resources
- Any level of complexity and nature including maintenance and expense projects

Project data was collected from CII member organizations through the development and administration of a multi-part electronic questionnaire, and selected projects taken from the CII Benchmarking and Metrics database. The portion of the questionnaire described in Liang et al. (2005) dealt only with project performance differences between small and large projects. Small projects were found (through statistical analysis) to have more variable cost, schedule, and change order performance (from the owner and contractors perspectives) than large projects based on an analysis of 356 projects.

4.4. Literature Review Findings

The primary focus of the CII front end planning tools to date has been to improve project performance on large, complex projects. This point is highlighted in Table 4-2, showing the average cost of projects utilized for the testing phase of the PDRI for Industrial, Building, and Infrastructure. Several of the small project research studies noted that procedures or processes designed for large projects scenarios are typically not effective for use on small projects, as they are too cumbersome to be effective. Several studies also noted the importance of front end planning for small projects; that it should not be underestimated, and that in many organizations the process is not well defined. All of these factors confirmed for Research Team 314 the need to develop a front end planning tool specifically for small industrial projects.

Table 4-2. Average Cost of Projects Used in PDRI Testing

	Number of Projects Collected	Total Expenditure (Approximate)	Average Project Cost
PDRI for Industrial Projects	40	$3,300,000,000	$82,500,000
PDRI for Building Projects	33	$889,500,000	$26,954,545
PDRI for Infrastructure Projects	22	$6,080,000,000	$276,363,636

The review of small project-related literature highlighted for the research team that a consistent definition of “small project” did not exist, as shown in Table 4-3. This lack of definition suggested that the research team would need to develop a definition of small project for the purpose of guiding industrial PDRI users to the appropriate tool. The small project literature did highlight several common attributes to be considered for successfully completing small projects that should be incorporated into a front end planning tool for small projects, such as having project management with the appropriate level of expertise (i.e., experienced managers, not new-hires in training), realizing that many small projects are R&R and/or completed as part of a larger program of projects, and completed in active environments, and that the aggregate importance of small projects should not be underestimated; the criticality of small projects oftentimes outweigh their cost.

Table 4-3. Small Project Definitions from Literature

References	Cost	Duration	Other
Westney (1985)	\$5,000 to \$50 million	N/A	Numerous other projects taking place concurrently, labor and equipment resources shared with other projects
CII (1991)	\$2,000-\$3.5 million for engineering only, \$100,000-\$25 million for construction only, \$100,000-\$100 million for EPC	1-15 months small engineering-only projects, 1-14 months for construction only, 2-30 months for EPC	Personnel hours - 200-65,000 for engineering only, 2,500-500,000 for construction only, 1,500-750,000 for EPC, part-time management, simpler project controls
Griffith and Headley (1995)	Limited cost	1-3 months	Low complexity, limited inputs, limited formal documentation, occur in active environments
Liang *et al.* (2005)	Total installed cost between \$100,000 and \$5 million	14 months or less	Site work hours up to 100,000, part-time project management, any level of complexity

4.5. Summary

The literature review provided the theoretical baseline concerning previous research investigations into front end planning and small projects that was utilized by Research Team 314 to develop the PDRI-Small Industrial, and the Industrial PDRI Selection Guide. The literature review highlighted that the front end planning research focus by CII over the past 25 years has consistently provided construction project stakeholders with tools to improve project performance. This has been accomplished through the development of PDRI tools for industrial, building, and infrastructure projects, as well as complementary tools for R&R projects, shutdown/turnaround/outage projects, project team alignment, integrated project risk assessment, information flow into front end planning, and construction input during front end planning. The literature also showed that the preceding PDRI tools were developed for large projects, and that tools developed for large projects are typically not effective for use on small projects.

CHAPTER 5. SMALL PROJECT PREVELANCE, PLANNING PRACTICES, AND DIFFERENTIATORS IN THE INDUSTRIAL CONSTRUCTION SECTOR

The author concluded that a sufficient and consistent definition of what differentiates a small project from a large project did not exist, based on a thorough literature review as discussed in Chapter 4. The author determined that additional information should be sought from industry to clarify the current metrics utilized to differentiate between small and large industrial projects, as well as the prevalence of small projects, and typical front end planning practices employed for small projects. The author, with input from the research team, developed a survey using previous small project research to poll industry members familiar with industrial projects. The next few sections describe the survey methodology, structure, response, and results.

5.1. Survey Development Methodology and Structure

The author developed a multi-part survey of 25 open-ended and closed-ended questions to collect information on small project prevalence, planning practices, and metrics used in industry to differentiate between small and large industrial projects. The survey instrument was developed and administered with the CII *Select Survey* system, a proprietary online survey tool owned by CII.

The survey included two questions regarding the prevalence of small industrial projects. The first question asked, “On a cost basis, what percentage of your organization’s yearly capital construction budget would be considered small projects?” The second question asked, “On a count basis, what percentage of your organization’s yearly capital construction budget would be considered small projects?” Each question included six possible response ranges, including < 10 percent, 11-30 percent, 31-50 percent, 51-70 percent, 71-90 percent, and > 90 percent, and the respondents were asked to choose one response range for each question. The survey did not included a definition for “small project”. Survey respondents were to answer the questions based on their organization’s definition.

The survey included four questions regarding front end planning practices for small industrial projects. The first question asked, “What is your organization’s front end planning process for projects that meet your definition of a small project?” Eight possible front end planning processes were posed, including: (1) front end planning happens only at the program/portfolio level, (2) dedicated task force for all small projects, (3) internally developed scope definition tools, (4) structured stage gate, (5) ad hoc, (6) standardized scope package deliverables for all small projects, (7) other, and (8) none. Respondents were asked to select all that applied to their organization.

Three questions asked specifically about the respondents familiarity with the PDRI tools, and if these tools were used during the front end planning of small projects. The first question asked, “How often has your organization used the Project Definition Rating Index (PDRI) tool in the past?” Four separate options were given, including on a few selected projects, on most projects, on all projects, and never, and the survey instructed respondents to choose one of the four. The second question asked, “Does your organization use the Project Definition Rating Index (PDRI) for projects that meet your definition of a small project?” The third question asked, “Has your organization developed a modified PDRI or other tool for projects that meet your definition of a small project?” Respondents were asked to choose “yes” or “no” to the second and third questions. If the respondent chose no to the third question, they were prompted to describe the modified PDRI or other tool used in their organization.

The research team chose 14 separate metrics taken from the literature review that they felt to be possible differentiators between small and large industrial projects. The research team gave each metric a set of associated “break points” for small and large projects, some of which were numerical (i.e., above or below US $10 Million of total installed cost), while others were scaled (i.e., minimal special or new expertise vs. extensive special or new expertise). The break points were based on the literature review, as well as the experience of the research team members. Table 5-1 shows the 14 metrics and associated break points. The author, in conjunction with the research team, developed separate, multi-part questions for each of the 14 metrics asking if (1) the metrics were used (within the respondents organization) as a differentiator between small and large industrial projects, and (2) if the metric was used as a differentiator, was the associated break point correct. Each part of the questions could be answered “yes” or “no”. If the respondent answered yes to the first portion of the question regarding the metric itself, but no to the second portion of the questing regarding the break points, they were prompted to provide the break point that was used in their organization. Each of the questions provided the respondents with the option to provide any additional comments that they may have regarding the metric or break points posed.

Table 5-1. Project Size Differentiators Posed in Survey

Metric	Small Projects	Large Projects
Total Installed Cost	< $10 Million	> $10 Million
Regulatory/Environmental	Minimal permitting required	Extensive permitting required
Construction Duration	< 6 Months	> 6 Months
Engineering Effort	< 5000 Hours	> 5000 Hours
Risk to Reputation	Minimal	Significant
Impact to Operations	Minimal	Significant
Visibility to Owner Management	Local/Department	Organization/Corporate
Team Expertise	Minimal special or new expertise required	Extensive special or new expertise required
Team Resources Availability	Mix of full or part-time	Dedicated full-time
Core Team Resources Numbers	1-5 individuals/firms	> 5 individuals/firms
Core Team Makeup (Engineering and Craft)	1-2 disciplines/crafts	> 2 disciplines/crafts
Experience with Project Characteristics	Repetitive or some new aspects - technology, processes	Extensive new aspects - technology, processes
Stakeholders Impacted	Internal	External
Funding Decisions	Plant/local	Corporate

Two open-ended questions were posed at the end of the survey, asking “If you could improve the PDRI to make it more applicable to projects that meet your definition of small project, what would you include or exclude?” and “Please add any additional comments you have about improving planning for small projects as compared to large projects.” The survey also provided for the respondent an option to provide their name and organizational affiliation.

5.2. Survey Respondent Solicitation

The research team determined that surveying individuals from CII member organizations could provide substantial insight into the prevalence of and planning practices for small industrial projects, as CII member organizations cover a vast cross-section of the industrial sector. CII provided the research team with contact information for approximately 170 practitioners from their member database that had agreed to provide data for ongoing research projects, namely the "CII Data Liaisons." The author sent an email to each of the CII data liaisons with a brief description of the study and a solicitation to complete the survey through a provided website link. The 20 industry members of Research Team 314 were also asked to complete the survey. Each individual was asked to pass along the solicitation to any other practitioner that they felt might be interested in providing data regarding the prevalence and planning practices of small industrial projects.

5.3. Survey Responses and Analysis

The survey was open for a two-month period between November 2013 and January 2014. In total, 90 responses (out of the 190 individuals contacted) to the survey were received, approximately a 47 percent response rate. Individuals from 35 separate organizations completed the survey, a listing of which is included in Appendix A. Figure 5-1 provides a breakdown of the organizational types between survey respondents. As shown, a majority of the respondents were from owner organizations. Those listing "Other" included engineer-procure-construct (EPC) organizations, as well as operations, government, and an automation product supplier.

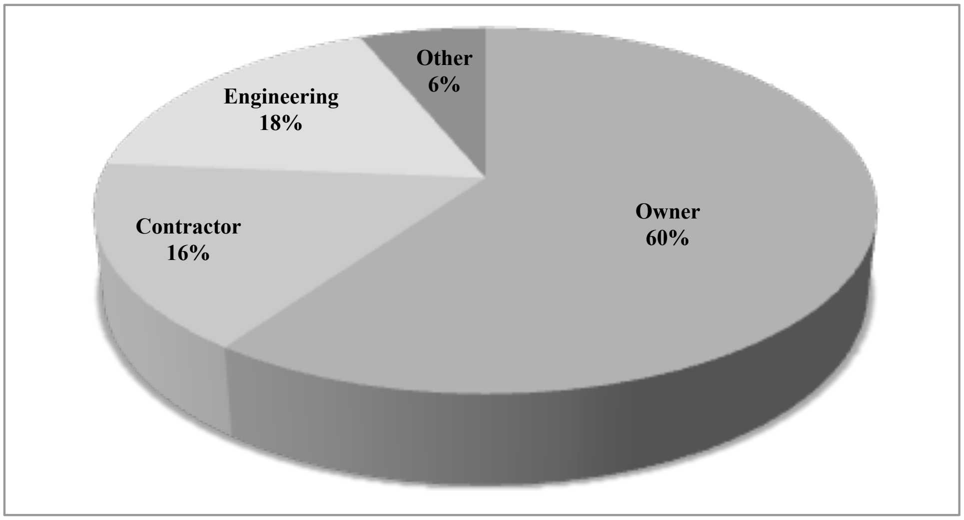


Figure 5-1. Survey Respondent Organizational Affiliations

5.3.1. Prevalence of Small Industrial Projects

Figure 5-2 provides a summary of the responses regarding the prevalence of small projects within the survey respondent's organizations during the fiscal year prior to survey being completed. A majority of respondents estimated that 11-30 percent of project completed during the preceding fiscal year met their definition of small project on a cost basis, and 71-90 percent on a count basis.

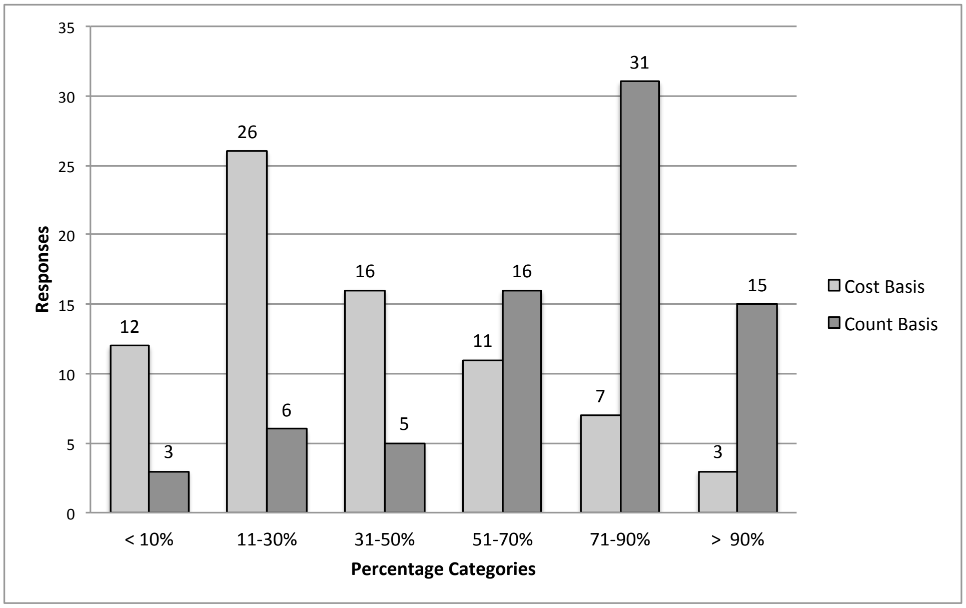


Figure 5-2. Prevalence of Small Projects within Survey Respondent Organizations

5.3.2. Front End Planning Processes for Small Projects

Figure 5-3 provides a summary of the responses regarding the typical front end planning processes used for small projects. Responses ranged across all eight possible processes, with "structured stage gate" and "internally developed scope definition tool" being the most prevalent, and receiving a nearly equal number of responses. "Other" front end planning processes includes responses such as "All of the above can apply depending on specific scope and complexity"; "Some of these processes are used in some instances but not for all small projects"; and "For small projects, different business units have their own procedures that may or may not be consistent across all other areas."

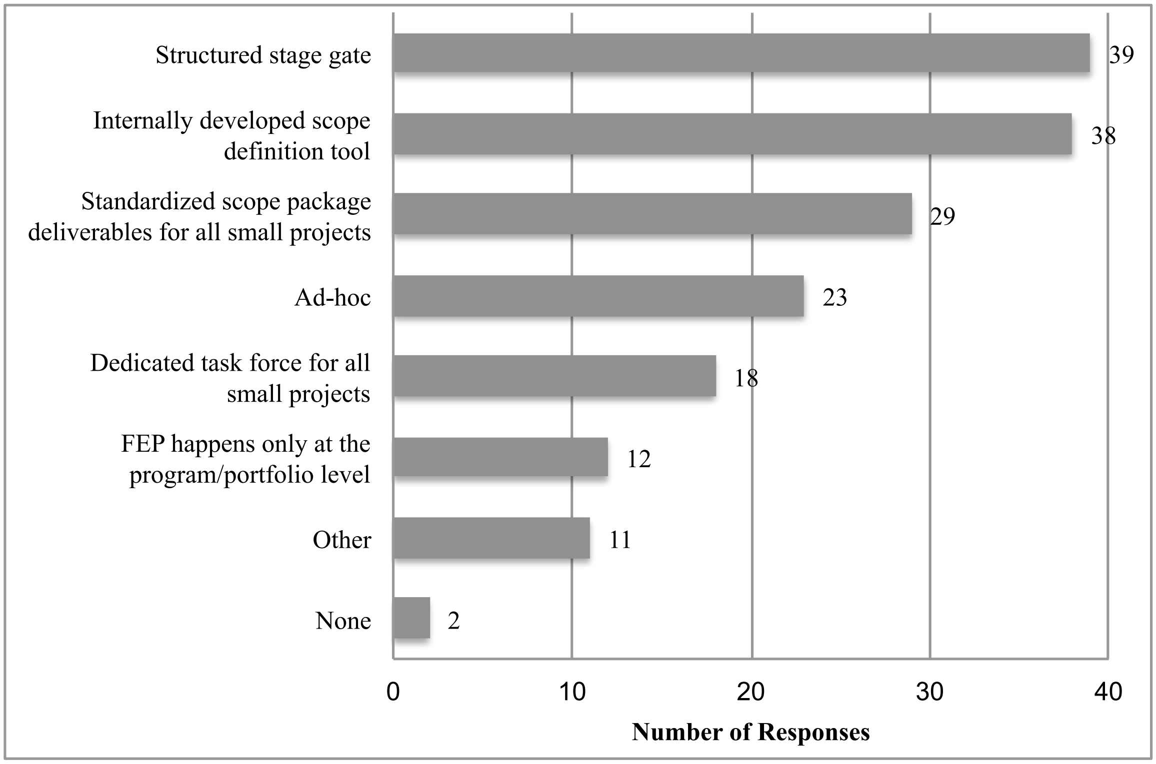


Figure 5-2. Front End Planning Processes for Small Projects within Survey Respondent Organizations

Figures 5-3 and 5-4 provide a summary of the responses regarding PDRI familiarity and usage on small projects. A majority of respondents stated that they had used the PDRI on only a few selected projects, as shown in Figure 5-3, and the PDRI tools had mostly not been used (or modified for use) for small projects, as shown in Figure 5-4.

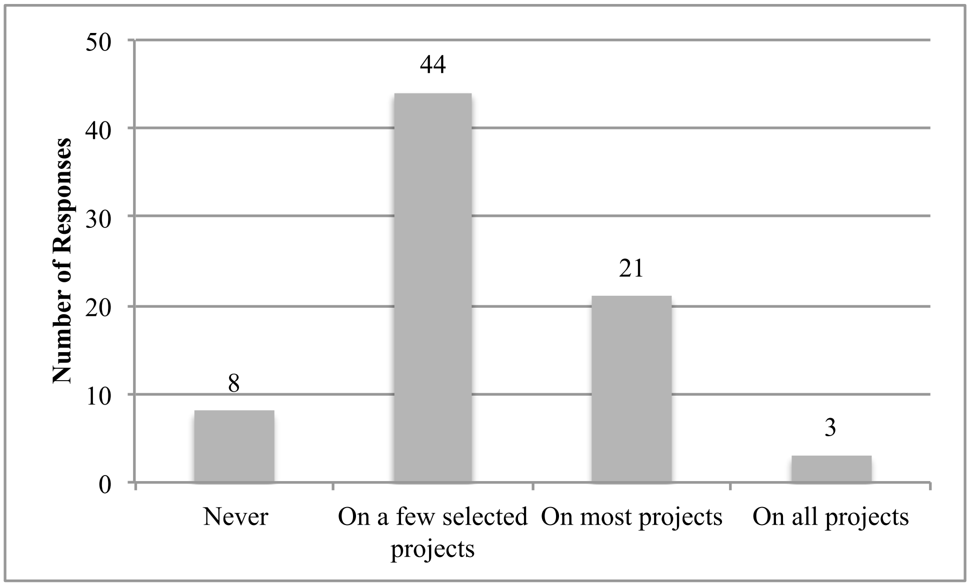


Figure 5-3. Usage of the PDRI Within Survey Respondent Organizations

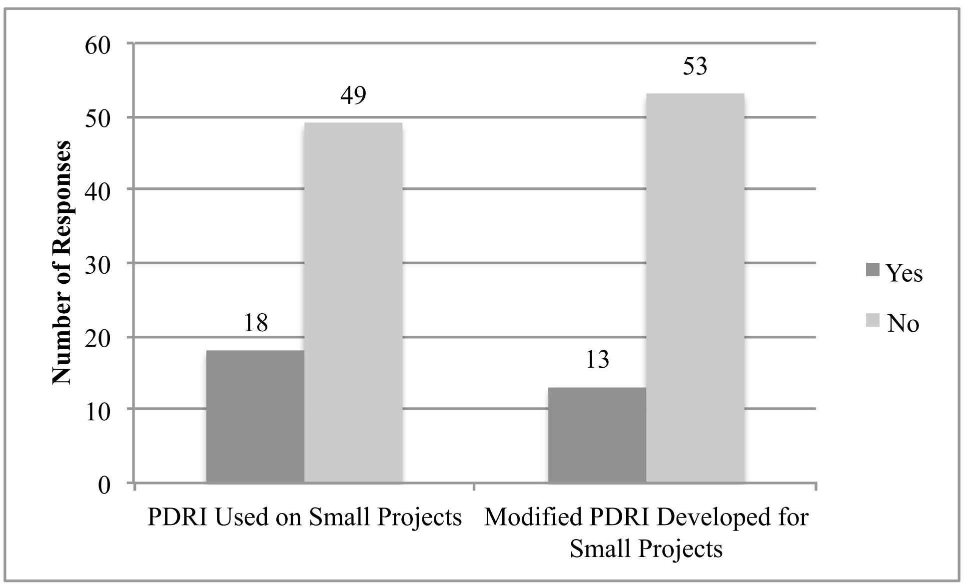


Figure 5-4. Usage and Modification of the PDRI for Small Projects within Survey Respondent Organizations

5.3.3. Small Project vs. Large Project Differentiators

Figure 5-5 summarizes the survey responses regarding adequacy of the fourteen separate metrics posed as possible differentiators between small and large projects, listed in the rank-order of their associated yes and no responses. Respondents only clearly agreed (i.e., responded “yes”) that three of the metrics posed were used in their organizations to differentiate between small and large projects: total installed cost, construction duration, and funding decisions. Five of the metrics had total agree/disagree (i.e., yes and no) responses that were very close and could be considered possible differentiators: engineering effort, expertise with project characteristics, impact to operations, team resources availability, and core team resources numbers. Respondents clearly disagreed (i.e., responded “no”) with six of the metrics, including: visibility to owner management, risk to reputation, core team makeup (engineering and craft), stakeholders impacted, regulatory/environmental permitting, and team expertise. Respondents disagreed with the numerical break points of all five metrics to which these were pertinent; total installed cost, construction duration, engineering effort, core team resources numbers, and core team makeup (engineering and craft).

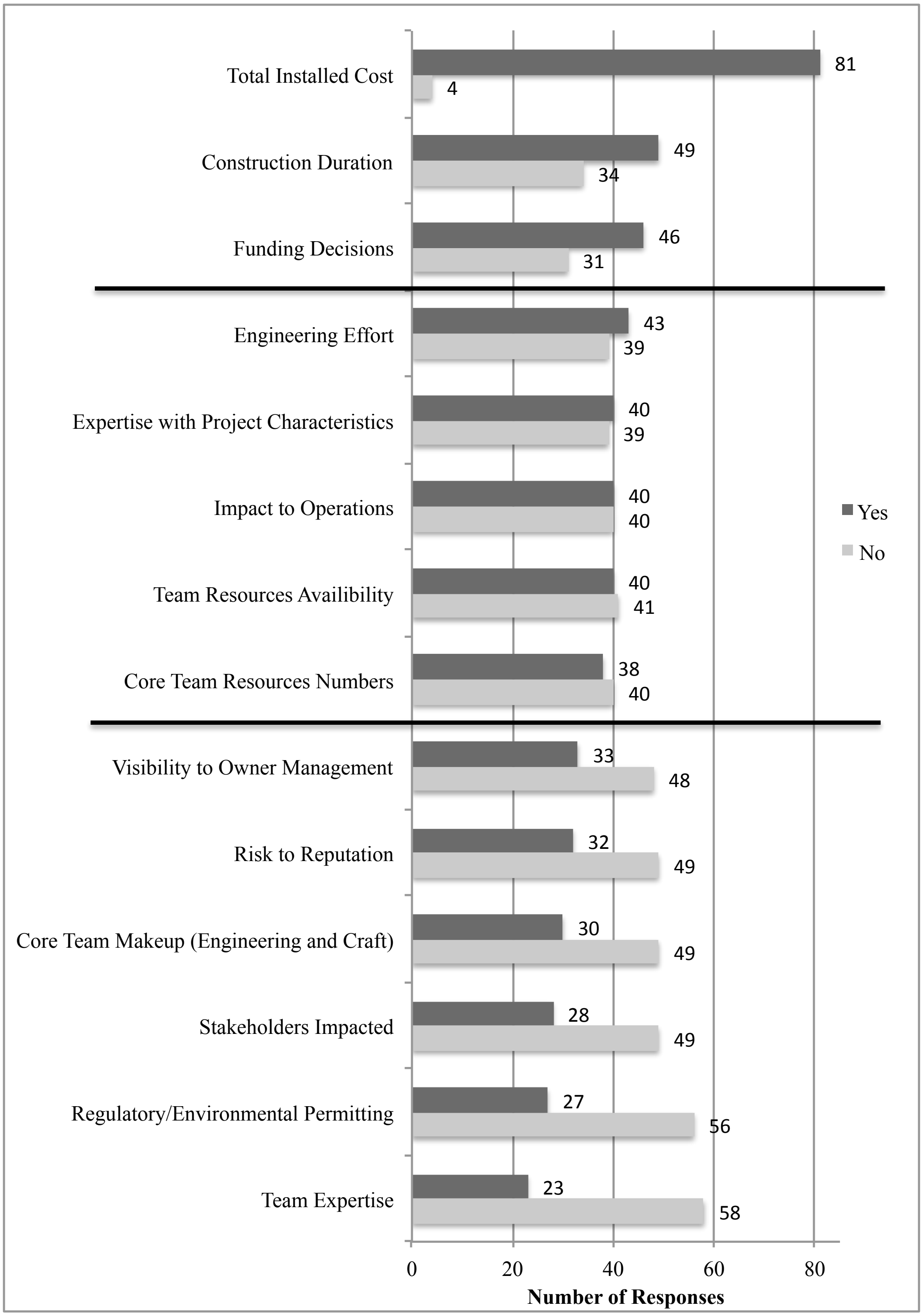


Figure 5-4. Survey Responses Regarding Project Size Differentiation Metrics

5.3.4. Discussion of Survey Results and Comments from Respondents

The responses shown in Figure 5-2 matched the assumptions of the author prior to the survey, as well as the results found in Gao et al. (2002), that the number of small projects completed in many organizations is substantial, but do not make up a large percentage of the total capital expenditure. The amount of expenditure is still considerable though, with a majority of the respondents estimating that 11-30 percent or 31-50 percent of their capital expenditure is spent on small projects.

Total installed cost was the metric most agreed upon by the survey respondents, as shown in Figure 5-4. This finding aligns with previous research, as well as the opinions of the research team, that cost alone is the most common differentiator in most organizations as to what is considered a small vs. a large project. The comments provided by those respondents that disagreed with the $10 million break point highlighted the vast difference across the industry regarding what is considered a “small project.” Suggested break points ranged from $200,000 to $250 million, with the most common answer being $5 million dollars. These responses show that with such a large discrepancy across the industry, solely defining a specific dollar amount as a differentiator would not be valid. Responses regarding construction duration followed a similar logic to total installed cost. A majority of respondents agreed that this could be used to differentiate between small and large projects, but most disagreed that 6-months was an appropriate break point. Suggested break points ranged from 1-18 months, with the most common answer being 12 months. The break point for project funding decisions for small projects being plant/local as opposed to corporate was agreed upon by the respondents, with several comments essentially stating that as projected project costs increases, so does the level of funding approval.

Comments regarding the metrics that had agree/disagree responses very close to being equal, i.e., those listed as being possible differentiators, provided insight that project complexity should be considered when planning for a small project. For example, the impact to operations metric (minimal vs. significant) received an equal number of agree/disagree responses. Some of the respondent comments included "While not a direct metric that we would use to classify a project, this metric would definitely be an indication of level of complexity, planning and coordination that would be required for project execution", and "Some small dollar-amount projects have a high impact on the operation, so they should receive more scrutiny than just a dollar amount would indicate." These comments were echoed in commentary received regarding the experience with project characteristics metric, "We may have a small project in overall cost and resource requirements that could include the implementation of a new technology. This metric would be an indication of project complexity and how we would staff the project." Respondent commentary also highlighted the fact that some of the metrics and breakpoints listed may actually be consequences of a project being small as opposed to a differentiator between small and large projects, such as project visibility to owner management. It was suggested that, consequentially, a project might not be visible to the upper levels of management because it is small, as opposed to considering a project as being small because it has no visibility to upper management.

A majority of the survey respondents disagreed that regulatory/environmental permitting along with risk to reputation, team expertise, core team makeup and stakeholders impacted differentiated small projects from large projects. Respondent commentary illustrated that those metrics transcend project size, with remarks such as "With social media, any project can create risk to reputation regardless of project size." Respondents also suggested that items such as permitting and team expertise could be just as significant, if not more so, on small projects than on large projects depending on the scope of work.

The survey respondents provided several general comments regarding suggestions for developing a PDRI specifically for small projects, including "Shorten the number of elements and provide clear direction in what stage(s) of a project the small project PDRI is to be used", "I think the amount of time it takes to complete is the most important thing to consider", and "The application of the PDRI would have to be much less granular than that which we have used on larger projects."

5.4. Summary

The author, in conjunction with the research team, surveyed 90 individuals from CII member organizations to discern the current metrics utilized to differentiate between small and large industrial projects, as well as the prevalence of small projects, and typical front end planning practices employed for small projects. The survey results showed that small projects make up a majority of projects completed in the industrial sector, planning of these projects varies greatly across the industry, and based on industry perceptions, the metrics posed were mostly not thought to be appropriate for use in differentiating between small and large projects. Survey respondent commentary also suggested that a PDRI tool specifically for small projects should be less granular than the PDRI tools used for large projects, and such a tool should require less time to assess a project's scope definition.

Table 5-2 provides the definition for "small industrial project" gleaned from the survey responses. The numerical values for total installed cost, construction duration, engineering effort, and core team resources numbers represent a weighted average of the survey responses. The author utilized the definition provided in Table 5-2 to help weighting workshop volunteer's select appropriate projects for use, described further in the next chapter.

Table 5-2. Small Industrial Project Definition From Survey Responses

Total Installed Cost	Less than $10 Million
Construction Duration	Less than 7 months
Funding Decisions	Typically plant/local approvals as opposed to corporate
Engineering Effort	Less than 15,000 man-hours
Expertise with Project Characteristics	Depends on project complexity/level of rigor along with experience
Impact to Operations	Project dependent, can range from minimal to significant
Team Resources Availability	Organization dependent, mix of full/part-time to dedicated full-time
Core Team Resources Numbers	Less than 12 individuals/firms
Visibility to Owner Management	Project dependent, depends on physical location, scope of the project, potential for adverse consequences

The author determined that all of the metrics considered in the survey might be more suitably thought of as *indicators* of the level of project complexity, as opposed to *differentiators* between small and large projects, based on the comments provided by the survey respondents. Chapter 9 describes additional research completed by the author concerning a method for indicating levels of complexity on industrial projects, and a tool developed to guide PDRI users to the appropriate tool for use on an industrial project based on levels of project complexity.

CHAPTER 6. PDRI DEVELOPMENT PROCESS

This chapter details the steps involved in developing the PDRI-Small Industrial. Specifically, the chapter outlines the results of data obtained during weighting workshops, and how input obtained from these workshops was used to develop the final PDRI element descriptions and weights. This chapter includes description of workshop facilitation, participant demographics, and data screening techniques, along with findings from the analyses of the finalized PDRI, and instructions on “how to use” the PDRI-Small Industrial.

6.1. Background of the PDRI for Small Industrial Projects

The thorough analysis of planning tasks recommended for industrial projects completed by CII Research Team 113 led to the development of the PDRI-Industrial in 1995. The tool has successfully been used to assess the level of scope definition on hundreds of industrial construction projects across the globe since its initial publication. Research Team 314 felt it prudent to use this document as the baseline for developing the PDRI-Small Industrial element descriptions.

The team was initially broken down into three sub-teams, each separately focusing on one of the three PDRI sections (Basis of Decision, Basis of Design, Execution Approach). The author was a member of the sub-team that focused on Section III, Execution Approach. The sub-teams reviewed and scrutinized the element descriptions in each section for applicability to small projects over the course of 10 months and four separate team meetings. The sub-teams utilized brainstorming sessions during team meetings, web-based conference calls, and individual reviews to complete this evaluation. Non-pertinent elements and “items to-be considered” bullets were removed, re-written, or combined with other elements. New elements were developed as necessary. The entire research team thoroughly reviewed all of the elements during four separate team meetings, and decided upon the final set of element descriptions after rigorous discussion and debate. The team broke the 41 element descriptions into three sections, and further broken down into eight categories to keep the same "look and feel" structure as the previously developed PDRIs.

Industry volunteers familiar with small industrial projects were asked to provide feedback regarding the element descriptions during the weighting workshops (described in further detail in the following sections). The workshop facilitators noted all items brought up during workshop discussions. Each participant could also record additional thoughts on "Suggestions for Improvement" sheets. Appendix E includes a sample copy of this form. The author reviewed all comments collected during the workshops, and revised the element descriptions as appropriate after the comments were thoroughly vetted by the entire research team. No elements were added or deleted after the workshop sessions had begun. Figure 6-1 shows the finalized list of element descriptions. Appendix B includes the complete list of elements and their descriptions.

SECTION I. BASIS OF PROJECT DECISION			
A.	**Project Alignment**	**B.**	**Project Performance Requirements**
A.1	Project Objectives Statement	B.1	Products
A.2	Project Strategy and Scope of Work	B.2	Capacities
A.3	Project Philosophies	B.3	Processes
A.4	Location	B.4	Technology
		B.5	Physical Site
SECTION II. BASIS OF DESIGN			
C.	**Design Guidance**	**D.**	**Process/Product Design Basis**
C.1	Lead/Discipline Scope of Work	D.1	Process Safety Management (PSM)
C.2	Project Design Criteria	D.2	Process Flow Diagrams along with Heat and Material Balance
C.3	Project Site Assessment	D.3	Piping and Instrumentation Diagrams (P&ID's)
C.4	Specifications	D.4	Piping System Stress Analysis
C.5	Construction Input	D.5	Equipment Location Drawings
		D.6	Critical Process/Product Items Lists
E.	**Electrical and Instrumentation Systems**	**F.**	**General Facility Requirements**
E.1	Control Philosophy	F.1	Site Plan
E.2	Functional Descriptions and Control Narratives	F.2	Loading/Unloading/Storage Requirements
E.3	Electrical Single Line Diagrams	F.3	Transportation Requirements
E.4	Critical Electrical Items Lists	F.4	Additional Project Requirements
SECTION III. EXECUTION APPROACH			
G.	**Execution Requirements**	**H.**	**Engineering/Construction Plan and Approach**
G.1	Procurement Plan	H.1	Engineering/Construction Methodology
G.2	Owner Approval Requirements	H.2	Project Cost Estimate
G.3	Distribution Matrix	H.3	Project Accounting and Cost Control
G.4	Risk Management Plan	H.4	Project Schedule and Schedule Control
G.5	Shutdown/Turnaround Requirements	H.5	Project Change Control
G.6	Precommissioning, Startup, & Turnover Sequence Requirements	H.6	Deliverables for Design and Construction
		H.7	Deliverables for Project Commissioning/Closeout

Figure 6-1. PDRI SECTIONS, Categories, and Elements

A basic tenet of front end planning is that not all items to be assessed are equally critical to project success. Certain elements are higher in the hierarchical order than others with respect to their relative importance. An analysis was necessary to “weight” the elements accordingly. The next section describes in detail the weighting workshop sessions held to gather feedback from industry professionals familiar with small industrial projects regarding the sufficiency and prioritization of the elements developed by the research team

6.2. PDRI Weighting Workshops

The author collected element weighting data through focus group sessions, referred to as "weighting workshops." This method was successfully utilized by each of the previous PDRI research teams, the details of which can be found in Gibson and Whittington (2010). Workshops were held in multiple locations in an effort to gain a variety of industry perspectives related to typical small industrial projects. Industry members of the research team hosted the workshops, and recruited industry professionals to participate. Table 6-1 provides the workshop locations, dates, and number of participants.

Table 6-1. Weighting Workshops

Location	Date	Number of Participants
Baton Rouge, Louisiana	April 10th, 2014	19
Houston, Texas	May 9th, 2014	12
Greenville, South Carolina	June 4th, 2014	12
Indianapolis, Indiana	July 21st, 2014	12
Houston, Texas	July 30th, 2014	10

The sixty-five workshop participants represented multiple owner and contractor organizations, industries, and geographic sectors. A list of participating organizations can be found in Appendix A. The industry participants were professionals such as project managers, project engineers, program managers, engineering managers, and construction managers. Figure 6-2 provides some demographical background information about the participants and the projects they used for reference during the workshops.

- 65 Weighted PDRI forms completed
- 65 participants
- 1,299 Collective years of experience
    - 20 years (on average) estimating/project management experience
    - 64% of experience (on average) related to small projects
    - 85% of experience (on average) related to industrial construction projects
- 29 Organizations represented
- $778 Million in project cost represented

Figure 6-2. Weighting Workshop Summary

6.3. Workshop Process

The academic members of Research Team 314 facilitated each of the workshop sessions described below. The author's role included development of information packets for the workshop participants (both pre-workshop packets and workshop packets), correspondence with potential workshop participants, tracking workshop attendance, developing presentations for the workshops, recording notes and suggestions provided by the participants during the sessions, data collection, data analysis, and providing the research team recommendations based on the data.

Five industry members from Research Team 314 volunteered to host weighting workshops. All industry members were tasked with recruiting practitioners familiar with small industrial projects to participate in the workshop sessions. The author sent information packets electronically to all confirmed workshop participants prior to each session; these included background information about the research study and the purpose of the workshop itself. Similar information packets were sent out prior to all of the workshop sessions. CII Research Summary 268-1a *Assessment of Effective Front End Planning Processes* was sent to potential participants for all workshops completed after the Baton Rouge, Louisiana session. Participants in the Baton Rouge session recommended this, feeling that sending information about the PDRI ahead of time would be beneficial for those individuals not previously familiar with the PDRI tools. Potential workshop participants were asked to review all of the “pre-read’ information prior to the workshop sessions, which included familiarizing themselves with specific front end planning details of a sample small industrial project recently completed by their organization that met the small project “definition” developed by the research team. The sample project would be used as reference throughout the workshop session.

Workshop participants were also provided with a packet at the beginning of each session that included: an agenda for the session, instructions for evaluating the PDRI, PDRI-Small Industrial element descriptions, blank weighting factor evaluation sheets, participant background information sheet, suggestions for improvement sheet, copies of the workshop session presentation slides, and small project/large project information sheets. Appendix D includes a copy of a typical workshop session packet. The packet contents were color-coded to assist in describing and collecting each research instrument.

Each session began with a Microsoft PowerPoint™ presentation (included in Appendix D) that briefly described the objectives of the workshop, background of the research project, background of the PDRI, and instructions for evaluating the PDRI-Small Industrial documents. Each of the forty-one PDRI element descriptions were then reviewed, one by one, once the background presentation was complete. Figure 6-3 provides an example element description for element A.4 Location.

A.4 Location

A location that considers the long-term needs of the owner organization, meets requirements and maximizes benefits should be selected. If locations have been pre-chosen, it is always a good idea to verify benefits. The selection of location(s) involves an assessment of the relative strengths and weaknesses of alternate locations. Evaluation criteria should include:

- Available utilities
- Operational requirements and hazards
- Interface with ongoing projects or operations
- Construction/operations and maintenance access
- Security constraints (consider separation of construction workers from operations, construction access and so forth)
- Regulatory/social constraints
- Orientation of project to facilitate future expansion
- Other (user defined).

Figure 6-3. Example Element Description, A.4 Location

Workshop participants were asked to consider all pertinent factors that could effect project success related to each element, including changes in project schedule, cost, or scope changes. Participants were then asked to assign two weights to each element based on their sample project: the first weight was to be based on if the items described in the element were completely defined and accounted for just prior to beginning detailed design, and the second weight was to be based on if the items described in the element were not defined or accounted for at all just prior to detailed design. The weights correspond to Level 1 and Level 5 scope definition, respectively. Preceding PDRI research teams concluded that participants involved in the weighting workshops tended to provide linear interpolation of contingency responses for definition levels 2, 3, and 4. The research team chose not to collect contingency amounts for these definition levels from the workshop participants, due to these values being fairly simple to calculate. The interpolation calculation method used by the author is described in detail later in this chapter.

Participants recorded the two weights as contingency amounts on blank weighting factor evaluation sheets. Contingency was defined as the element's individual impact on total installed cost, stated as a percentage of the overall estimate at the point just prior to the commencement of detailed project design. Contingency amounts were to be given as integers. Figure 6-4 provides an example of how a workshop participant would record the contingency amounts.

SECTION I - BASIS OF PROJECT DECISION							
	Definition Level						
CATEGORY Element	**N/A**	**1**	**2**	**3**	**4**	**5**	**Comments**
A. PROJECT ALIGNMENT							
A.1 Project Objectives Statement		10%				30%	
A.2 Project Strategy and Scope of Work		4%				25%	
A.3 Project Philosophies		0%				22%	
A.4 Location	X						

Definition Levels

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

Figure 6-4. Sample of Workshop Weighting Category A

The workshop facilitators conveyed that if an element were completely defined just prior to detailed design, it would logically have a lower contingency than if the element was not defined at all. The facilitators further explained that any amount of contingency could be given, as long as a relative consistency of element importance (as compared to the balance of elements in the tool) was kept for all responses. Participants were provided time at the end of each session to review their weights, and ensure that this consistency was kept throughout their responses.

It was noted that some elements (and possibly entire categories) might not be applicable to the projects being referenced by the participants. Non-applicable elements were described as elements that truly would not need to be considered during front end planning. Participants were instructed to indicate an element was not-applicable (i.e., N/A) by making a check in the N/A column, and not to list contingency amounts for either Level 1 or Level 5 definition (see Figure 6-4). Non-applicable elements were to be recorded separately from elements that would not need any contingency (i.e., zero percent contingency for Level 1 definition) if the element were completely defined prior to detailed design. Assessing the elements in this fashion mitigated the possibility of receiving incorrect data that could possibly skew the overall responses during the data analysis.

The facilitators addressed any questions posed by the workshop participants as the elements were individually reviewed. Adequate time was provided for participants to assess each element, but not enough time to "over think" the elements, keeping a consistent flow throughout the session. Participants were asked to record additional thoughts/comments about specific elements or the PDRI in general in either the comments section of the blank weighting factor evaluation sheets, or the suggestions for improvement sheet. The author reviewed all commentary received, and incorporated it into the PDRI element descriptions and score sheet where applicable. The comments were then reviewed by the entire research team during subsequent team meetings.

In summary, the weighting workshops for PDRI-Small Industrial followed the methodology used by Research Team 113, PDRI-Industrial, Research Team 155, PDRI-Building, and Research Team 268, PDRI-Infrastructure. Industry practitioners were asked to weight each element based on relative importance to typical small industrial projects. The workshops were very successful in both collecting weighting data and receiving insight from experience industry professionals on the value and use of the tool. Workshop data was used to develop a weighted score sheet for the PDRI, as described in the next section.

6.4. Developing the PDRI Element Weights

The author reviewed the weighting factor evaluation sheets for completeness after each workshop. Responses from five workshop participants were not used in the data analysis: one due to unresponsive answers (the participant did not follow instructions), and four due to lack of sufficient industry experience (i.e., less than 2 years). The research team deemed data from the remaining 60 responses satisfactory for analysis, and that data was normalized for statistical comparison.

6.4.1. Normalizing Process

The workshop facilitators did not provide a contingency range to the workshop participants. The only stipulation posed was that the contingency amounts provided should indicate the relative importance of each element as compared to the balance of elements in the tool. For example, if an element were given a Level 5 contingency amount of 20 percent, this element would be twice as critical to project success as an element that received a Level 5 contingency amount of 10 percent. This same consistency could be used by a separate workshop participant, but with different contingency amounts. For example, instead of using 20 percent and 10 percent, another participant may use 50 percent and 25 percent. In relative terms, both of these participants weighted the elements equally, with one element being twice as important to project success as the other. An issue arises when attempting to compare the responses from these two workshop participants, as the numerical values appear to be drastically different, when in fact both participants assign equal relative importance to the two elements at hand. Normalizing, or adjusting values to match a standard scale, is necessary to compare responses such as these.

The normalizing process consisted of four steps: (1) compiling all workshop participant data, (2) calculating non-applicable element weights, (3) calculating normalizing multipliers, and (4) calculating adjusted element weights. Figure 6-2 gives an example of the normalization process for participant BR-EC-4. This figure is used throughout the explanation of the four normalization steps. The same methodology was used for all workshop participants. The research team chose to use the same scale as the previously developed PDRIs (e.g., sum of all Level 1 definitions equals 70, the sum of all Level 5 definitions equals 1000) for the normalization process.

Table 6-2. Example of Normalizing Level 1 and Level 5 Weights for BR-EC-4

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Contingency Weight		Non-Applicable Elements		Normalizing Multiplier		Normalized Weight	
Element	Level 1	Level 5	Added Weight for 1's	Added Weight for 5's	Level 1 Multiplier	Level 5 Multiplie r	Level 1	Level 5
A.1	5	10	-	-	0.39	2.80	1.96	28.03
A.2	5	10	-	-	0.39	2.80	1.96	28.03
A.3	5	10	-	-	0.39	2.80	1.96	28.03
A.4	N/A	N/A	2.04	35.49	1.00	1.00	2.04	35.49
B.1	5	10	-	-	0.39	2.80	1.96	28.03
B.2	10	20	-	-	0.39	2.80	3.91	56.05
B.3	5	10	-	-	0.39	2.80	1.96	28.03
B.4	2	5	-	-	0.39	2.80	0.78	14.01
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
F.2	N/A	N/A	1.48	16.56	1.00	1.00	2.04	35.49
F.3	N/A	N/A	1.13	14.65	1.00	1.00	2.04	35.49
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
H.6	2	2	-	-	0.39	2.80	0.78	5.61
H.7	2	2	-	-	0.39	2.80	0.78	5.61
Totals	167	333	4.65	66.7	-	-	70.00	1000.00

Step 1 – Compiling all workshop participant data

- Weighting data from the 60 workshop participants was compiled into one Microsoft Excel™ spreadsheet. Each participant was given an alphanumeric code based on the workshop in which they participated in, and the type of organization they represented. For example, BR-EC-4 stands for the Baton Rouge workshop, engineer/contractor, and participant number 4. The alphanumeric code was created to keep personal workshop participant and proprietary project information guarded.
- The data was categorized by element and definition level weights provided by the participants

- The Level 1 and Level 5 weights were totaled. As shown in columns 1 and 2, the total Level 1 and Level 5 elements weights given by workshop participant BR-EC-4 were 167 and 333, respectively.

Step 2 – Calculating Non Applicable Element Weights

- Non applicable elements notwithstanding, the basic process for normalizing a participant's Level 1 responses would be to divide 70 by the total Level 1 element weights, or 167 in this case. As shown in columns 1 and 2, three elements, A.4, F.2, and F.3, were not applicable to the project assessed by BR-EC-4. As previously stated, non-applicable elements should lower the potential Level 1 and Level 5 scores on a pro-rata basis depending on the element weighting. To take this into account, weights were added to the non-applicable elements based on the average weight of that element from all workshop participants that considered the element applicable (shown in columns 3 and 4).
- The total Level 1 and Level 5 non-applicable elements weights attributed to workshop participant BR-EC-4 were 4.65 and 66.70, respectively.

Step 3 - Calculating Normalizing Multipliers

- Equation 1 shows the calculation for the Level 1 normalizing multiplier, used to normalize the Level 1 responses to a total score of 70.

$$Normalizing\ Multiplier = \frac{70 - Total\ Level\ 1\ Non - Applicable\ Weights}{Total\ Level\ 1\ Element\ Weights}$$

- Equation 2 shows the calculation for the Level 5 normalizing multiplier, used to normalize the Level 5 responses to a total score of 1000.

$$Normalizing\ Multiplier = \frac{1000 - Total\ Level\ 5\ Non - Applicable\ Weights}{Total\ Level\ 5\ Element\ Weights}$$

- The Level 1 and Level 5 normalizing multipliers calculated for workshop participant BR-EC-4 were 0.39 and 2.80, respectively.

Step 4 – Calculating adjusted element weights

- Each individual element weight was multiplied by the normalizing factors to determine the participant's adjusted Level 1 and Level 5 weights, shown in columns 7 and 8. The result of totaling the adjusted weights for each element (including those considered non-applicable) at definition Level 1 and Level 5 equal 70 and 1000, respectively.

In summary, the normalization process for PDRI-Small Industrial followed the methodology used by Research Team 113, PDRI-Industrial, Research Team 155, PDRI-Building, and Research Team 268, PDRI-Infrastructure. Workshop participant weighting scores were normalized to a standard scale for comparison purposes. The next section describes the screening of the adjusted element weights.

6.4.2. Screening the Data Using Boxplots

The research team sought to include only those data sets that were as close to a normal distribution as possible to determine appropriate mean element weights that would be used to create the weighted score sheet. The author utilized SPSS™ and Microsoft Excel™ to calculate the descriptive statistics (e.g., mean, median, standard deviation, variance, skewness) after the adjusted element weights were developed. Analysis of descriptive statistic data revealed that several of the elements were either moderately or highly skewed, indicating that responses from several of the participants were skewing the overall data set.

The author generated boxplots in SPSS™ detailing the interquartile range, median, outliers (shown as circles in Figure 5-6), and extreme values (shown as stars in Figure 5-6) for each element, at both Level 1 and Level 5 weights to visually identify participant weights that were skewing the mean element weights. Figure 5-6 shows the boxplots for Level 1 Category A.

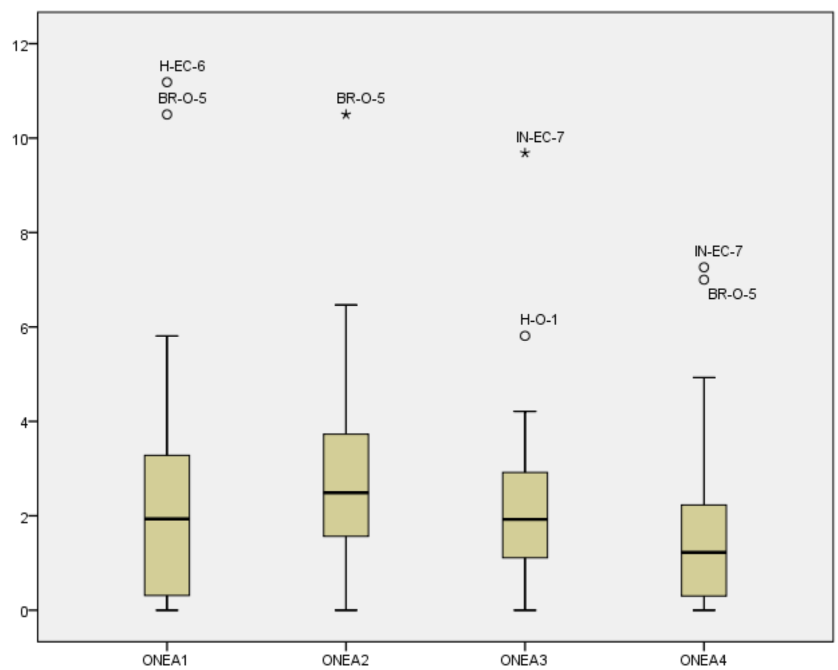


Figure 6-5. Boxplots of Category A, Definition Level 1 Weights

The author utilized Microsoft Excel™ to derive the interquartile range, median, outlier, and extreme value thresholds associated with each element. The author highlighted individual workshop participant element weights considered outliers or extreme, and calculated the total number of outliers and extremes per participant. The author also calculated “Contribution scores” (i.e., the amount a participant was skewing the data) for each workshop participant based on the number of outlier and extreme values. The contribution scores were calculated as:

$$Contribution\ Score = 3\ x\ (Number\ of\ Extremes) + \ 1\ x\ (Number\ of\ Outliers)$$

Table 6-3 shows each workshop participant’s contribution score. Figure 6-8 provides the contribution scores (by score category) in a bar chart format. Viewing the weighting data in this fashion highlighted the contribution score ranges skewing the mean element weights the most, and ranges of scores that were relatively higher than the total workshop participant set.

Table 6-3. Workshop Participant Contribution Scores (Ranked Highest to Lowest)

Workshop Participant	Contribution Score	Workshop Participant	Contribution Score	Workshop Participant	Contribution Score
BR-EC-2	0	BR-EC-12	1	H-O-4	4
BR-EC-8	0	H-EC-8	1	G-EC-6	4
BR-EC-10	0	IN-O-3	1	IN-EC-5	4
BR-O-3	0	IN-O-4	1	IN-EC-6	4
H-EC-1	0	IN-EC-8	1	IN-EC-7	4
H-EC-4	0	H2-EC-3	1	H2-EC-2	4
H-EC-5	0	BR-EC-4	2	IN-EC-4	6
G-EC-1	0	H-EC-6	2	H2-O-6	6
G-O-4	0	G-O-2	2	H-EC-3	7
G-EC-5	0	H2-O-3	2	H-O-1	7
IN-O-1	0	BR-EC-7	3	H2-EC-1	7
IN-O-2	0	BR-O-4	3	BR-EC-9	8
IN-EC-1	0	H-EC-7	3	BR-O-2	8
IN-EC-2	0	G-EC-2	3	BR-O-5	8
IN-EC-3	0	G-EC-7	3	H-O-2	9
H2-O-4	0	H2-O-1	3	G-O-1	9
H2-O-5	0	BR-EC-1	4	H-EC-2	10
H2-O-7	0	BR-EC-3	4	G-O-3	12
BR-EC-5	1	BR-EC-6	4	H2-O-2	12
BR-O-6	1	BR-O-1	4	H-0-3	14

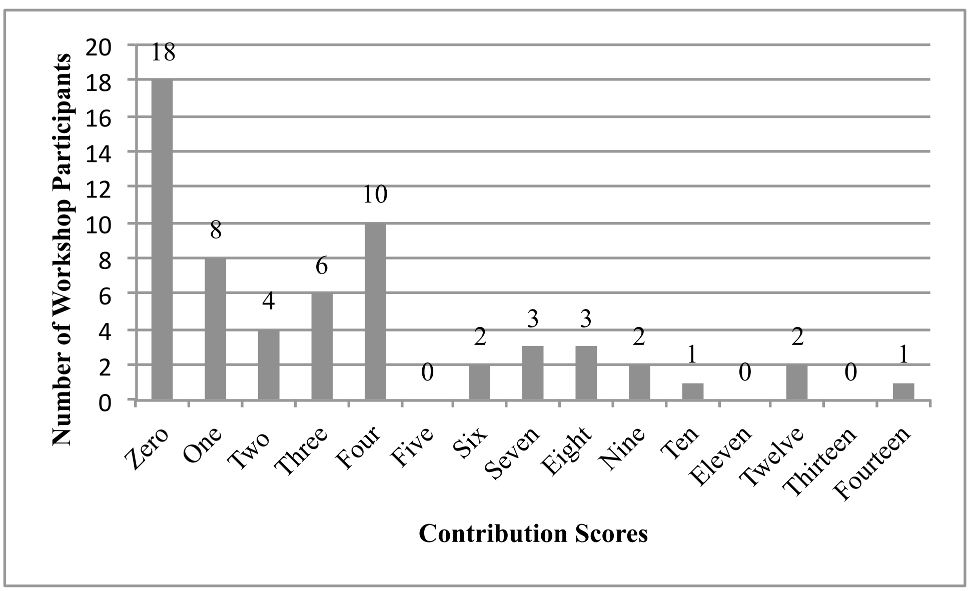


Figure 6-6. Workshop Participant Contribution Scores (By Score Category) (n=60)

Previous PDRI research teams had contemplated five options for removing data that was skewing the mean element weights. The first option was to decide if the outliers and extremes were still valid data points and use all data sets and points to determine the element weights. The second option was to throw out entire data sets, or workshop participants, who had contribution scores determined “too high” by the research team. The third option was to keep all data sets but remove only the data points that were outliers or extremes on any given element. The fourth option was a combination of options two and three, to remove entire data sets for the workshop participants whose contribution score was determined to be “too high” by the research team, similar to option two, but also remove any remaining outliers and extremes on individual elements, similar to option three. The fifth and final option was to remove only those data points that were calculated as extremes and leave the data points calculated as outliers.

Option two, to remove entire data sets of those workshop participants whose contribution scores were determined to be “too high”, was used. This was the option chosen by all of the previous PDRI research teams, and Research Team 314 deemed it prudent for this research effort. The team determined that workshop participants with a contribution score greater than nine should be removed from the data set. This was a logical conclusion based on the groupings of scores shown in Table 6-3 and Figure 6-8. Data sets from four workshop participants (e.g., H-O-3, G-O-3, H2-O-2, H-EC-2) were removed from the total data set.

The author utilized the same procedure for normalizing weights and calculating adjusted element weights on the remaining 56 workshop participant element weights. The author also used the same procedure to create boxplots, and calculate interquartile range, median, outlier, and extreme value thresholds, and contribution scores. Appendix C includes the set of boxplots from this analysis. The author found that several workshop participants has contribution scores that could be considered "too high" (i.e., higher than nine) after completing the second round of analysis. The author realized that after removing these data sets from the total data set, the mean element scores were only slightly adjusted, and that this slight adjustment would make little difference when developing the final PDRI score sheet. No further workshop participant responses were removed from the analysis based on this determination.

The next section describes the procedures used for finalizing the PDRI-Small Industrial score sheet, including interpolation of scores for Levels 2, 3, and 4, and rounding of element weights.

6.4.3 Finalizing the PDRI Score Sheet

The individual Level 1 and Level 5 element scores were developed through the data analysis described in the previous section, as the typical 70-1000 PDRI scoring range was used during the normalization process. The next step was to determine the Level 2, 3, and 4 element weights. Calculating these scores was done by linear interpolation between the Level 1 and Level 5 scores already established. The weights were calculated as follows:

Level 2 Weight = ((Level 5 Weight – Level 1 Weight) / 4) + Level 1 Weight
Level 3 Weight = ((Level 5 Weight – Level 1 Weight) / 4) + Level 2 Weight
Level 4 Weight = ((Level 5 Weight – Level 1 Weight) / 4) + Level 3 Weight

The calculations used to determine the adjusted element weights for Levels 1 and 5, and interpolated weights for Level 2, 3, and 4 produced non-integer numbers. Rounding of each number was necessary to complete the PDRI score sheet, as only integers are used as weights on the PDRI score sheets. A standard rounding procedure was used, where numbers with decimals equal to or greater than .50 were rounded up, and numbers with decimals less than .50 were rounded down. This held true for a majority of the weights, but a few of the element weights that were just below .50 were rounded up instead of down so that the Level 1 and Level 5 scores could exactly equal 70 and 1000, respectively. Adjusting numbers in this fashion was determined acceptable by the research team, as the PDRI is not necessarily a precision tool; slight adjustments to scores make little difference to project success. Table 6-4 provides the results of the interpolation calculations (including rounding).

Table 6-4. Results of Interpolation for Level 2, 3, and 4 Element Weights

	Definition Level						Definition Level				
	1	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**
A.1	2	13	24	35	47	F.1	1	6	10	15	20
A.2	3	13	24	34	45	F.2	2	5	9	13	17
A.3	2	8	14	19	25	F.3	1	5	8	12	15
A.4	2	11	19	28	36	F.4	2	8	13	19	24
A Totals	**9**	**45**	**81**	**116**	**153**	**F Totals**	**6**	**24**	**40**	**59**	**76**
B.1	1	8	15	21	28	**Sec II Totals**	**30**	**130**	**226**	**326**	**425**
B.2	2	9	17	24	31	G.1	2	9	15	22	28
B.3	2	7	12	17	23	G.2	1	5	9	13	17
B.4	2	8	15	21	28	G.3	1	3	4	6	8
B.5	2	8	14	19	25	G.4	2	7	13	18	23
B Totals	**9**	**40**	**73**	**102**	**135**	G.5	3	10	17	25	32
Sec I Totals	**18**	**85**	**154**	**218**	**288**	G.6	2	7	11	16	21
C.1	2	8	14	20	27	**G Totals**	**11**	**41**	**69**	**100**	**129**
C.2	2	8	14	20	26	H.1	2	8	14	20	25
C.3	2	9	15	22	29	H.2	3	12	21	30	39
C.4	2	8	14	20	26	H.3	1	4	8	11	14
C.5	2	8	14	19	25	H.4	2	8	13	19	25
C Totals	**10**	**41**	**71**	**101**	**133**	H.5	1	6	10	15	19
D.1	1	6	10	14	19	H.6	1	6	11	16	21
D.2	2	8	15	22	28	H.7	1	5	8	12	15
D.3	2	11	19	28	36	**H Totals**	**11**	**49**	**85**	**123**	**158**
D.4	1	5	9	13	17	**Sec III Totals**	**22**	**90**	**154**	**223**	**287**
D.5	1	7	12	17	22						
D.6	2	7	12	17	23	**PDRI Totals**	**70**	**305**	**534**	**767**	**1000**
D Totals	**9**	**44**	**77**	**111**	**145**						
E.1	2	7	12	17	22						
E.2	1	4	7	11	14						
E.3	1	5	9	13	17						
E.4	1	5	10	14	18						
E Totals	**5**	**21**	**38**	**55**	**71**						

The author completed a final check of the element weights for definition Levels 1-5 and a weighted score sheet created after the data interpolation. Appendix B provides the weighted score sheet. The score sheet has a definition level 0 added for elements not applicable to projects being assessed with the tool.

6.5. Analyzing the Weighted PDRI

The weighted element score sheet can be used to highlight sections, categories, and elements of greatest importance to project success. Reviewing only the highest weighted elements could be a method to quickly assess a project if a project team had limited time. Project teams should focus on the sections, categories and elements that have the highest contribution to the PDRI score. Section II, Basis of Design, has the highest total score. Elements in this section have the highest probability to effect project success if the scope of a project were such that all categories would be pertinent. Figure 6-9 shows the PDRI sections and their corresponding Level 5 weights.

Section	Weights
SECTION I - BASIS OF PROJECT DECISION	288
SECTION II - BASIS OF DESIGN	425
SECTION III - EXECUTION APPROACH	287
Total	1000

Figure 6-7. PDRI Sections and Total Level 5 Weights

Figure 6-10 provides a breakout of each of the three sections based on their categories. Category H, Engineering/Construction Plan and Approach, carries the highest weight of all of the categories, followed by Category A, Project Alignment, and Category D, Process/Product Design Basis. If a project team wanted to focus on specific elements that would have the highest impact on project success, concentrating on elements with the highest weights would be prudent.

Category	Weights
Section I	
A. Project Alignment	153
B. Project Performance Requirements	135
Section I	
C. Design Guidance	133
D. Process/Product Design Basis	145
E. Electrical and Instrumentation Systems	71
F. General Facility Requirements	76
Section I	
G. Execution Requirements	129
H. Engineering/Construction Plan and Approach	158

Figure 6-8. PDRI Categories and Total Level 5 Weights

Figure 6-11 provides a listing of the top eight PDRI elements based on Definition Level 5 weight. The workshop participants judged these elements as being the most critical to project success for process and non-process small industrial projects. The top eight elements make up over 30 percent of the total weight of all elements. Five of the eight elements are included in Section I, one element is included in Section II, and two elements are included in Section III.

Rank	Element	Element Description	Definition Level 5 Weights	Section
1	A.1	Project Objectives Statement	47	I
2	A.2	Project Strategy and Scope of Work	45	I
3	H.2	Project Cost Estimate	39	III
4	D.3	Piping and Instrumentation Diagrams (P&ID's)	36	II
	A.4	Location	36	I
6	G.5	Shutdown/Turnaround Requirements	32	III
7	B.2	Capacities	31	I
8	C.3	Project Site Assessment	29	I
		Total	295	

Figure 6-9. Top Eight PDRI Elements by Weight (Definition Level 5)

6.5.1. Element Weights for Project Types

The author was curious about how different small industrial project subsets were represented within the PDRI, in addition to understanding the blended results of the small industrial project types (represented by the workshop participants). The question was "how would the element weights change if a select group of participants or project types were evaluated separately?" The author analyzed the data in the following two ways to address this question:

- Element weight ranking by owners vs. engineers/contractors
- Element weight ranking on process vs. non-process projects

The next section describes the results of this analysis.

6.5.2. Comparison of Owners and Engineers/Contractors

Twenty-two workshop participants were owners and 34 were engineers/contractors, of the 56 total workshop participants used for developing the weighted PDRI score sheet. The author categorized and analyzed the element weights reported by these workshop participants separately to discern if there was a significant difference between the two data sets. Figure 6-12 details the top ten elements based on Definition Level 5 ranks of the two groups. Although there were differences between the two data sets, in general, the element weight rankings were fairly similar. The analysis also highlighted areas where owners and engineers/contractors would typically differ in ranking the importance of different project aspects.

Owners

Rank	Element	Element Description	Definition Level 5 Weight
1	A.1	Project Objectives Statement	54
2	A.2	Project Strategy and Scope of Work	41
3	A.4	Location	39
4	H.2	Project Cost Estimate	38
5	B.2	Capacities	37
6	B.4	Technology	34
7	G.5	Shutdown/Turnaround Requirements	33
	B.1	Products	33
9	C.3	Project Site Assessment	32
10	D.2	Process Flow Diagrams along with Heat and Material Balance	31
		Total	372

Engineers/Contractors

Rank	Element	Element Description	Definition Level 5 Weight
1	A.2	Project Strategy and Scope of Work	49
2	A.1	Project Objectives Statement	45
3	H.2	Project Cost Estimate	43
4	D.3	Piping and Instrumentation Diagrams (P&ID's)	40
5	G.5	Shutdown/Turnaround Requirements	33
6	G.1	Procurement Plan	32
7	C.1	Lead/Discipline Scope of Work	30
	B.2	Capacities	30
9	A.4	Location	29
	A.3	Project Philosophies	29
		Total	360

Figure 6-10. Comparison of Top Ten Definition Level 5 Ranks from Owners and Engineers/Contractors

Elements A.1, Project Objectives Statement, A.2 Project Strategy and Scope of Work, and H.2 Project Cost Estimate were ranked in the top four of highest weight elements for both owners and contractors/engineers. This shows a consensus of how important it is to understand what the objectives of the project are, how the objectives will be accomplished, and what financial considerations will be necessary to complete the objectives of typical small industrial projects. The other two elements included in the top ten were G.5 Shutdown/Turnaround Requirements, and A.4 Location.

Owners highly ranked elements such as B.2 Capacities, B.4 Technology, and B.1 Products. These elements stress the importance of understanding operational characteristics of the project, as opposed to construction characteristics. An operational focus would be expected of an owner more than a contractor/engineer, as they will "live with" the final outcomes of the project long after construction is completed.

Engineers/contractors highly ranked elements such as D.3 Piping and Instrumentation Diagrams, G.1 Procurement Plan, and C.1 Lead/Discipline Scope of Work. These elements emphasize a typical area of project scope on many industrial projects (i.e., piping and instrumentation), the procurement of equipment, materials, and labor to complete the project in a timely fashion, and the breakdown of separate project tasks. It is incumbent for engineers/contractors to address these project aspects during front end planning if small industrial projects are to be successful for those actually designing and building them.

The difference in rankings is not enough to warrant the creation of separate PDRIs for owners and engineers/contractors, but does suggest areas where these different groups may want to focus their efforts during front end planning to mitigate the potential of future risks related to project unknowns. In the end, RT 314 felt that it was important to keep the PDRI blended with both owner and engineer/contractor perspectives to better represent a true risk level during assessment.

6.5.3. Comparison of Process and Non-Process Projects

The PDRI-Small Industrial was designed for use on both process and non-process related projects. The author, along with the research team, developed definitions for both process and non-process related projects. Process related projects are defined as:

> *Any project in an industrial facility related to constructing or refurbishing the systems, equipment, utilities, piping, and/or controls that directly affect the production rate, efficiency, quantity, or quality of the product being produced. These projects would typically have a stated Return on Investment (ROI) expectation to be met directly related to improved production factors, and may affect how the product is marketed to consumers (e.g., higher quality than before, increase in quantities available). In most cases, documents pertaining to the ongoing operations of the facility (e.g., Piping and Instrumentation Diagrams, Process Safety Management Plans) would need to be created, or existing documents updated.*

A “non-process” related project is defined as:

> *Any project in an industrial facility that is ancillary to production processes, but does not directly affect the quantity or quality of the product being produced. Examples of these types of projects include additions to or expansion of the infrastructure that supports a facility, facility updates necessary for environmental or safety compliance, replacement-in-kind of facility components (e.g., equipment, structural, piping) that do not directly affect the nature of the product being produced. If an ROI is required on these projects, it will typically be attributed to improving the operating efficiencies of the facility that are not directly related to production, such as increased energy efficiency related to installing Variable Frequency Drives (VFD’s) on HVAC equipment, or installing solar panels to lessen the amount of power needed from a public utility provider. Documents pertaining to the ongoing operations of the facility (e.g., Piping and Instrumentation Diagrams, Process Safety Management Plans) may or may not need to be created or updated.*

Workshop participants were asked to provide typical small industrial projects recently completed in their organization, either process and non-process related. Forty-one projects were process related, and 15 projects were non-process related, of the 56 total projects used by the workshop participants for the final PDRI element weighting. The element weights reported on these projects (regardless of owner or engineer/contractor participant) were categorized separately and analyzed to discern if there was a significant difference between the two data sets. Figure 6-13 details the top ten elements based on Definition Level 5 ranks of the two groups. The analysis shows some differences between the two data sets, but in general, the element weight rankings were fairly similar. This is analogous to the owner and engineer/contractor comparison described in the previous section.

Process

Rank	Element	Element Description	Definition Level 5 Weight
1	A.1	Project Objectives Statement	48
2	A.2	Project Strategy and Scope of Work	45
3	H.2	Project Cost Estimate	39
4	D.3	Piping and Instrumentation Diagrams (P&ID's)	34
	G.5	Shutdown/Turnaround Requirements	34
	B.2	Capacities	34
7	B.1	Products	32
8	A.4	Location	31
9	G.1	Procurement Plan	30
10	C.3	Project Site Assessment	29
		Total	356

Non-Process

Rank	Element	Element Description	Definition Level 5 Weight
1	A.1	Project Objectives Statement	49
2	A.2	Project Strategy and Scope of Work	47
3	H.2	Project Cost Estimate	46
4	D.3	Piping and Instrumentation Diagrams (P&ID's)	40
5	A.4	Location	38
6	B.2	Capacities	31
	D.2	Process Flow Diagrams along with Heat and Material Balance	31
8	G.5	Shutdown/Turnaround Requirements	30
9	A.3	Project Philosophies	30
10	C.3	Project Site Assessment	29
		Total	371

Figure 6-11. Comparison of Top Ten Definition Level 5 Ranks from Process and Non-Process Projects

Eight elements are ranked in the top ten highest weighted elements for both process and non-process projects, namely A.1 Project Objectives Statement, A.2 Project Strategy and Scope of Work, G.5 Shutdown/Turnaround Requirements, H.2 Project Cost Estimate, D.3 Piping and Instrumentation Diagrams (P&ID's), B.2 Capacities, A.4

Location, and C.3 Project Site Assessment. This consistency confirms that the PDRI-Small Industrial is suitable for assessing both process and non-process projects.

Elements B.1 Products and G.1 Procurement Plan are ranked in the top ten highest weighted elements for process projects. This makes sense, as understanding the product attributes to be realized at the completion of the project, as well as the methods for procuring essential project components would be paramount for a process related project, but not necessarily so for a non-process related project.

Elements A.3 Project Philosophies and D.2 Process Flow Diagrams along with Heat and Material Balance are ranked in the top ten highest weighted elements for non-process projects. As non-process projects are ancillary to production processes but not directly related to them, it would make sense that these elements are included in the list. Element A.2 Project Philosophies addresses items related to ensuring the project meets the continual operating needs of the facility, both related to processing/manufacturing capabilities and the facility in general. Organizations frequently undertake small industrial projects to address this need, such as replacement-in-kind of process piping or equipment. Element D.2 Process Flow Diagrams along with Heat and Material Balance also addresses the need to ensure continual facility operation, as ensuring fluid materials (whatever they may be) are consistently delivered throughout a facility is vital to many industrial operations. Research Team 314 felt it prudent to keep a blended PDRI to reflect the issues of both process and non-process related small industrial projects.

6.6. Alternative Workshop Data Collection Methodology

Section 6.3 described the data collection method utilized during the weighting workshops. To summarize, using a recently completed or ongoing project within their respective organizations, workshop participants were asked to provide two contingency amounts for each the PDRI elements: the first was to be based on if the items described in the element were completely defined and accounted for just prior to beginning detailed design, and the second based on if the items described in the element were not defined or accounted for at all just prior to detailed design. These two contingency amounts were then compiled, normalized, analyzed, and used to create the definition Level 1 and Level 5 weights included in the weighted score sheet. The definition Level 1 weights were normalized to 70, to keep consistency with the previously developed PDRI tools. The Level 1 weights for all elements ranged from one to three, with the most prevalent weight being two.

The author completed additional analysis to determine if a substantial difference to the definition Level 1 weights would be realized if the contingency amounts provided by the workshop participants for definition Level 5 were normalized to 70, as well as 1000. The purpose of this analysis was to determine if less data could be collected during the weighting workshops (i.e., one contingency amount for all elements as opposed to two) and still be utilized by a research team to develop a weighted score sheet. Less data being collected would equate to less time being needed during the weighting workshops themselves, as well as less analysis needing to be completed after the fact by the research team to compile, normalize and analyze the workshop data.

6.6.1. Alternative Weighting Analysis

Table 6-5 provides the results of the alternative weighting analysis. The methodology used to determine the weights in Table 6-5 is described in section 6.4.1. Columns 1, 3, and 5 provide the normalized, rounded, and adjusted weights for definition

Level 1 based on the definition Level 1 contingency amounts provided by the workshop participants. These weights were included in the final PDRI-Small Industrial weighted score sheet that is provided in Appendix B. Columns 2, 4, and 6 provide the normalized, rounded, and adjusted weights for definition Level 1 based on the definition Level 5 contingency amounts provided by the workshop participants. Column 7 provides the difference in weight between the two methods.

Table 6-5. Comparison of Standard and Alternative Weighting Calculations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Normalized Weights		**Rounded to Whole Numbers**		**Adjusting to Equal 70**		
Element	**Level 1 Weights from Workshops**	**Level 5 Weights from Workshops**	**Level 1 Weights from Workshops**	**Level 5 Weights from Workshops**	**Level 1 Weights from Workshops**	**Level 5 Weights from Workshops**	**Delta**
A.1	2.091	3.280	2	3	2	3	1
A.2	2.715	3.117	3	3	3	3	-
A.3	1.945	1.780	2	2	2	2	-
A.4	2.041	2.484	2	2	2	2	-
B.1	1.405	1.898	1	2	1	2	1
B.2	1.784	2.187	2	2	2	2	-
B.3	1.437	1.600	1	2	2	2	-
B.4	1.850	1.881	2	2	2	2	-
B.5	2.028	1.757	2	2	2	2	-
C.1	2.170	1.891	2	2	2	2	-
C.2	1.853	1.801	2	2	2	2	-
C.3	2.050	1.987	2	2	2	2	-
C.4	1.623	1.837	2	2	2	2	-
C.5	2.081	1.729	2	2	2	2	-
D.1	1.379	1.283	1	1	1	1	-
D.1	1.462	1.948	1	2	2	2	-
D.3	2.346	2.561	2	3	2	2	-
D.4	1.288	1.185	1	1	1	1	-
D.5	1.299	1.596	1	2	1	2	1
D.6	1.513	1.570	2	2	2	2	-
E.1	1.475	1.580	1	2	2	2	-
E.2	0.929	0.963	1	1	1	1	-
E.3	1.090	1.209	1	1	1	1	-
E.4	1.126	1.271	1	1	1	1	-
F.1	1.096	1.358	1	1	1	1	-
F.2	1.480	1.159	1	1	2	1	-1
F.3	1.134	1.026	1	1	1	1	-
F.4	2.240	1.668	2	2	2	2	-
G.1	2.369	2.015	2	2	2	2	-
G.2	1.340	1.169	1	1	1	1	-
G.3	0.542	0.582	1	1	1	1	-
G.4	1.692	1.615	2	2	2	2	-
G.5	2.754	2.259	3	2	3	2	-1
G.6	1.794	1.502	2	2	2	1	-1
H.1	2.289	1.784	2	2	2	2	-
H.2	3.003	2.747	3	3	3	3	-
H.3	1.080	1.032	1	1	1	1	-
H.4	2.210	1.772	2	2	2	2	-
H.5	1.348	1.376	1	1	1	1	-
H.6	1.348	1.499	1	1	1	1	-
H.7	1.300	1.042	1	1	1	1	-
Totals	70	70	66	72	70	70	0

As shown, the weights for only 6 of the 41 elements were different between the two methods, with the biggest change being a one-point difference. This minimal difference suggests that the alternative method to calculate definition Level 1 weights would be a viable option. The element weights are routinely adjusted by ± one point so that the Level 1 and Level 5 weights can equal exactly 70 and 1000, as described in section 5.4.3. Slight adjustments to the element weights are deemed acceptable, as minor point differences make little difference to the overall project scores determined through a project assessment with the PDRI.

6.6.2. Alternative Data Collection During Weighting Workshops

Research teams could potentially save time during the weighting workshops (and subsequent data analysis) if the proposed alternative data collection method was utilized. This time could either be used to make the workshops themselves shorter in duration, or to possibly collect additional data from the workshop participants. A possible set of data that could be collected during the weighting workshops would be completed project data to be used to test the PDRI.

The typical procedure utilized by all of the PDRI research teams was to solicit completed project data after the weighting workshops were completed, as described in Chapter 7. Alternatively, research teams could solicit completed project data from the workshop participants themselves, based on the projects that the participants use as a basis for the workshops. For example, the workshop facilitators would ask the participants to provide two pieces of information for each of the elements in the PDRI tool. The first piece of information would be, based on their sample projects, what was the level of definition the project had achieved just prior to detailed design. The second piece of information would be, based on their sample projects, what percent contingency would they attribute to the elements if it were completely undefined (i.e., Definition Level 5) just prior to detailed design. Figure 6-14 provides an alternative data collection sheet that could be utilized during the weighting workshops to collect the two pieces of information. The workshop participants would also be asked to submit the completed project questionnaire, shown in Appendix F. This questionnaire could be sent to the workshop participants ahead of the workshop sessions, along with the workshop information packets. The completed project data could be analyzed in the same manor described in Chapter 6 once the PDRI weighted score sheet was completely developed, after all of the weighting workshops were finished.

PDRI WEIGHTING FACTOR EVALUATION FORM - PROJECT DEFINITION RATING INDEX (PDRI)
FOR SMALL INDUSTRIAL PROJECTS

NAME: ____________________ DATE: ____________________

SECTION I - BASIS OF PROJECT DECISION							
	Definition Level						Contingency Amount (as a percentage of total installed cost) if the element was completely undefined at the end of front end planning
CATEGORY Element	n/a	1	2	3	4	5	
A. PROJECT ALIGNMENT							
A1. Project Objectives Statement							
A2. Project Strategy and Scope of Work							
A3. Project Philosophies							
A4. Location							
B. PROJECT PERFORMANCE REQUIREMENTS							
B1. Products							
B2. Capacities							
B3. Processes							
B4. Technology							
B5. Physical Site							

Figure 6-12. Alternative Data Collection Worksheet

Future research teams could realize two advantages if the alternative data collection method was utilized: time savings and additional testing data. Weighting workshops were conducted from April 2014 to July 2014 by the research team during the development of the PDRI-Small Industrial, and included 65 participants. The completed project data collection phase began after the completion of the weighting workshops, and lasted for approximately eight months (September 2014 to April 2015). Data on 40 completed projects was received during that time period. Instead, the Research Team could have collected data on 65 completed projects had the alternative data collection method been utilized during weighting workshops. This is approximately 63 percent more data. The data collection period would have ended in conjunction with the last workshop, i.e., July of 2014, rather than in April 2015, representing a nine-month time savings for the project. A final alternative would be to collect data both during workshops and for a fixed period thereafter, to collect completed project data independent of the projects used to develop the weights. This would be a hybrid of the traditional and alternative approaches that would offer more total projects in a reduced time frame.

6.6 Summary

This chapter outlined the process that the research team followed to develop the PDRI-Small Industrial. Data was primarily collected through several workshops held across the United States. The workshop facilitation was described and the process of weighting elements was given. This chapter also discusses interesting comparisons of element weights based on workshop participant and project types.

This chapter also provided the results of an analysis to determine if an alternative method could be utilized to develop the definition Level 1 weights for the weighted PDRI score sheet. The analysis showed the using Definition Level 5 contingency amounts in lieu of Definition Level 1 contingency amounts yielded the same weight for 36 of the 41 elements in the PDRI-Small Industrial. It was also suggested that future research teams could utilize the spare time during the weighting workshops to collect completed project data, potentially providing a considerable amount of additional completed project data for use during testing of the PDRI.

CHAPTER 7. PDRI TESTING

This chapter summarizes the testing process for the PDRI-Small Industrial. The purpose of the testing process was to determine the efficacy of the PDRI-Small Industrial tool to predict project success. The author utilized two methods to test the efficacy of the tool: statistically comparing PDRI scores vs. cost, schedule, change, financial performance, and customer satisfaction, on a sample of recently completed small industrial projects, and soliciting industry volunteers to assess projects currently in the front end planning phase (i.e., in-progress projects) with the tool. This chapter describes the testing questionnaires, supporting statistical analysis data, and conclusions derived from the statistical analysis.

7.1. Completed Projects

The author collected completed project data in order to test the hypothesis that scores derived by assessing a project with the PDRI-Small Industrial tool correlate to levels of project performance. A higher PDRI score indicates incomplete scope definition during front end planning, leading to poor project performance. A lower PDRI score indicates sufficient scope definition, leading to improved project performance.

The author sought both process and non-process industrial projects that met the "small project" definition provided in Chapter 5. Research team members and workshop participants that indicated a desire to test the tool once it had been completely developed were the primary means of data collection. The author asked that volunteers provide project data on both "successful" and "unsuccessful" projects so that a thorough analysis of typical small industrial projects could be completed.

7.1.1. Testing Questionnaire

The author developed a multi-part questionnaire of open and closed-ended questions to collect information on recently completed successful and unsuccessful small industrial projects. Appendix F includes a copy of the questionnaire. The questionnaire packet consisted of:

- Background information describing the PDRI tools
- The motivation for developing a tool specifically for small industrial projects
- A definition of small industrial projects
- The PDRI-Small Industrial element descriptions
- An un-weighted PDRI score sheet corresponding to the element descriptions
- A worksheet for recording detailed project background and performance information such as:
    - Project name, location, facility type
    - If the project was new construction, renovation/revamp, or both
    - If the project would be considered process or non-process related
    - Project driver (maintenance/replacement, production process improvement, technology upgrade, governmental regulation, etc.)
    - Project schedule information, both planned and actual
    - Project cost information, both planned and actual
    - Project change information
    - Operating performance information (i.e., if the project met operating expectations)

- Financial information (i.e., level of approval, financial measurement used to authorize the project, if the project met financial expectations)
- Customer satisfaction with the project

Volunteers were asked to evaluate a small industrial project recently completed by their organization based on the element descriptions provided in the PDRI-Small Industrial tool, as well as provide the detailed project background information described in the testing packet. The volunteers determined the level of scope definition the project team responsible for planning the project had achieved just prior to the start of detailed design and construction based on the PDRI scoring scheme, and recorded the levels on the un-weighted PDRI score sheet. Figure 7-1 provides an excerpt of the instruction documents regarding how to assess and element.

Example, Assessing Element C3

The completed project that I am assessing was the installation of a new packaging line. I have addressed all of the elements up to C3. Reading the definition of element C3 Project Site Assessment on page 7 in the PDRI Element Descriptions, I felt that the site assessment for my project had some deficiencies since a comprehensive assessment had not been completed, and some conflicts between the intent of the proposed design and the actual site conditions were thought to exist at that time.

C3. Project Site Assessment

The actual conditions pertaining to the project site should be identified and documented. Availability/non-availability or redundancy of site utilities needed to operate the unit/facility and equipment should be identified. Items to consider should include the following:

- ☐ Survey and benchmark (coordinate and elevation) control system
- ☐ Geotechnical report
- ☐ Soil treatment or removal/replacement requirements
- ☐ Environmental permits now in force
- ☐ Existing environmental problems with the site
- ☐ Other factors such as light, dust, noise, emissions, or erosion control
- ☐ Fluid/gas utility sources with supply conditions (including temperature, pressure, and quality)
- ☐ Power sources with supply conditions (including location, voltage level, available power, reliability, and electrical power quality)
- ☐ Other user defined

**** Additional items to consider for Renovation & Revamp projects****

- ☐ Field verify condition of isolation and tie-in points, including operational approval
- ☐ Field verify condition of existing or reused equipment
- ☐ Existing horizontal and vertical position analysis (e.g., use of laser scanning)

Therefore I checked level 3 "Some Deficiencies" in the score sheet below. Note that this uncertainty manifested itself during the design phase and caused some conflict during construction.

Example

CATEGORY Element	Definition Level					
	N/A	**1**	**2**	**3**	**4**	**5**
SECTION II - BASIS OF DESIGN						
C. DESIGN GUIDANCE						
C3. Project Site Assessment				✓		

1 = Complete Definition **2 = Minor Deficiencies** **3 = Some Deficiencies**
4 = Major Deficiencies **5 = Missing or Very Poor Definition**

Figure 7-1. Excerpt from PDRI Testing Packet

7.1.2. Sample Characteristics

The author distributed the questionnaire packet electronically to each industry member of Research Team 314, each industry participant from the weighting workshops, members of the CII Risk Management, Front End Planning, and NextGen Communities of Practice, and members of the CII Implementation Champions Committee. In total, the 40 completed-project questionnaires were collected. The sample projects represented a total cost of nearly US $152 million, and covered an array of industrial project facility types. The sample projects were constructed in three separate countries, and included renovation an revamp projects, new construction projects, and projects that included both renovation and revamp and new construction. The sample projects were both process and non-process related, based on the definitions process and non-process projects developed by the research team. The author calculated the PDRI scores for each of the completed projects based on the levels of definition noted in each completed project's questionnaire. The PDRI scores ranged from 93 to 774, with an average score of 290. Table 7-1 provides a breakdown of the completed project sample. It should be noted that four of the 40 projects used in testing were above the $10 million cost threshold noted in the small project definition developed by the research team. The author chose to keep these projects in the testing sample as they represented projects considered "small" by the organizations that submitted them.

Table 7-1. Completed Small Industrial Projects used during Testing of the PDRI for Small Industrial Projects tool

Project Number	Project Facility Type	Process or Non-Process Related	Total Installed Cost	PDRI Score
1	Chilled water refrigeration plant	Process	$4,066,615	324
2	Steam heat boilers and chilled water refrig. plant	Process	$376,565	228
3	Manufacturing	Non-Process	$140,000	346
4	Refinery	Process	$9,161,435	273
5	Manufacturing	Non-Process	$281,469	623
6	Chemical resins pneumatic transport facility	Process	$63,826	164
7	Chemical resin extrusion machine	Process	$151,380	113
8	Power generation	Non-Process	$387,145	590
9	Refinery	Process	$1,797,632	335
10	Salt water disposal facility	Process	$2,057,000	389
11	Tank battery	Process	$4,105,000	572
12	Tank battery	Process	$1,047,000	556
13	Tank battery	Process	$4,746,000	499
14	Chemical plant	Process	$10,000,000	316
15	Chemical plant	Process	$3,800,000	223
16	Power generation	Non-Process	$5,830,000	100
17	Warehouse	Non-Process	$561,571	282
18	Pipeline meter station	Non-Process	$556,889	126
19	Pipeline delivery meter station	Non-Process	$625,000	134
20	Petrochemical	Process	$4,060,000	166
21	Petrochemical	Process	$4,868,897	177
22	Crude oil terminal	Non-Process	$7,476,247	774
23	Refinery	Non-Process	$11,100,000	217
24	Refinery	Process	$20,030,000	383
25	Refinery	Process	$4,073,646	313
26	Refinery	Process	$1,318,510	174
27	Refinery	Process	$1,483,240	146
28	Power generation	Process	$7,000,000	402
29	Chemical plant	Process	$361,000	170
30	Chemical plant	Process	$1,810,000	130
31	Chilled water refrigeration plant	Non-Process	$883,083	237
32	Steam plant	Process	$1,939,000	264
33	Food processing	Process	$1,729,557	93
34	Food processing	Process	$4,998,564	166
35	Brewery	Non-Process	$530,000	166
36	Agricultural	Non-Process	$93,000	176
37	Power generation	Process	$2,382,540	214
38	Power generation	Process	$3,337,000	373
39	Oil and gas recovery site	Process	$20,500,000	264
40	Oil and gas production facility	Process	$2,041,307	389
	Total Project Expenditure		**$151,770,118**	
	Average Project Expenditure		**$3,794,253**	

7.1.3. Project Performance Analysis

The author sought to determine what a "good" PDRI score would be, where "good" meant a score threshold (i.e., level of scope definition) that a project team should achieve prior to moving a small industrial project forward into detailed design. Three separate project performance factors (e.g., schedule, cost, change) were calculated and compared to each project's corresponding PDRI score at five separate scoring thresholds (e.g., 150, 200, 250, 300, 350) to discern if and how project performance changed as PDRI scores increased. The author calculated schedule, cost, and change performance of the projects in the sample using the following formulas:

$$Schedule\ Performance = \frac{Actual\ Project\ Duration - Planned\ Project\ Duration}{Planned\ Project\ Duration}$$

Where:

$$Actual\ Project\ Duration = Actual\ Date\ of\ Mechanical\ Completion - Actual\ Project\ Start\ Date$$

$$Planed\ Project\ Duration = Planned\ Date\ of\ Mechanical\ Completion - Planned\ Project\ Start\ Date$$

$$Cost\ Performance = \frac{Actual\ Project\ Cost - Budgeted\ Project\ Cost}{Budgeted\ Project\ Cost}$$

$$Change\ Performance = \frac{Positive\ Change\ Orders + \ |Negative\ Change\ Orders|}{Actual\ Project\ Cost}$$

The positive change order costs added to the absolute value of negative change order costs was calculated to determine the total change order costs on the projects. Calculating the total change order costs in this manor allowed the research team to discern the total cost "turbulence" (i.e., additions and subtractions) of the projects.

The results of the analysis are shown in Table 7-2. The values shown in Table 7-1 are averages of the project performance factors for the projects included in each group (i.e., the projects with scores above and below each threshold). As shown, projects that scored above and below the 300-point PDRI score threshold had the biggest difference in cost and schedule performance of any of the thresholds tested. A 15 percent difference in schedule performance was shown between projects scoring above and below 300, and a 16 percent cost performance difference was shown. Change performance for the 150 and 300 categories showed equal differences (i.e., three percent) for projects scoring above and below the PDRI score thresholds.

Table 7-2. PDRI Scores vs. Project Performance Factors

	Normalized PDRI Score									
	< 150	> 150	< 200	> 200	< 250	> 250	**< 300**	**> 300**	< 350	> 350
Schedule Performance	-11%	18%	8%	16%	5%	20%	**7%**	**22%**	11%	17%
Cost Performance	-3%	6%	-5%	10%	-2%	11%	**-2%**	**14%**	1%	11%
Change Performance	12%	15%	14%	15%	13%	15%	**13%**	**16%**	14%	14%
n	7	33	15	25	20	20	**24**	**16**	29	11

The author utilized independent samples t-tests, boxplots, and regression analysis to determine if a statistical difference existed between project scoring above and below the 300-point PDRI score threshold. The next few sections describe this analysis.

7.1.3.1. Project Performance vs. PDRI Scores using Independent Samples t-tests

Figure 7-2 provides the independent samples t-test results from SPSS™, which was performed to determine if a statistical difference existed between the schedule, cost and, change performances of the two groups (e.g., projects with PDRI scores above 300, projects with PDRI score below 300). As shown, the variances were assumed to be equal for all three project performance factors based on the results of the Levene's test (p values = .090, .087, and .616, respectively), but only cost performance showed a statistical difference between the two groups based on a p-value of .025 (p-values less than .05 denote statistical difference for a 95% confidence interval). Schedule performance had a p-value of .345, and change performance had a p-value of .612.

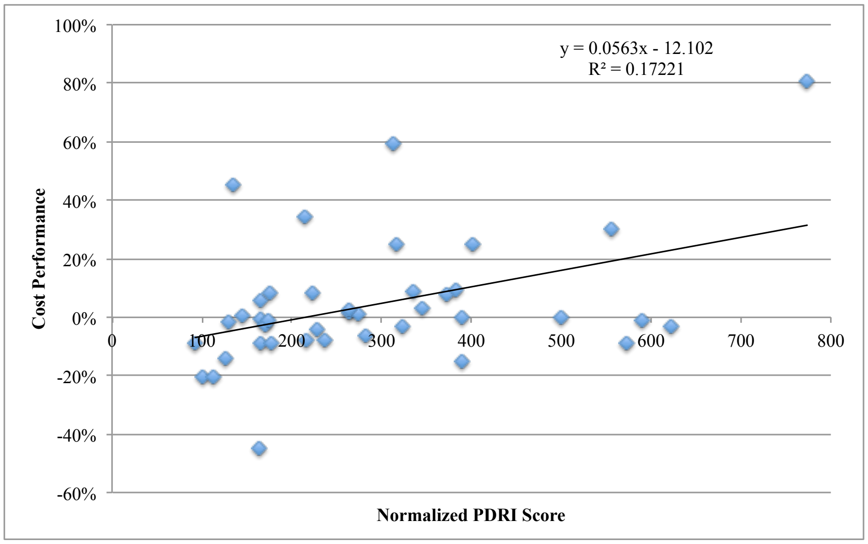
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Schedule Performance	Equal variances assumed	3.022	.090	-.956	38	.345	-.15423	.16138	-.48093	.17247
	Equal variances not assumed			-.860	21.517	.399	-.15423	.17935	-.52667	.21820
Cost Performance	Equal variances assumed	3.096	.087	-2.339	38	.025	-.15756	.06737	-.29394	-.02117
	Equal variances not assumed			-2.162	23.923	.041	-.15756	.07287	-.30797	-.00714
Change Performance	Equal variances assumed	.256	.616	-.512	38	.612	-.02704	.05283	-.13398	.07991
	Equal variances not assumed			-.492	27.965	.626	-.02704	.05492	-.13955	.08547

Figure 7-2. Independent Samples t-test Results for Schedule, Cost, and Change Performance at the 300 Point PDRI Score Cutoff

7.1.3.2. Project Performance vs. PDRI Scores using Regression Analysis

The author completed a regression analysis to compare the cost performance factors of the sample projects against their normalized PDRI scores to discern if a linear relationship existed between the variables. Cost performance was considered the dependent variable, and the associated PDRI score was considered the independent variable. Regression analysis was also used to test the hypothesis that a lower PDRI score indicates sufficient scope definition, which leads to improved project performance. Improved project performance could also be considered less variable project performance. The distribution of performance factors for projects with lower PDRI scores should be tighter. As PDRI scores rise, so would the variability in project performance, leading to a wider distribution of project performance factors.

Figure 7-3 provides the summary of the regression analysis and Analysis of Variance (ANOVA) for cost performance. The r-value of .415 indicates that there is a positive correlation between PDRI score and cost performance. The r^2 value of 0.173 indicates that approximately 17 percent of the variability in the cost performance is explained by the PDRI score, meaning that over 80 percent of the variability is not explained by the PDRI score. The p-value of .008 corresponding to the f-test in the ANOVA table indicates that the regression is significant at a 95% confidence level (p-values less than .05 denote statistical difference for a 95% confidence interval). The author performed regression analysis to compare schedule and change performance factors vs. PDRI scores as well, but the results were not found to be statistically significant, same as the independent samples t-test results from the previous section.



Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.415[a]	.173	.151	.20310

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.327	1	.327	7.922	.008[b]
	Residual	1.567	38	.041		
	Total	1.894	39			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.121	.066		-1.827	.076
	PDRI Score	.001	.000	.415	2.815	.008

Figure 7-3. Cost Performance Regression Analysis Summary

7.1.4. Change Performance (Alternative Method)

The author tested an alternative method for change performance due to the minimal difference shown in the base analysis method. Change order costs and actual project costs (at completion of the projects) taken from the testing questionnaires were used to derive alternative change performance factors for each submitted completed projects. The alternative method change performance was calculated as:

$$Change\ Performance = \frac{Positive\ Change\ Orders + \ Negative\ Change\ Orders}{Actual\ Project\ Cost}$$

The positive change order costs added to the negative change order costs was calculated to determine the actual change order costs on the projects. The method was chosen as total project changes are typically summed in this fashion when calculating the final total installed cost of a project, where:

$$Final\ Total\ Installed\ Cost$$
$$= Original\ total\ installed\ cost + actual\ change\ order\ costs$$

The alternative change performance factors were summed for projects scoring above and below the 300 point PDRI score cutoff, and a mean value of the alternative change performance factors was calculated. Completed projects scoring below 300 averaged total change orders of 4 percent of the final project cost, and projects scoring above 300 averaged total change orders of 12 percent of the final project cost, a ±8 percent mean change performance difference. Figure 7-4 provides the alternative change performance independent samples t-test results from SPSS™, which was performed to determine if a statistical difference existed between the change performances of the two groups. As shown, the variances were assumed to be equal based on the results of the Levene's test (p value = .769), but there was not a statistical difference at a 95%

confidence interval between the two groups based on the p-value of .136 (p-values less than .05 denote statistical difference for a 95% confidence interval).

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper
Change Performance (Alternative Method)	Equal variances assumed	.087	.769	-1.524	38	.136	-.08206	.05385	-.19107	.02695
	Equal variances not assumed			-1.609	37.211	.116	-.08206	.05100	-.18539	.02126

Figure 7-4. Independent Samples t-test Results for Alternative Change Performance at the 300 Point PDRI Score Cutoff

7.1.5. Analysis of Project Financial Performance and Customer Satisfaction

The author sought to determine if lower PDRI scores (i.e., better scope definition) indicate better financial performance and customer satisfaction for the completed projects. Most volunteers that submitted completed project data noted in their questionnaires the project's financial performance and customer satisfaction, each on a scale of one to five. For financial performance, a score of one equated to the project falling far short of expectations at authorization, and a score of five equated to the project far exceeding expectations at authorization. For customer satisfaction, a score of one equated to the overall success of the project being very unsuccessful, and a score of five equated to the overall success of the project being very successful.

The financial performance and customer satisfaction ratings were summed for projects scoring above and below the 300 point PDRI score cutoff, and mean values of each were calculated. Figure 7-5 shows the comparison of the mean financial performance and customer satisfaction ratings for projects with PDRI scores above and below 300.

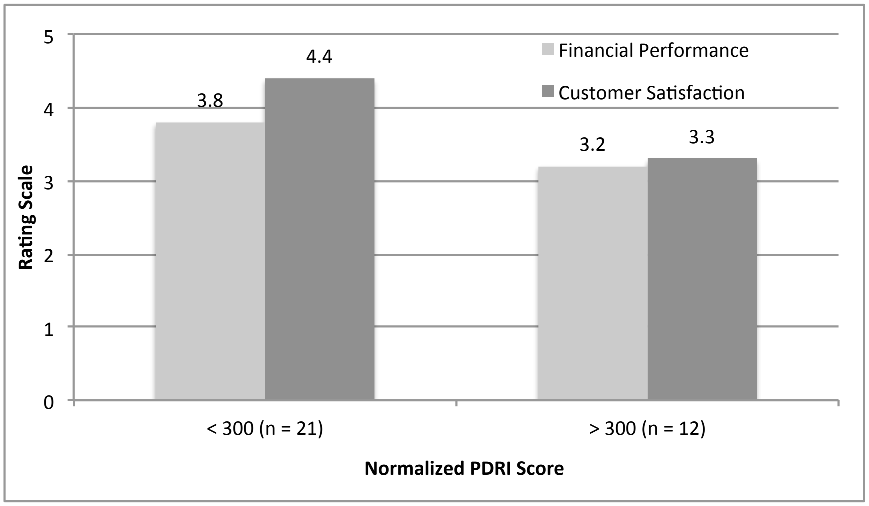


Figure 7-5. Average Financial Performance and Customer Satisfaction Rating by PDRI Score Grouping

Completed projects with PDRI scores below 300 had better mean financial performance and customer satisfaction ratings than projects with PDRI scores above 300, as shown in Figure 7-5. The author performed a Mann-Whitney U Test to determine if a statistical difference existed between the financial performance and customer satisfaction of the two groups. Figure 7-6 provides the Mann-Whitney U Test results from SPSS™. As shown, the financial performance rank-order differences were not a statistically different at a 95% confidence level between the two groups based on a calculated p-value of .191, but customer rank-order differences were statistically different at a 95 percent confidence level between the groups based on a calculated p-value of .016 (p-values less than .05 denote statistical difference for a 95% confidence interval).

Mann-Whitney Test

Ranks

		N	Mean Rank	Sum of Ranks
FinancialPerformance	1.00	19	17.63	335.00
	2.00	12	13.42	161.00
	Total	31		
CustomerSatisfaction	1.00	19	18.89	359.00
	2.00	12	11.42	137.00
	Total	31		

Test Statistics[a]

	Financial Performance	Customer Satisfaction
Mann-Whitney U	83.000	59.000
Wilcoxon W	161.000	137.000
Z	-1.308	-2.418
Asymp. Sig. (2-tailed)	.191	.016

Figure 7-6. Mann-Whitney U Test Results for Financial Performance and Customer Satisfaction at the 300 Point PDRI Score Cutoff

7.1.6. Summary of Completed Project Performance Evaluation

The results of the completed-project analysis showed that projects with PDRI scores lower than 300 outperform projects with PDRI scores above 300 regarding cost performance, schedule performance, change performance, financial performance, and customer satisfaction. Figure 7-7 summarizes the mean cost, schedule, and change performance factors for project with PDRI scores above and below 300.

	PDRI Score		
Performance	**< 300**	**> 300**	**Δ**
Cost	2% below budget	14% above budget	16%
Schedule	7% behind schedule	22% behind schedule	15%
Change Orders	13% of budget	16% of budget	3%
	(n=24)	(n=16)	

Figure 7-7. Summary of Cost, Schedule, and Change Performance at the 300 Point PDRI Score Cutoff

The independent samples t-test and regression analysis tests for cost performance were both statistically significant at a 95 percent confidence level. No statistically significant difference was found for schedule performance and change performance, with change performance calculated with two separate methods. The opinion of the author (corroborated by the research team) is that statistical significance was not found for schedule and change performance for two reasons. First, changes to project scope after front end planning is complete (both addition and deletion) can drastically affect even well-planned projects, as the original scope of small projects is limited and more sensitive to change. Second, concurrency of design and construction, which is typical of many small industrial projects, may play a role in schedule and change performance. Change orders will typically be necessary to complete projects to meet the owner's needs if the design intent is incomplete during front end planning.

Note that regression analysis was performed as part of the hypothesis testing; specifically, regression analysis tested the hypothesis that projects with lower PDRI scores indicate projects with better cost, schedule, and change performance. Regression analysis is a statistical method used to determine the dependency between two variables, and to understand the magnitude of their association (Wilcox 2009), as noted in Chapter 3. The greater the association, the closer the coefficient of determination, or r^2 value, will be to 1. Regression analysis may not be an accurate assessment method for this research, as it would be impossible to ever achieve an r^2 value at or close to 1 with the hypothesis that lower PDRI scores indicate projects with greater levels of scope definition, and higher PDRI scores indicate projects with lesser levels of scope definition. This is evidenced in Figure 7-3 showing the regression analysis of cost performance. The regression is statistically significant, but the r^2 value is .173, meaning that on 17 percent of the variability in the cost performance of the sample of completed projects is explained by the PDRI score.

Lesser scope definition would arguably equate to more variable cost, schedule, and change performance on projects, meaning that the distribution of performance factors would be wider as PDRI scores grow larger. With wider distributions of project performance, less of the variability can be explained through regression. The red dashed lines in Figure 7-8 highlight this point, showing the width of the 95% confidence intervals based on the regression equation calculated for cost performance. It would be expected that the distribution of cost performance factors would generally match these intervals if additional projects with PDRI scores greater than 400 were collected, analyzed, and plotted.

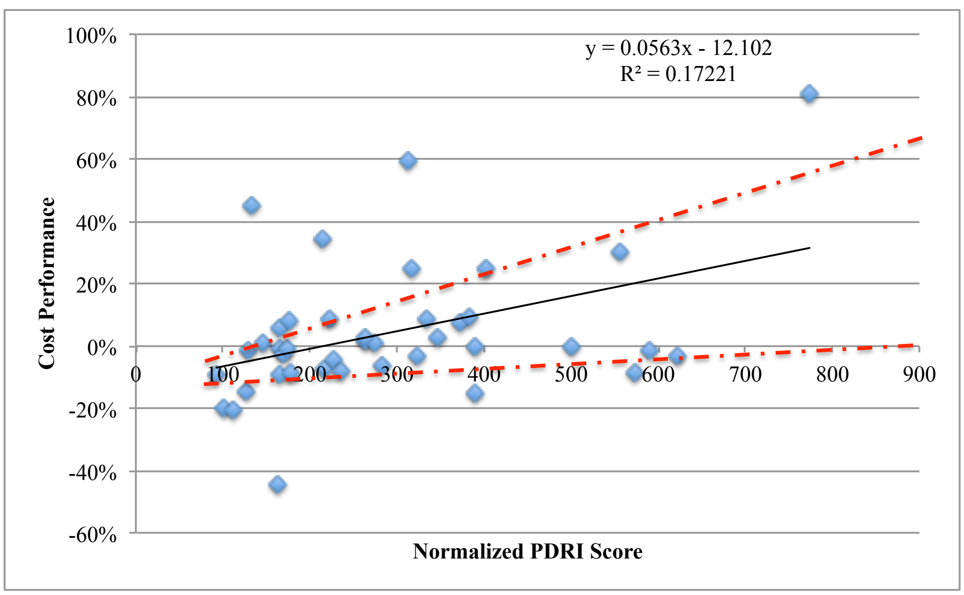


Figure 7-8. Regression Line and Confidence Intervals for Cost Performance

This point is further emphasized with the boxplots provided in Figure 7-9, showing the distribution of cost performance factors for sample projects with PDRI scores above and below 300. As shown, the distribution of cost performance values for sample projects with PDRI scores greater than 300 have a greater spread than the sample projects with PDRI scores lower than 300. In general, the cost performance factors for projects scoring above 300 are also higher than the projects scoring below 300, indicative of additional costs being necessary to complete projects with less scope definition.

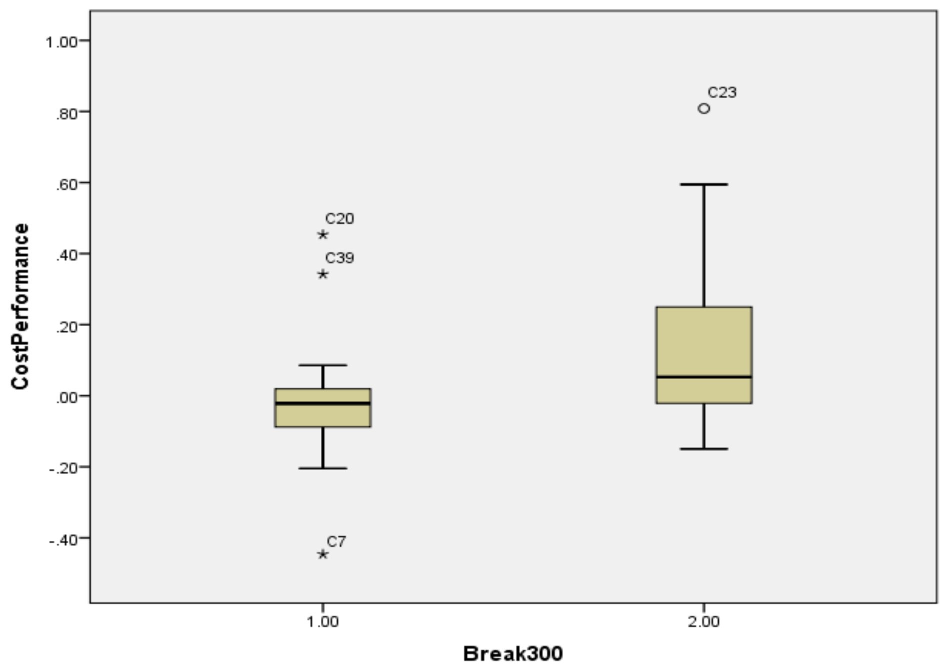


Figure 7-9. Boxplot of Cost Performance at 300-point PDRI Score Breakpoint

7.2. In-Progress Projects

The author created a separate multi-part questionnaire to observe the effectiveness of the PDRI tool to develop a scope definition package on projects currently in the front end planning phase, and distributed it electronically to the same potential volunteers as the completed projects questionnaire. In total, the tool was used to assess scope definition of 14 separate small industrial projects by eight organizations. Table 7-3 lists the projects, which comprise budgeted total project expenditure of approximately US $50 million. The projects covered an array of industrial facility types, with budgeted costs ranging from $122,000 to nearly US $15 million.

Table 7-3. In-Progress Projects Used During Testing of the PDRI-Small Industrial

Project Number	Project Facility Type	Process or Non-Process Related	Total Installed Cost (Estimated)	PDRI Score
1	Utility generation (i.e., steam, chilled water)	Process	$335,706	165
2	Pharmaceutical manufacturing	Process	$5,000,000	453
3	Chemical manufacturing	Process	$122,000	759
4	Pipeline pump station	Non-Process	$1,219,453	451
5	Natural gas processing	Process	$140,000	285
6	Manufacturing	Non-Process	$2,670,000	190
7	Manufacturing	Process	$14,730,000	184
8	Pharmaceutical manufacturing	Process	$4,500,000	196
9	Copper processing facility	Non-Process	$300,000	428
10	Pipeline meter station	Non-Process	$2,800,000	70
11	Pharmaceutical manufacturing	Process	$9,000,000	252
12	Manufacturing	Process	$5,000,000	168
13	Food processing	Process	$1,000,000	81
14	Food processing	Process	$3,570,132	116
	Total Project Expenditure		**$50,387,291**	
	Average Project Expenditure		**$3,599,092**	

The author analyzed each of the complete questionnaires, and found that the timing of use for all of the projects was either at the end of the front end planning process, or early in the detailed design process. The average time to complete a project assessment was 1.3 hours, with an average of 4 individuals in each assessment. The author also found that the overall feedback from users was extremely positive. Users noted that the tool performed well in identifying critical risk issues during the front end planning process, and spurred important conversations about elements not yet considered by the project teams. Overwhelmingly, users felt that the element descriptions were sufficient to assess a typical small industrial projects, that assessing a project with the tool added value to the front end planning process, and that they would use the tool again to assess a future project. One user noted that the tool "not only provided for a structured process to assess the status of project scope definition and execution readiness, it also assisted the team in bringing newly assigned individuals on the project up to speed on the project scope and status, as well as gaining alignment with the team on the project plan." Another user stated that "My first reaction was – this is going to take a long time…I picked it up and realized it wasn't complicated at all. I like (the tool) because it is easy and straight forward."

7.3. Summary

The research team collected data on 54 completed and in-progress projects with an overall expenditure of over US $200 million to test the efficacy of the PDRI-Small Industrial tool. The data showed a difference regarding schedule, cost, change, and financial performance, and customer satisfaction on projects with PDRI scores below 300. The research team determined that a project scoring below 300 would be appropriate to move forward into detailed design based on two factors:

- The 300-point cutoff had the greatest percentage difference (between projects scoring above and below the mark) in schedule, cost, and change performance of any of the score levels tested, based on the performance factors of the sample projects used during the testing process.

- The 300-point cutoff had the greatest statistical difference (between projects scoring above and below the mark) in cost performance of any of the score levels tested, based on the performance factors of the sample projects used during the testing process.

It should be noted that this score differs from the PDRI-Industrial, PDRI-Buildings, and PDRI-Infrastructure tools which all suggest a 200 point PDRI score cutoff as being appropriate to move a project forward into detailed design.

Users of the tool on in-progress projects stated that the tool added value to their front end planning process, that they would use the tool again in the future, and that assessment times were much shorter (i.e., 1.3 hours) than typical assessment times when using the PDRI-Industrial, which typically take 2 to 5 hours to complete.

Several limitations exist with this data analysis, as with any data analysis. A majority of the data collected and used for this analysis came from individuals who were asked to refer back to a point in time just prior to the start of detailed design on their chosen projects, which may have been weeks, months, or even years prior to the testing questionnaire being completed. This method may have led to slightly inaccurate information due to memory lapse of the project participants during that time period. Having knowledge of the actual project outcomes may also have biased the respondent's answers to be more favorable. Also, the sample of completed projects used in this analysis is relatively small as compared to the total population of small industrial projects completed each year across the globe, which easily numbers in the thousands.

CHAPTER 8. COMPARISON OF THE PDRI-INDUSTRIAL VS. THE PDRI-SMALL INDUSTRIAL

The research team utilized the PDRI-Industrial as a baseline to develop the PDRI-Small Industrial. This chapter provides a detailed comparison completed by the author of the PDRI-Industrial versus the PDRI-Small Industrial tools.

8.1. Methodology

The methodology for the qualitative and quantitative comparison of the tools consisted of 3 steps, including:

1. The element descriptions from each tool were analyzed for content to determine how the research team revised, combined, changed, or deleted elements from the PDRI-Industrial when developing the element descriptions for the PDRI-Small Industrial.
2. The element descriptions were analyzed to determine if structural differences existed between the two tools, such as number of sections, categories, elements, words, and bullets.
3. The element weighting within each tool was analyzed, including the top eight highest weighted elements within each tool, and the weighting of each tool's sections.

8.2. Content Analysis

Table 8-1 summarizes the 21 elements that are titled the same, or nearly the same, between the PDRI-Industrial and the PDRI-Small Industrial. The left-hand side of the table provides the element number and title included in the PDRI-Small Industrial, and the right-hand side of the table provides the corresponding element from the PDRI-

Industrial. It should be noted that none of the element descriptions themselves are exactly the same between the two tools. The element descriptions from the PDRI-Industrial were thoroughly reviewed by the research team to ensure their applicability to small industrial projects, and updated accordingly.

Table 8-1. Common Elements

PDRI-Small Industrial		PDRI-Industrial	
A.1	Project Objectives Statement	D.1	Project Objectives Statement
B.1	Products	B.1	Products
B.2	Capacities	B.5	Capacities
B.3	Processes	C.2	Processes
B.4	Technology	C.1	Technology
C.1	Lead/Discipline Scope of Work	D.5	Lead/Discipline Scope of Work
C.5	Construction Input	E.3	Design for Constructability Analysis
D.1	Process Safety Management (PSM)	G.4	Process Safety Management
D.4	Piping System Stress Analysis	G.7	Piping System Requirements
D.5	Equipment Location Drawings	H.2	Equipment Location Drawings
E.1	Control Philosophy	K.1	Control Philosophy
E.2	Func. Descrip. and Control Narratives	K.2	Logic Diagrams
E.3	Electrical Single Line Diagrams	K.5	Electric Single Line Diagrams
F.1	Site Plan	G.8	Plot Plan
F.2	Loading/Unloading/Storage Req.	J.2	Loading/Unloading/Storage Fac. Req.
F.3	Transportation Requirements	J.3	Transportation Requirements
G.2	Owner Approval Requirements	P.1	Owner Approval Requirements
G.3	Distribution Matrix	M.3	Distribution Matrix
G.4	Risk Management Plan	N.3	Risk Analysis
G.5	Shutdown/Turnaround Requirements	P.3	Shut down/Turn-Around Requirements
H.1	Engineering/Construction Methodology	P.2	Engineering/Construct. Plan & Approach

Table 8-2 lists 18 elements from the PDRI-Small Industrial that were developed through combining elements from the PDRI-Industrial, or where the crux of an element from the PDRI-Industrial was used to develop a new element. The left-hand side of the table provides the element number and title included in the PDRI-Small Industrial, and the right-hand side of the table provides the elements from the PDRI-Industrial that were combined and/or utilized to develop the PDRI-Small Industrial elements. Some of the element descriptions and “Items to be Considered” bullets from the PDRI-Industrial

Projects, such as those in D.3 Site Characteristics Available vs. Required, were used to develop more than one element in the PDRI-Small Industrial.

Table 8-2. Combined Elements

PDRI-Small Industrial		PDRI-Industrial	
A.2	Project Strategy and Scope of Work	B.2	Market Strategy
		B.3	Project Strategy
A.3	Project Philosophies	A.1	Reliability Philosophy
		A.2	Maintenance Philosophy
		A.3	Operating Philosophy
		B.7	Expected Project Life Cycle
A.4	Location	F.1	Site Location
		B.8	Social Issues
		B.6	Future Expansion Considerations
		D.3	Site Characteristics Avail. vs. Req.
B.5	Physical Site	D.3	Site Characteristics Avail. vs. Req.
C.2	Project Design Criteria	D.2	Project Design Criteria
		K.3	Electrical Area Classifications
		B.6	Future Expansion Considerations
		F.4	Permit Requirements
C.3	Project Site Assessment	F.2	Surveys & Soil Tests
		F.3	Environmental Assessment
		F.5	Utility Sources with Supply Conditions
C.4	Specifications	G.6	Specifications
		I.1	Civil/Structural Requirements
		I.2	Architectural Requirements
D.2	Process Flow Diagrams along with Heat and Material Balance	G.1	Process Flow Sheets
		G.2	Heat & Material Balances
D.3	Piping and Instrumentation Diagrams	G.3	Piping and Instrumentation Diagrams
		G.5	Utility Flow Diagrams
D.6	Critical Process/Product Items Lists	G.9	Mechanical Equipment List
		G.10	Line List
		G.11	Tie-In List
		G.12	Piping Specialty Items List
		G.13	Instrument Index
		H.1	Equipment Status
		H.3	Equipment Utility Requirements
E.4	Critical Electrical Items Lists	K.6	Instrument & Electrical Specifications
		K.4	Substation Req. Power Sources Identified
F.4	Additional Project Requirements	D.4	Dismantling and Demolition Requirements
		F.6	Fire Protection & Safety Considerations
		I.1	Civil/Structural Requirements
		I.2	Architectural Requirements
		J.1	Water Treatment Requirements
G.1	Procurement Plan	L.1	Identify Long Lead/Critical Equip. & Mat.
		L.2	Procurement Procedures and Plans
		L.3	Procurement Responsibility Matrix
G.6	Precommissioning, Startup, & Turnover Sequence Requirements	P.4	Pre-Commissioning Turnover Seq. Req.
		P.5	Startup Requirements
		P.6	Training Requirements
H.3	Project Accounting and Cost Control	N.2	Project Accounting Requirements
		N.1	Project Control Requirements
H.4	Project Schedule and Schedule Control	D.6	Project Schedule
		N.1	Project Control Requirements
H.6	Deliverables for Design and Construction	M.2	Deliverables Defined
		M.1	CADD/Model Requirements
H.7	Del. for Project Commissioning/Closeout	M.2	Deliverables Defined

Three elements from the PDRI-Industrial Projects were not directly included in the PDRI-Small Industrial: B.4 Affordability/Feasibility, E.1 Process Simplification, and E.2 Design & Material Alternatives. The PDRI-Small Industrial has two new elements that were developed independently of the PDRI-Industrial: H.2 Project Cost Estimate, and H.5 Project Change Control.

8.3. Structural Analysis

Table 8-3 summarizes a structural comparison of the elements within the PDRI-Industrial and PDRI-Small Industrial. As shown, the only item that is exactly the same between the two tools is the number of sections, both equaling three. The number of categories, elements, and pages of element descriptions in the PDRI-Small Industrial are all significantly lower than the PDRI-Industrial. The greatest reduction in the number of elements is in Section I, with 59 percent fewer elements in the PDRI-Small Industrial than in the PDRI-Industrial. The amount of element description words, “Items to be Considered” bullets, elements with R&R sections, and R&R bullets are also all fewer in the PDRI-Small Industrial.

Table 8-3. Quantitative Comparison of Element Descriptions

	PDRI-Industrial	PDRI-Small Industrial	Δ	Percent Change
Overall Comparison				
Number of Sections	3	3	0	0%
Number of Categories	15	8	-7	-47%
Number of Elements	70	41	-29	-41%
Number of Pages of Element Descriptions	44	25	-19	-43%
Elements per Section Comparison				
Section I	22	9	-13	-59%
Section II	33	19	-14	-42%
Section III	15	13	-2	-13%
Text Comparison				
Element Description Words	2,327	1,656	-671	-29%
Average Words Per Element	*33.2*	*40.4*	*7.1*	*22%*
"Items to be Considered" Bullets	703	309	-394	-56%
Average Bullets Per Element	*10.0*	*7.5*	*-2.5*	*-25%*
Renovation and Revamp Comparison				
Elements with R&R Items	37	25	-12	-32%
Number of R&R Bullets	104	59	-45	-43%
Average Bullets Per Element	*2.8*	*2.4*	*-0.4*	*-16%*

8.4. Weighting Analysis

Figure 8-1 provides a comparison of the top eight highest weighted elements within the PDRI-Industrial, and the PDRI-Small Industrial. As shown, only two of the highest weighted elements are common to both tools: Capacities, and Piping and Instrumentation Diagrams. The top eight highest weighted elements in the PDRI for Industrial Projects account for 333 points, or approximately 36 percent (333 out of 930 total points) of the total points. The top eight highest weighted elements in the PDRI for Small Industrial Projects account for 295 points, or approximately 32 percent (295 out of 930 total points) of the total points. Five of the eight highest weighted elements in both tools are included in Section I. The three remaining highest weighted element in the PDRI-Industrial are all included in Section II. Only one of the three remaining highest weighted elements in the PDRI-Small Industrial is in Section II, while the other two elements are in Section III.

PDRI-Industrial

Rank	Element	Element Description	Definition Level 5 Weights	Section
1	B.1	Products	56	I
2	B.5	Capacities	55	I
3	C.1	Technology	54	I
4	C.2	Processes	40	I
5	G.1	Process Flow Sheets	36	II
6	F.1	Site Location	32	II
7	G.3	Piping and Instrumentation Diagrams	31	II
8	D.3	Site Characteristics Available vs. Required	29	I
		Total	333	

PDRI-Small Industrial

Rank	Element	Element Description	Definition Level 5 Weights	Section
1	A.1	Project Objectives Statement	47	I
2	A.2	Project Strategy and Scope of Work	45	I
3	H.2	Project Cost Estimate	39	III
4	D.3	Piping and Instrumentation Diagrams (P&ID's)	36	II
	A.4	Location	36	I
6	G.5	Shutdown/Turnaround Requirements	32	III
7	B.2	Capacities	31	I
8	C.3	Project Site Assessment	29	I
		Total	295	

Figure 8-1. Comparison of Top Eight Highest Weighted Elements

Table 8-4 provides a comparison of the section weights of the PDRI-Industrial and the PDRI-Small Industrial. As shown, Section I of the PDRI-Small Industrial has 42 percent lower total weight than the PDRI-Industrial, while Section II of both tools is approximately the same. The weight of section III of the PDRI-Small Industrial is 268 percent higher than the PDRI-Industrial.

Table 8-4. Comparison of Section Weights

Section	PDRI-Industrial	PDRI-Small Industrial	Δ	Percent Change
I - Basis of Project Decision	499	288	-211	-42%
II - Basis of Design	423	425	2	0.5%
III - Execution Approach	78	287	209	268%

8.5. Discussion of Qualitative and Quantitative Analysis

Over half of the elements within the PDRI-Small Industrial are also included in the PDRI-Industrial, and a majority of the remaining elements were developed by combining elements (or parts of elements) from the PDRI-Industrial. This shows that many of the aspects of industrial projects to be considered during front end planning are the same for both large and small projects. The biggest difference between planning for small projects as opposed to large projects is the level of rigor needed to completely address each pertinent element. As shown in Table 8-3, the PDRI-Small Industrial is much less granular than the PDRI-Industrial, with 41 percent less elements, 43 percent less pages of element descriptions, and 56 percent less "Items to be Considered" bullets. The research team developed the PDRI-Small Industrial to be less granular intentionally, as small projects are less complex than large projects, hence the front end planning efforts can be more concise. An objective of the research team was also to shorten the amount of time needed to complete a PDRI assessment, as project teams routinely have less time to plan for small industrial projects. The shorter, yet still sufficiently detailed tool, meets this objective.

Certain issues that are pertinent to large industrial projects were shown to still be pertinent to small industrial projects, but to a much lesser degree. For example, Element

B.8 Social Issues, is a separate element in the PDRI-Industrial. Social issues are still addressed in the PDRI-Small Industrial, but as part of an "Items to be considered" bullet in element A.4 Location. The research team felt this to be sufficient when creating the element descriptions, as on large industrial projects, social issues can be a "show-stopper" if not sufficiently addressed and planned for. This may possibly be an issue on a small industrial project as well, which is why it is included in the tool, but typically is not the case. Several elements from the PDRI-Industrial were also used in combination to develop new elements in the PDRI for Industrial Projects. For example, Elements G.6 Specifications, I.1 Civil/Structural Requirements, and I.2 Architectural Requirements from the PDRI-Industrial were condensed and combined to create element C.4 Specifications in the PDRI-Small Industrial Projects. This was done for two reasons. First, each of the elements could be pertinent to small industrial projects, but to a much lesser degree, similar to social issues. Secondly, the elements were combined so that these issues could be discussed/considered simultaneously when planning for small industrial projects.

Three elements in the PDRI-Industrial were not carried over to the PDRI-Small Industrial, namely B.4 Affordability/Feasibility, E.1 Process Simplification, and E.2 Design and Material Alternatives Considered/Rejected. The essence of the three elements is to ensure that project teams are considering alternative methods/materials when designing and constructing a new production facility, with the intent to improve project or operating performance through altering the project scope. The research team did not include these elements in the PDRI-Small Industrial, as alternative methods/materials would most likely not be feasible due to the limited amount of project scope inherent to small industrial projects.

The PDRI-Small Industrial has two elements not included in the PDRI-Industrial, namely H.2 Project Cost Estimate, and H.5 Project Change Control. Elements pertaining to cost estimates were included in the PDRI-Building and the PDRI-Infrastructure when those tools were developed. The research team felt it appropriate to include an element for cost estimate in the PDRI-Small Industrial as well. It was also suggested that a cost estimate element be added to the PDRI-Industrial during a future revision of the tool. The research team added an element for change control, as small projects are very sensitive to changes after the start of construction, due to having limited cost, scope, and schedule. Having a structured process for managing change was determined to be essential to keep small projects on track for successful completion. The same could be said about large industrial projects as well, the difference being that large projects with longer schedules have more time to recover from project changes.

The PDRI-Small Industrial has 25 elements with R&R sections, 32 percent lower than the PDRI-Industrial. Overall, the R&R sections are more pronounced in the PDRI-Small Industrial though, with 61 percent (25 out of 41) of the elements having R&R mention, as opposed to 53 percent (37 out of 70) in the PDRI-Industrial. The PDRI-Small Industrial also has 12 elements that include items to be considered for projects that are part of a repetitive program, a project trait often typical of small industrial projects, but not large industrial projects.

Figure 8-1 provides the top eight highest weighted elements in each tool, and shows that only two elements are on both of the lists. This finding highlights the value of the weighting workshops utilized by the research team to prioritize the elements. If a separate method had been used to prioritize the elements, such as attempting to use the weights within the PDRI-Industrial to weight the elements within the PDRI-Small Industrial, the key elements to consider specifically for small industrial projects would not have been prioritized correctly.

The section-weight differences shown in Figure 8-4 highlight how the planning focus differs between small and large industrial projects. The elements in Section I of both tools focus on “why” the project is happening, and the elements in Section III focus on “how” the project will get done. Section I in the PDRI-Small Industrial tool is weighted over 200-points lower than the PDRI-Industrial, all of which essentially moved to Section III. These results make sense, as many small industrial projects are not optional; they must be completed to meet financial, maintenance, or regulatory project drivers imposed on or by an organization. As the projects are set, the focus shifts away from “why” the project is happening to “how” the project can be completed in a safe, timely, and financially effective manner. Shorter project timeframes also provide less time to react to problems that may arise during construction; hence increased execution planning can greatly project performance.

8.6. Summary

This chapter summarizes a comparison between the PDRI-Industrial and the PDRI-Small Industrial. The two tools were found by the author to be complementary, but the PDRI-Small Industrial was designed to match the structural differences, timing differences, and lower complexity of typical small industrial projects. The PDRI-Small Industrial is much less granular than the PDRI-Industrial, which was an objective of the research team. The element weighting within the PDRI-Small Industrial shows the enhanced focus towards planning for project execution over project feasibility typical of small industrial projects.

CHAPTER 9. INDUSTRIAL PROJECT DEFINITION RATING INDEX (PDRI) SELECTION GUIDE

An imperative for the research team was providing a method for PDRI users to choose the appropriate tool for use on an industrial project: the PDRI-Industrial, or the PDRI-Small Industrial. The author determined that additional investigation should be completed regarding project complexity, based on the comments provided by the survey respondents described in Chapter 5.

Project complexity literature (discussed in Appendix G) shows that a project's technical, organizational, and environmental factors most affect its complexity, and that project complexity is driven by unknowns regarding differentiation and interdependence of project units, the project schedule, project size, and the novelty of certain project scope items. The author proposes a new definition of project complexity based on the existing literature. Project complexity is defined as:

> *The uncertainty of project teams to achieve success based on inherent technical (i.e., scope), organizational (i.e., structure), and environmental (i.e., context) project characteristics. The intensity, or level, of complexity, is driven by unknowns concerning the differentiation and interdependence of project units and stakeholders, the size or scale of the project, the speed of the project schedule, and the novelty of the project (or parts of the project) to the team itself. The measurement of complexity is subjective, and is not constant from team to team, or project to project. Levels of complexity are dynamic throughout the project lifecycle, but are best managed through early identification and effective planning.*

PDRI tools address all three of the inherent project characteristics. Project specific scope, organizational structure, and environment are addressed within the element descriptions, and prioritized with the associated element weightings. PDRI assessments are meant to foster discussion and alignment amongst project team members regarding project goals and objectives, hence mitigating the potential "unknowns" that could arise during construction very early in the project life cycle.

The author hypothesized that large projects are typically more complex than small projects. Large projects have more substantial scope than small projects, leading to the possibility of a greater number of unknowns between interrelated units (i.e., stakeholders) of the project, both within and outside of the owner's organization. Stakeholders can include project managers and engineers, contractors and subcontractors, suppliers, internal governance groups or boards, and regulatory agencies. The next few sections describe the project complexity questionnaire utilized to collect industrial project data, analysis of the project data, and development of an index-based selection guide for the industrial-focused PDRI tools based on indicators of project complexity.

9.1. Project Complexity Questionnaire

The author developed a multi-part questionnaire (included in Appendix D) of open and closed-ended questions to collect information regarding attributes of completed industrial projects, both large and small. The questionnaires for small projects and large projects were identical, other than labeling (i.e., Sample SMALL Project Information Sheet, Sample LARGE Project Information Sheet), and included questions regarding:

- Project background information (project name, industry, description of project)
- Type of work (new construction, renovation, both)
- Total installed cost (in US dollars)
- Construction duration (in months)
- Project contingency (dollar amount budgeted, dollar amount used)

- Level of funding approval (local, regional, corporate, board of directors)
- Engineering specialties required to design the project (number)
- Impact on facility operations/production (minimal, significant)
- Production shutdown required (yes/no)
- Visibility of the project to owner management (none, minimal, significant)
- Core team members involved (number)
- Availability of core team members (part-time, full-time, combination of both)
- New or unfamiliar technology involved (yes/no)
- Level of permitting required (none, minimal, significant)
- Types of permits required (none, local, national, combination)
- Separate trade contractors (number)
- Project delivery method (design-bid-build, EPC, other)
- Planning process used (none, ad-hoc, structured)
- Time spent planning project (weeks)
- Individuals involved in planning (number)
- Success of the project (scale of 1 to 5)

9.1.1. Questionnaire Sample Selection and Administration

The timing of the questionnaire development was just prior to the start of the PDRI weighting workshops described in Chapter 6. The author determined that the individuals participating in the weighting workshops would be appropriate for completing the project complexity questionnaires. The author distributed the questionnaires to the workshop participants via email as part of the informational packets they received prior to the workshop sessions. The author asked that the participants complete the questionnaires ahead of the workshop sessions, and bring with them to the sessions themselves. Hard copies of the questionnaires were also provided during the workshop sessions, and time allotted to complete the questionnaires for individuals that had not completed them before the sessions.

9.1.2. Questionnaire Responses

In total, workshop participants provided data on 98 projects. The projects submitted covered a vast range of project costs, scopes, industries, and locations. The author reviewed the project complexity questionnaires for completeness after each workshop. Questionnaires for eight of the projects were found to either be incomplete, or for projects that would drastically skew the data analysis due to their substantial project cost (i.e., greater than US $1 billion. The remaining 90 projects (with combined project expenditure totaling over $2.7 billion) were deemed to be satisfactory, and were compiled for analysis. The author also determined that in lieu of analyzing the small projects and large projects separately, all of the projects would be combined for analysis.

The author compiled the project data into a Microsoft Excel spreadsheet for analysis. Projects were divided into six separate categories based on their total installed costs, in US $5 million increments. The author segregated the project data in this fashion to determine if differences existed between the categories based on the mean values of the project attributes for projects within each category. Table 9-1 provides a summary of the nine project attributes that showed the greatest ranges across the cost categories, as well as the number of projects in each category. The values shown for total installed cost, construction duration, number of core team members, and number of separate trade contractors are the mean values of the projects in each category. For example, the mean construction duration (in months) for projects with total installed cost less than $5 million was 4.54 months. The values shown for level of funding approval, visibility of the project to owner management, availability of core team resources, level of permitting required, and types of permits required are percentage values of the number of projects in each category that aligned with each possible answer within the attribute. For example, 39.3 percent of projects with total installed cost less than $5 million required local funding approval, while 25 percent required regional funding approval.

Table 9-1. Project Complexity Indicators and Associated Value Ranges

		All Projects	<= $5m	>5m - $10m	>$10m - $15m	>$15m - $20m	>$20m - $25m	Over $25m
Number of Projects		90	28	23	4	2	2	31
Total Installed Cost (in millions)		$38.65	$1.84	$8.65	$13.75	$18.0	$25.0	$99.58
Construction Duration (in months)		9.07	4.54	7.33	11.50	5.50	6.00	14.35
Number of Core Team Members (each)		14.80	8.21	9.91	9.50	23.50	10.00	24.71
Number of Separate Trade Contractors (each)		5.69	3.18	5.05	4.25	3.00	4.00	9.33
Level of Funding Approval	Local	16.7%	39.3%	17.4%	0.0%	0.0%	0.0%	0.0%
	Regional	12.2%	25.0%	8.7%	0.0%	0.0%	50.0%	3.2%
	Corporate	46.7%	32.1%	60.9%	75.0%	50.0%	50.0%	45.2%
	Board	24.4%	3.6%	13.0%	25.0%	50.0%	0.0%	51.6%
	No Resp.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Visibility of Project to Owner Management	None	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Minimal	22.2%	50.0%	17.4%	25.0%	0.0%	0.0%	3.2%
	Significant	77.8%	50.0%	82.6%	75.0%	100.0%	100.0%	96.8%
	No Resp.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Availability of Core Team Resources	Part	32.2%	67.9%	21.7%	25.0%	0.0%	0.0%	12.9%
	Combo	50.0%	28.6%	65.2%	75.0%	100.0%	50.0%	51.6%
	Full	15.6%	3.6%	8.7%	0.0%	0.0%	50.0%	32.3%
	No Resp.	2.2%	0.0%	4.3%	0.0%	0.0%	0.0%	3.2%
Level of Permitting Required	None	28.9%	53.6%	26.1%	25.0%	50.0%	50.0%	6.5%
	Minimal	44.4%	35.7%	47.8%	25.0%	50.0%	0.0%	54.8%
	Significant	23.3%	10.7%	17.4%	50.0%	0.0%	50.0%	35.5%
	No Resp.	3.3%	0.0%	8.7%	0.0%	0.0%	0.0%	3.2%
Types of Permits Required	None	30.0%	53.6%	26.1%	25.0%	50.0%	50.0%	9.7%
	State/Local	45.6%	39.3%	39.1%	50.0%	0.0%	0.0%	58.1%
	National	3.3%	3.6%	0.0%	0.0%	0.0%	0.0%	6.5%
	Combo	18.9%	3.6%	30.4%	25.0%	50.0%	50.0%	22.6%
	No Resp.	2.2%	0.0%	4.3%	0.0%	0.0%	0.0%	3.2%

Note: The values shown for total installed cost, construction duration, number of core team members, and number of separate trade contractors are the mean values of the projects in each category. The values shown for level of funding approval, visibility of the project to owner management, availability of core team resources, level of permitting required, and types of permits required are percentage values of the number of projects in each category that aligned with each possible answer within the attribute.

9.1.3. Discussion of Questionnaire Responses

The values provided in Table 9-1 highlight the differences in project attributes, where as the project cost increases, so does the potential for a project to be more complex. For example, with a greater number of core team members, the possibility of unknowns between core team members would potentially increase, indicating that the project may be more complex. Griffith and Gibson (1997) (summarized in Chapter 2) detailed the importance of having alignment between project stakeholders to achieve project success. With a greater number of core team members, the individual goals to achieve project success may vary, and may not be explicit to each of the other core team members. A project with more core team members could potentially be more complex than a project with a lesser number of core team members based on this premise. From the sample, projects with total installed cost less than or equal to US $5 million averaged just over eight core team members, and projects with total installed cost greater than US $25 million averaged nearly 25 core team members.

A project with a greater number of trade contractors would potentially be more complex than a project with less trade contractors. For example, the completion (or non-completion) of certain critical path schedule tasks by one trade contractor could affect the ability of other trade contractors to complete their tasks. A project would be considered more complex if the ability of the trade contractors to complete their tasks was highly dependent on other trade contractors, but the actual dependence between the trade contractors wasn't completely known. From the sample, projects with total installed cost less than or equal to US $5 million averaged just over three core team members, and projects with total installed cost greater than US $25 million averaged over nine core team members.

Availability of core team resources, construction duration, and permitting follow a similar logic, where a project with more full-time management, a longer duration, and/or a greater number of permits would indicate a project with a greater amount of scope. The potential for unknown interactions between different scope items would potentially increase as the amount of project scope increases, making a project more complex. A higher level of approval could also potentially make a project more complex, both concerning internal funding approval and external permitting approval. As the level of approval increases, so would the number of individuals/groups providing approval, leading to the possibility of a greater number of unknown requirements necessary to achieve approval. A higher level of approval would also provide a higher level of project visibility to the owner management of an organization. From the sample, projects with total installed cost less than or equal to US $5 million averaged a lower number of core team members, construction durations, visibility to owner management, and permits than projects with total installed cost greater than US $25 million.

9.2. Development of PDRI Industrial Selection Guide

The author determined that PDRI users would benefit from a guide to assist them in selecting the appropriate PDRI tool for use on an industrial project based on the findings concerning levels of project complexity. The basis of the guide was taken from the notional works provided in Griffith and Headley (1998), where small projects were said to fall along a spectrum of projects (shown in Figure 4-11), and as the magnitude of project characteristics such as cost, scale, and complexity increase, so does the project size.

9.2.1. PDRI Industrial Selection Guide Scoring Scheme

The author utilized the nine project attributes discussed in the previous section to develop an index that encompassed a series of ranges for each attribute, considered project complexity indicators. The author developed the ranges based on the mean values and percentages shown in Table 9-1. Each possible range value was given an associated index value, where the index values increased as the range-values increased for each indicator.

Table 9-2 provides the project complexity indicators and their associated index values. For simplicity, the index was developed so that scores could range anywhere between zero and 100. Scores closer to 100 indicate a project with a high level of complexity, and scores closer to zero indicate a project with a low level of complexity. Again, for simplicity, each of the nine project complexity indicators were weighted equally with the highest possible score being 11, other than total installed cost, which has the highest possible score being 12. Total installed cost had one additional point added so that each of the index values would be whole numbers, and the total score would be an even 100. The research team chose to weight each project complexity indicator equally so that the guide would be generic enough for use in most organizations. For example, in a smaller organization, a project with a cost of US $5 million may be considered a very large project, while in a larger organization, a project with a cost of US $5 million may be considered a very small project. These two organizations would not weight project cost equally, hence a weighted index would not be appropriate. Another example is level of funding approval. The research team received feedback during the weighting workshops that in some organizations, typically smaller organizations, all projects must receive approval from the highest level of the corporate governance no matter the cost. This is not the case in all organizations; hence a weighted index would not be appropriate.

Table 9-2. Industrial PDRI Selection Guide Index Values

Indicator	Range	Index Values
Total Installed Cost (in $ millions)	< 5	0
	5.01 to 10	2
	10.01 to 15	4
	15.01 to 20	6
	20.01 to 25	8
	> 25	12
Construction Duration (in months)	< 3	0
	3.01 to 6	2
	6.01 to 9	4
	9.01 to 12	6
	12.01 to 15	8
	> 15.01	11
Level of Funding Approval	None	0
	Local	3
	Regional	6
	Corporate	9
	Board	11
Visibility of Project	None	0
	Minimal	4
	Moderate	8
	Significant	11
Number of Core Team Members (each)	< 3	0
	4 to 6	2
	7 to 9	4
	10 to 12	6
	13 to 15	8
	> 16	11
Availability of Core Team Resources	None	0
	Part-Time	4
	Combination	8
	Full-Time	11
Level of Permitting Required	None	0
	Minimal	6
	Significant	11
Type of Permits Required	None	0
	State/Local	4
	National	8
	Combination	11
Number of Separate Trade Contractors (each)	< 2	0
	3 to 4	2
	5 to 6	4
	7 to 8	6
	9 to 10	8
	> 11	11

9.2.2. Testing of the Index Scoring Scheme

The author tested the index through scoring each of the 90 projects submitted for the index development. Some of the projects lacked information for each of the nine project complexity indicators, but 79 of the 90 projects had information on all nine indicators. The author scored each of the 79 projects with complete data sets based on the index provided in Table 9-2. The mean value of index scores for all 79 projects was found to be 51.6, with a median value of 50.0. The project data was broken into two groups; project with index scores above 50, and project with index scores below 50. Mann-Whitney U tests were employed to determine if differences existed between the two groups based on the rank-order of the index values for each of the attributes.

Figure 9-1 provides a summary of the Mann-Whitney U tests from SPSS™. As shown, there was a statistical difference at a 95% confidence level between the two groups for eight of the nine attributes included in the selection guide, all except for visibility of project to owner management, which had an associated p value of .098 (p-values less than .05 denote statistical difference for a 95% confidence interval).

	Total Installed Cost	Construction Duration	Level of Funding Approval	Visibility of Project to Owner Management	Number of Core Team Members	Availibility of Core Team Members	Extent of Permitting	Types of Permits Required	Number of Separate Trade Contractors
Mann-Whitney U	186.500	235.000	294.000	631.500	380.500	303.000	246.500	278.500	264.000
Wilcoxon W	1047.500	1096.000	1155.000	1492.500	1241.500	1164.000	1107.500	1139.500	1125.000
Z	-6.100	-5.478	-5.122	-1.654	-4.009	-5.121	-5.623	-5.295	-5.205
Asymp. Sig. (2-tailed)	.000	.000	.000	.098	.000	.000	.000	.000	.000

Figure 9-1. Mann-Whitney U Test Results for PDRI Selection Guide Attributes

9.2.3. Discussion of Testing of the Index Scoring Scheme

The results of the Mann-Whitney U tests show that projects with index scores greater than 50 are overall statistically different than projects with index scores lower than 50. That is to say that projects with index scores greater than 50 would be indicative of more complex projects, hence better assessed with the PDRI-Industrial. Projects with index scores lower than 50 would be indicative of less complex projects, hence better assessed with the PDRI-Small Industrial. Visibility of project to owner management was the only attribute not statistically different between the two groups, but the research team determined that it should still be considered an indicator of project complexity. The visibility of a project to owner management can be organization driven as opposed to project driven, where in many small organizations, a project will be visible to owner management no matter the size. Small projects may also be visible to owner management if they are not overly complex, but critical to the ongoing operations of a facility.

9.2.4. How to Use the Industrial PDRI Selection Guide

The Industrial Project Definition Rating Index (PDRI) Selection Guide is meant for use any time during front end planning, but prior to completing a project assessment with an Industrial PDRI tool. Project teams can review the guide, and score their project based on the nine project complexity indicators. Appendix G provides the complete Industrial PDRI Selection Guide.

The author (in accordance with the research team) determined that projects scoring above 55, considered higher complexity projects, would be best assessed with the PDRI-Industrial. Project scoring below 45, considered lower-complexity projects, would be best assessed with the PDRI-Small Industrial. Figure 9-2 provides a graphic that visually represents the scoring scheme, and the spectrum of industrial projects.

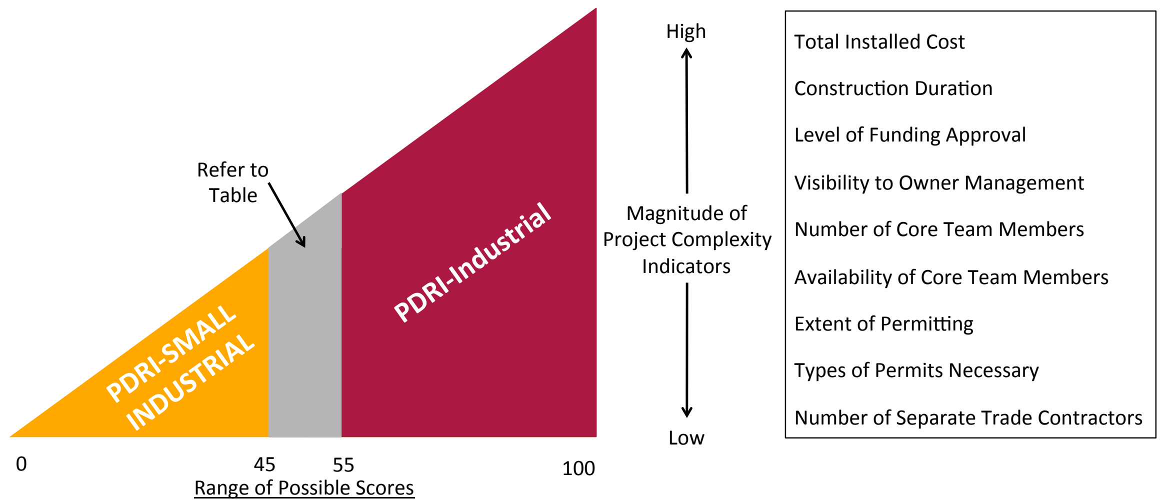


Figure 9-2. Project Complexity Spectrum from Industrial PDRI Selection Guide

The author felt it important to include in the selection guide special instructions for projects that score between 45 and 55, shown as the gray area in Figure 8-3. Instructions within the selection guide direct project teams to review Table 9-3 when their projects score within the gray-area range, and use the average values provided in the table to help determine which tool better aligns with their project.

Table 9-3. Industrial PDRI Selection Guide Index Values

Project Complexity Indicator	PDRI-Small Industrial	PDRI-Industrial
Total Installed Cost	Less than $10 Million (US Dollars)	More than $10 Million (US Dollars)
Construction Duration	Between 3 and 6 months	Between 9 and 15 months
Level of Funding	Between regional and corporate	Between corporate and Board of Directors
Project Visibility	Moderate	Significant
Number of Core Team Members	Between 7 and 9 individuals	Between 10 and 15 individuals
Availability of Core Team Members	Part-time availability	Between a combination of part-time and full-time to completely full time
Extent of Permitting	Between none and minimal permitting	Between minimal and significant permitting
Types of Permits	Between none to local/state permits	Between local/state to national permits
Number of Trade Contractors	Between 3-4 separate trade contractors	Between 7-8 separate trade contractors

9.2.5. Pilot Testing of the Industrial PDRI Selection Guide

The author pilot tested the Industrial PDRI Selection guide amongst the industry members of Research Team 314 to discern if the guide was a sufficient method for determining the appropriate PDRI for use on an industrial project. The author provided industry team members with a draft copy of the guide at a team meeting in September of 2014, and asked that they score an upcoming industrial project based on the index, either a large or small project. The time to complete the scoring exercise was less than five minutes. Each of the 11 industry team members who completed the exercise commented that the guide was sufficient to determine an appropriate industrial PDRI for use, and that the instructions provided regarding how to select a PDRI tool were adequate. One industry team member from an owner-organization also used the guide to complete an overall assessment of typical projects completed within their organization. They found that, on average:

- Projects with total installed costs ranging from US $250,000 to US $1 million (approximately 90 percent of their completed projects) would have index scores between 15 and 48
- Projects with total installed costs ranging from US $1 million to US $5 million (approximately 8 percent of their projects) would have index scores between 26 and 59
- Projects with total installed costs greater than US $ 5 million (approximately 2 percent of their projects) would have index scores between 38 and 84

Any project with total installed cost greater than US $ 5 million must be assessed with the PDRI-Industrial, based on the internal funding approval guidelines of their organization. The industry team member found that the Industrial PDRI Selection Guide was aligned with this mandate, based on the average index scores determined in the assessment.

9.3. Summary

An imperative for the research team was providing a method for PDRI users to choose the appropriate tool for use on an industrial project: the PDRI-Industrial Projects, or the PDRI-Small Industrial. The author collected project data from the weighting workshop participants regarding completed industrial projects, both large and small. This data was used to develop a selection guide that can be utilized by industrial PDRI users to determine the appropriate PDRI tool for their projects based on indicators of project complexity. Pilot testing of the selection guide showed that it was a quick, easy, and accurate method for determining an appropriate industrial PDRI.

CHAPTER 10. CONCLUSIONS AND RECOMMENDATIONS

This chapter provides the conclusions of the PDRI-Small Industrial research, and the recommendations of the author based on the research results.

10.1. Research Objectives

The research team initially set forth the following objectives:

1. Produce a user-friendly tool for measuring project scope definition of small industrial projects with the following characteristics and functions:
   - Based upon the PDRI-Industrial, yet tailored specifically to small industrial projects
   - Less time-consuming than the PDRI-Industrial
   - Is easy to use, yet detailed enough to be effective
   - Helps reduce total project costs
   - Improves schedule performance
   - Serves as a communication and alignment tool
   - Supports decision-making
   - Identifies risks
   - Reliably predicts project performance
   - Is flexible among industrial facility types
2. Test the tool by comparing the level of project scope definition during the front end planning phase vs. corresponding project performance factors for a sample of completed small industrial projects

The research results presented in this dissertation have met all of the stated research objectives. An extensive literature review highlighted the value of implementing the front end planning tools developed by CII, the lack of a non-proprietary tool specifically for small industrial projects, and the inherent differences between small and large projects. The 23 members of Research Team 314 utilized the existing literature (summarized by the author) to develop a simple, easy to use tool specifically for small industrial projects, a project type found to make up 70 to 90 percent of completed projects (by count) each year in the industrial sector. Sixty-five industry professionals participated in five separate weighting workshops providing valuable feedback on the tool's element descriptions, in addition to providing input for element prioritization, and data project data that was used to develop an industrial PDRI selection guide. The tool was tested on 40 completed projects with an overall expenditure of over US $151 million, which showed a difference regarding schedule, cost, change, and financial performance, and customer satisfaction on projects with PDRI scores below 300. These results demonstrate the ability of the tool's scoring scheme to highlight the risk factors most important to address during the front end planning of small industrial projects, and the negative impacts to project performance if they are not properly addressed. The tool is also currently being used in industry, with every indication that its implementation within organizations will provide just as much value as the preceding PDRIs have. Feedback from industry professionals that test the tool on 14 separate projects (with overall project budgets totaling more that $50 million) suggested that the tool provides an effective platform for aligning team members to project goals, and individuals that the PDRI added value to their projects.

A survey of CII member organizations showed that planning practices for small industrial projects vary greatly across the industry, and even within organizations. The PDRI-Small Industrial was designed to provide a structured approach to the industry for the purpose of improving project performance. The PDRI-Small Industrial was also developed so that it is flexible enough to be used on a wide assortment of small industrial project types, but detailed enough to add value to the front end planning process. The number of elements within the tool is significantly lower than the PDRI-Industrial, but this was not done simply for the purpose of lowering the assessment time. The purpose of front end planning is to sufficiently define scope items necessary to complete a project, and the rigor of that process should match the rigor of the project itself. The detail within the PDRI-Small Industrial element descriptions is sufficient for assessing the scope definition of industrial projects with a lesser amount of project scope, hence less project complexity.

10.1.1. Research Hypotheses

The specific hypotheses were as follows:

> ***Hypothesis 1****: A finite and specific list of critical issues related to scope definition of small industrial projects can be developed.*

The PDRI-Industrial tool was used as a baseline to develop the PDRI-Small Industrial. Element descriptions within the PDRI-Industrial were reviewed, scrutinized, adapted, and revised by the research team, leading to the development of 41 elements specifically for assessing small industrial projects. 65 industry professionals reviewed and prioritized the elements, providing sufficient feedback to develop a final set of element descriptions and corresponding score sheets, as described in Chapter 5. The tool was also tested on 14 in-progress projects, of which the users noted the effectiveness of the tool to sufficiently address key issues in the front end planning of small industrial projects.

Hypothesis 2*: Projects with low PDRI scores outperform projects with high PDRI scores.*

The results of the completed-project analysis showed that projects with PDRI scores lower than 300 outperform projects with PDRI scores above 300 regarding cost performance, schedule performance, change performance, financial performance, and customer satisfaction, as described in Chapter 6. Independent samples t-tests (p-value of .025) and regression analysis (p-value of .008) for cost performance were both statistically significant at a 95 percent confidence level. No statistically significant difference was found for schedule performance and change performance.

Hypothesis 3*: Project complexity indicators can be used to distinguish small projects from large projects.*

The results of a literature review and collection of project data from completed industrial projects led to the author developing an index-based Industrial PDRI Selection Guide that utilizes indicators of project complexity to determine a project's size. Statistical analysis showed that eight of the nine metrics (p-value of .000 for all project complexity indicators other than level of funding approval) included in the index were statistically different between small and large industrial projects at a 95 percent confidence level. Industry members from RT 314 pilot tested the selection guide, and found it to be sufficient in providing guidance as to which PDRI is most appropriate for use on an industrial project.

10.2. Advice to Users

The PDRI-Small Industrial is intended for use as a scope assessment, project alignment, and risk assessment tool. The tool was designed so that it can be used only once during front end planning, or successively if time allows. If the tool is used only once, the earlier in the front end planning process the better. Project teams are urged not to solely focus on the scores derived through using the tool. Even projects that score below the 300-point threshold suggested in this document might still have significant issues that should be addressed prior to moving a project forward into detailed design and construction. Disregarding these risk issues might significantly affect project performance.

The PDRI-Small Industrial was designed for use on small, less complex, industrial projects, NOT as a shortcut to the PDRI-Industrial tool. Users are urged to closely consider the attributes of their project through use the Industrial PDRI Selection Guide or other internally developed guidelines, and choose the PDRI tool that best suites their project. The PDRI-Small Industrial (or any PDRI) should also not be used to forecast project performance. The results provided in this report are based on a small sample size of completed and in-progress projects, but these projects may not be representative of the entire population of industrial projects.

10.3. Contributions to Knowledge

The research efforts completed by the author (in conjunction with the research team) have provided several contributions to the current front end planning and small projects body of knowledge. The most substantial contribution was the development of a novel, non-proprietary tool specifically for the front end planning of small industrial projects. The development of the tool has not only expanded the long-standing CII best practice of front end planning, but also greatly contributed to the limited small project research base. Moreover, the testing results provide quantitative proof that a greater level of scope definition during the front end planning of small industrial projects drastically effects cost and schedule performance. The author's research into project complexity also expanded the current knowledge base through a new definition of project complexity being developed, as well as a novel method for distinguishing project size based in indicators of project complexity. The methodology used to develop the Industrial PDRI Selection Guide can also provide a systematic approach for future researchers to develop similar guides for other construction sectors.

10.4. Research Limitations

The research described in this dissertation was limited on to the industrial construction sector. The PDRI-Small Industrial would not be appropriate for use on projects in the building or infrastructure construction sectors, but the methods that have been outlined could be used to develop tools for small building and/or infrastructure projects. The data collected for testing of the PDRI-Small Industrial was also a relatively small sample of all small industrial projects completed across the industry. The testing results provided in the dissertation may not be accurate for all small industrial projects, or all industrial-focused organizations. Moreover, the data was primarily collected from industry professionals and organizations based out of North America. The author (and research team) made every effort to collect data from a diverse group of individuals and organizations, but again, the results provided in the dissertation may not be accurate for all small industrial projects, or all industrial-focused organizations.

10.5. Recommendations for Future Research

The author recommends four areas of future research regarding small projects. Development of an HTML-based front end planning toolkit specifically for small projects could provide great value to industry. The current CII front end planning toolkit was designed for use on large, complex projects, and used the pre-project planning handbook developed by the Pre-Project Planning Task Force as a baseline. The structured, phase-gated front end planning process is embedded in the toolkit, with links to the PDRI-Industrial, PDRI-Building, and PDRI-Infrastructure, as well as the other complementary front end planning tools developed by CII. This structure is too cumbersome for use on small projects, similar to the preceding PDRI tools themselves. A new toolkit could be developed using the Manual for ~~Small~~ Special Project Management (CII 1991) and Small Projects Toolkit (CII 2002) (described in Chapter 4) as a baseline. These documents include substantial information regarding the planning and execution of small projects, which could be reviewed and updated to develop a toolkit pertinent to the current construction environment.

CII Executing Small Capital Projects Research Team (CII 2002) suggested that a small project program team best manages small projects, where the project managers within this team are solely responsible for the small projects completed within an organization. Future researchers could perform case studies to determine if there is a statistically significant difference (regarding project performance) between organizations that utilize small project program teams vs. those that assign small projects to project managers that are also responsible for large projects.

Future researchers could also perform case studies to discern how use of the PDRI-Small Industrial specifically affects project change, specifically cost and schedule changes. Chapter 7 detailed the procedures used by RT 314 to test the efficacy of the PDRI-Small Industrial, but the project performance differences that were found came from a sample of completed projects. The PDRI-Small Industrial has been used on 14 in-progress projects, but the final cost and schedule performance of these projects is not known at the time of this publication. Future researchers could compare the performance of these 14 projects that utilized the PDRI-Small Industrial to in-progress projects of similar complexity and scope that do not employ the PDRI-Small Industrial. Researchers would thus need to expand their inquiry within or outside of organizations who have already provided in-progress data to test the efficacy of the tool. Understanding the efficacy of the PDRI-Small Industrial to improve project performance may provide further incentive for organizations to use the tool.

Lastly, the author suggests that PDRI tools be developed for small infrastructure and building project types. Empirical evidence would suggest that small projects are just as prevalent in the building and infrastructure sectors, and wrought with similar project performance issues as the industrial sector. Further extending the CII front end planning focus towards small infrastructure and building projects could greatly benefit those sectors as the PDRI-Small Industrial will do for the industrial sector.

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APPENDIX A

PARTICIPATING ORGANIZATIONS

PDRI for Small Industrial Projects Research Team

Brad Lynch, Chair	TransCanada
Scott Penrod, Vice Chair	Walbridge
Jeffrey Allen	Burns & McDonnell
Jere Brubaker	Wood Group Mustang
David Buttrum	Technip
Wesley Collins, Student	Arizona State University
Thea Cummings	Anheuser-Busch InBev
Wesley DuBois	SABIC Innovative Plastics
Gregory Duffy	Pioneer Natural Resources
John Fish	Ford, Bacon & Davis
G. Edward Gibson, Jr.	Arizona State University
Doug Helmann	Architect of the Capitol
Paul Katers	American Transmission Company
Kristen Parrish	Arizona State University
Stephanie Quinn	Pioneer Natural Resources
Brett Smedley	Eli Lilly
David Sonntag	DTE Energy
Graham Targett	Irving Oil Refining
William Thornton	Hargrove Engineers + Constructors

Former Members:

Amy Busse	Air Products
Eskil Carlsson	CSA Group
Don Cooley (retired)	CH2MHill
Arno Jansen	CCC Group
Julia Speed	Audubon Engineering

Organizations Participating in Small Project Definition Survey

Access Midstream
Air Products
American Transmission Company
Anheuser-Busch InBev
Architect of the Capitol
ATC
AZCO, Inc.
Bechtel
Cargill, Inc.
CH2MHill
DTE Energy
Eastman Chemical Company
Eli Lilly and Company
Emersen Process Management
Fluor Canada, Ltd.
Foster Wheeler
International Paper
INVISTA
Jacobs
Koch Fertilizer
Kvaerner North American Construction
Linde North American
Matrix Services
Matrix SME
McDermott Intl, Inc.
Occidental
Ontario Power Generation
Proctor & Gamble
S&B Engineers and Constructors
SABIC Innovative Plastics
SunCoke Energy
Technip
Teck Resources
Willbros. Group, LLC
Wood Group Mustang

Organizations Participating in Weighting Workshops

Albemarle
Anheuser-Busch InBev
Audubon Engineering
BMWC Constructors
Burns & McDonnell
CH2M Hill
Chevron
Chevron Phillips Chemicals
Cytec
EDA Inc.
Eli Lilly and Company
FA Wilhelm Construction
Flint Hills Resources
Ford, Bacon, and Davis
Hargrove Engineers + Constructors
International Paper
Jacobs
Meadwestvaco
Motiva
Performance Contracting
Phillips 66
Rubicon
S&B Constructors
SABIC Innovative Plastics
TransCanada
Valero
Walbridge
Willbros Engineering
Wood Group Mustang

Organizations Providing Testing Data

Anheuser-Busch InBev
Architect of the Capitol
Audubon Companies
Burns & McDonnell
CCC Group
Comfort Systems USA
DTE Energy
Eli Lilly and Company
Hargrove Engineers + Constructors
Irving Oil
Pioneer Natural Resources
SABIC Innovative Plastics
Stantec
TransCanada
Wood Group Mustang

APPENDIX B

PDRI FOR SMALL INDUSTRIAL PROJECTS DOCUMENTS

SECTION I - BASIS OF PROJECT DECISION							
	Definition Level						
CATEGORY Element	**0**	**1**	**2**	**3**	**4**	**5**	**Score**
A. PROJECT ALIGNMENT							
A.1 Project Objectives Statement							
A.2 Project Strategy and Scope of Work							
A.3 Project Philosophies							
A.4 Location							
B. PROJECT PERFORMANCE REQUIREMENTS							
B.1 Products							
B.2 Capacities							
B.3 Processes							
B.4 Technology							
B.5 Physical Site							

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

SECTION II - BASIS OF DESIGN							
	Definition Level						
CATEGORY Element	0	1	2	3	4	5	Score
C. DESIGN GUIDANCE							
C.1 Lead/Discipline Scope of Work							
C.2 Project Design Criteria							
C.3 Project Site Assessment							
C.4 Specifications							
C.5 Construction Input							
D.PROCESS/PRODUCT DESIGN BASIS							
D.1 Process Safety Management (PSM)							
D.2 Process Flow Diagrams along with Heat and Material Balance							
D.3 Piping and Instrumentation Diagrams (P&ID's)							
D.4 Piping System Stress Analysis							
D.5 Equipment Location Drawings							
D.6 Critical Process/Product Items Lists							
E. ELECTRICAL AND INSTRUMENTATION SYSTEMS							
E.1 Control Philosophy							
E.2 Functional Descriptions and Control Narratives							
E.3 Electric Single Line Diagrams							
E.4 Critical Electrical Items Lists							
F. GENERAL FACILITY REQUIREMENTS							
F.1 Site Plan							
F.2 Loading/Unloading/Storage Requirements							
F.3 Transportation Requirements							
F.4 Additional Project Requirements							

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

SECTION III - EXECUTION APPROACH							
CATEGORY Element	Definition Level						
	0	1	2	3	4	5	Score
G. EXECUTION REQUIREMENTS							
G.1 Procurement Plan							
G.2 Owner Approval Requirements							
G.3 Distribution Matrix							
G.4 Risk Management Plan							
G.5 Shutdown/Turnaround Requirements							
G.6 Precomissioning, Startup, & Turnover Sequence Requirements							
H. ENGINEERING/CONSTRUCTION PLAN AND APPROACH							
H.1 Engineering/Construction Methodology							
H.2 Project Cost Estimate							
H.3 Project Accounting and Cost Control							
H.4 Project Schedule and Schedule Control							
H.5 Project Change Control							
H.6 Deliverables for Design and Construction							
H.7 Deliverables for Project Comissioning/Closeout							

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

SECTION I - BASIS OF PROJECT DECISION							
	Definition Level						
CATEGORY Element	**0**	**1**	**2**	**3**	**4**	**5**	**Score**
A. PROJECT ALIGNMENT (Maximum Score = 153)							
A.1 Project Objectives Statement	0	2	13	24	35	47	
A.2 Project Strategy and Scope of Work	0	3	13	24	34	45	
A.3 Project Philosophies	0	2	8	14	19	25	
A.4 Location	0	2	11	19	28	36	
CATEGORY A TOTAL							
B. PROJECT PERFORMANCE REQUIREMENTS (Maximum Score = 135)							
B.1 Products	0	1	8	15	21	28	
B.2 Capacities	0	2	9	17	24	31	
B.3 Processes	0	2	7	12	17	23	
B.4 Technology	0	2	8	15	21	28	
B.5 Physical Site	0	2	8	14	19	25	
CATEGORY B TOTAL							
Section I Maximum Score = 288 **SECTION I TOTAL**							

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

SECTION II - BASIS OF DESIGN							
CATEGORY Element	**Definition Level**						
	0	**1**	**2**	**3**	**4**	**5**	**Score**
C. DESIGN GUIDANCE (Maximum Score = 133)							
C.1 Lead/Discipline Scope of Work	0	2	8	14	20	27	
C.2 Project Design Criteria	0	2	8	14	20	26	
C.3 Project Site Assessment	0	2	9	15	22	29	
C.4 Specifications	0	2	8	14	20	26	
C.5 Construction Input	0	2	8	14	19	25	
CATEGORY C TOTAL							
D.PROCESS/PRODUCT DESIGN BASIS (Maximum Score = 145)							
D.1 Process Safety Management (PSM)	0	1	6	10	14	19	
D.2 Process Flow Diagrams along with Heat and Material Balance	0	2	8	15	22	28	
D.3 Piping and Instrumentation Diagrams (P&ID's)	0	2	11	19	28	36	
D.4 Piping System Stress Analysis	0	1	5	9	13	17	
D.5 Equipment Location Drawings	0	1	7	12	17	22	
D.6 Critical Process/Product Items Lists	0	2	7	12	17	23	
CATEGORY D TOTAL							
E. ELECTRICAL AND INSTRUMENTATION SYSTEMS (Maximum Score = 71)							
E.1 Control Philosophy	0	2	7	12	17	22	
E.2 Functional Descriptions and Control Narratives	0	1	4	7	11	14	
E.3 Electric Single Line Diagrams	0	1	5	9	13	17	
E.4 Critical Electrical Items Lists	0	1	5	10	14	18	
CATEGORY E TOTAL							
F. GENERAL FACILITY REQUIREMENTS (Maximum Score = 76)							
F.1 Site Plan	0	1	6	10	15	20	
F.2 Loading/Unloading/Storage Requirements	0	2	5	9	13	17	
F.3 Transportation Requirements	0	1	5	8	12	15	
F.4 Additional Project Requirements	0	2	8	13	19	24	
CATEGORY F TOTAL							
Section II Maximum Score = 425 **SECTION II TOTAL**							

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

SECTION III - EXECUTION APPROACH							
CATEGORY Element	**Definition Level**						
	0	**1**	**2**	**3**	**4**	**5**	**Score**
G. EXECUTION REQUIREMENTS (Maximum Score = 129)							
G.1 Procurement Plan	0	2	9	15	22	28	
G.2 Owner Approval Requirements	0	1	5	9	13	17	
G.3 Distribution Matrix	0	1	3	4	6	8	
G.4 Risk Management Plan	0	2	7	13	18	23	
G.5 Shutdown/Turnaround Requirements	0	3	10	17	25	32	
G.6 Precomissioning, Startup, & Turnover Sequence Requirements	0	2	7	11	16	21	
CATEGORY G TOTAL							
H. ENGINEERING/CONSTRUCTION PLAN AND APPROACH (Maximum Score = 158)							
H.1 Engineering/Construction Methodology	0	2	8	14	20	25	
H.2 Project Cost Estimate	0	3	12	21	30	39	
H.3 Project Accounting and Cost Control	0	1	4	8	11	14	
H.4 Project Schedule and Schedule Control	0	2	8	13	19	25	
H.5 Project Change Control	0	1	6	10	15	19	
H.6 Deliverables for Design and Construction	0	1	6	11	16	21	
H.7 Deliverables for Project Comissioning/Closeout	0	1	5	8	12	15	
CATEGORY H TOTAL							
Section III Maximum Score = 287 — **SECTION III TOTAL**							

PDRI TOTAL SCORE

(Maximum Score = 1000)

Definition Levels

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

PDRI ELEMENT DESCRIPTIONS

The following descriptions have been developed to help generate a clear understanding of the terms used in the un-weighted Project Score Sheet. Some descriptions include checklists of sub-elements. These sub-elements clarify concepts and facilitate ideas to make the assessment of each element easier. Note that these checklists are not all-inclusive and that the user may supplement these lists when necessary.

The descriptions follow the order in which they are presented in the Un-weighted or Weighted Project Score Sheet; they are organized in a hierarchy by section, category, and element. The score sheet consists of three main sections, each of which is a series of categories broken down into elements. Note that some of the elements have issues listed that are specific to projects that are renovations and revamps or part of a repetitive program. These issues are identified as "Additional items to consider for Renovation & Revamp projects" and "If this is an instance of a Repetitive Program." Use these issues for discussion if applicable. Scoring is performed by evaluation of each element's definition level.

It should be noted that this tool and these descriptions have been developed to address a variety of types of small industrial projects, both process and non-process related. Throughout the descriptions, the user will see sub-elements that relate to the variety of projects the tool is meant to encompass. These sub-elements are provided in the order in which they are discussed above. If the sub-element is not applicable to the project that the user is assessing, then it should be ignored. The sections, categories, and elements are organized as discussed below.

SECTION I – BASIS OF PROJECT DECISION

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

Categories:

A – Alignment
B – Project Performance Requirements

SECTION II – BASIS OF DESIGN

This section consists of processes and technical information elements that should be evaluated to fully understand the engineering/design requirements necessary for the project.

Categories:

C – Design Guidance
D – Process/Product Design Basis
E – Electrical and Instrumentation Systems
F – General Facility Requirements

SECTION III – EXECUTION APPROACH

This section consists of elements that should be evaluated to fully understand the owner's strategy and required approach for executing the project construction and closeout.

Categories:

G – Execution Requirements
H – Engineering/Construction Plan and Approach

The following pages contain detailed descriptions for each element in the PDRI

SECTION I – BASIS OF PROJECT DECISION

A. PROJECT ALIGNMENT

The elements in this category align key stakeholders around "whys, whats, and hows" of the project in order to meet the needs of the organization.

A.1 Project Objectives Statement

The project objectives statement clearly defines why the project is being performed and what its value is to the organization. Project objectives and priorities for meeting the business drivers should be documented and shared. The statement should outline the relative priority among cost, schedule, and quality. Key stakeholders (e.g., owner/operations, environmental/permitting, design/engineering, procurement, construction, commissioning/startup, and external stakeholders) should be engaged to ensure the project is aligned to applicable objectives and constraints. Items to consider should include the following:

Objectives:

- ☐ Safety/security
- ☐ Quality of product/quality of life
- ☐ Performance/capacity
- ☐ Environmental/sustainability

Stakeholder understanding of the objectives, including questions or concerns answered

Constraints or limitations placed on the project, which, if not addressed or overcome, could adversely affect the project's ability to meet objectives (e.g., space, operations, timing/schedule of project, funding)

Other (user defined)

**** If this is an instance of a repetitive program****

Ensure compatibility of project objectives with program objectives.

A.2 Project Strategy and Scope of Work

The project strategy and scope of work supports the identified market and/or business drivers and objectives, and also addresses applicable project constraints. The team should document a brief, generally discipline-oriented narrative description of the project, laying out the major components of work to be accomplished. The project strategy and scope of work should be evaluated against the preliminary cost estimate and schedule, to determine project feasibility. The narrative should include the following:

Assurance of safe construction and operations

A strategy that aligns with project objectives based on project priorities:

- ☐ Cost
- ☐ Schedule
- ☐ Quality
- ☐ Other (e.g., supply chain, environmental, human resources, labor)

A project funding strategy to ensure that the project can move forward without any unintended stoppages (e.g., internal or external funds or savings from process or energy efficiency improvements)

A contracting strategy (e.g., lump sum, reimbursable, unit price, parallel prime)

Sequencing of work

Interface issues for various contractors, contracts, or work packages

Any ancillary or temporary equipment required for:

- ☐ Installation and commissioning
- ☐ Regulatory compliance or reporting

Other user defined

**** Additional items to consider for renovation & revamp projects****

If the project is within an existing facility, the project scope should align with overall plant/process strategy.

Identification of interface or coordination efforts with operations and owner's staff, and with existing equipment and systems; grouping of work to minimize outages

**** If this is an instance of a repetitive program****

Compatibility of project scope and strategy with program's scope and strategy

A.3 Project Philosophies

General project design philosophies to meet the performance goals of the unit/facility should be documented. Philosophies should define the following:

Operating philosophy (achieving the projected overall performance requirements such as on-stream time or service factor)

- ☐ Operating time sequence (e.g., ranging from continuous operation to five- day to day-shift only); necessary level of segregation and clean-out between batches or runs
- ☐ Level of operator coverage and automatic control to be provided; aligned with union operator contractual agreements
- ☐ Desired unit turndown capability; design requirements for routine start-up and shutdown
- ☐ Security protection for material management and product control

Reliability philosophy (achieving dependable operating performance)

- ☐ Control, alarm, security and safety systems redundancy, and access control; measures to be taken to prevent loss
- ☐ Mechanical/structural integrity of components (e.g., metallurgy, seals, types of couplings, bearing selection, corrosion allowance)
- ☐ Installed spare equipment and strategic spares

Maintenance Philosophy (meeting maintenance goals)

- ☐ Scheduled unit/equipment shutdown frequencies and durations
- ☐ Equipment access/monorails/cranes/other lifting equipment sized appropriately
- ☐ Equipment monitoring requirements (e.g., lubricants, vibrations)

Other (user defined).

**** Additional items to consider for renovation & revamp projects****

Align new project component's life cycle with existing systems/plant/process life cycle

Maintenance requirements during renovation

Common/spare parts (repair versus replace existing components)

Interruptions to existing and adjacent facilities and operations

Compatibility of maintenance philosophy for new systems and equipment with existing use and maintenance philosophy

Coordination of the project with ongoing or planned maintenance projects

**** If this is an instance of a repetitive program****

Compatibility and alignment of project's philosophies with program's philosophies

A.4 Location

A location that considers the long-term needs of the owner organization, meets requirements and maximizes benefits should be selected. If locations have been pre-chosen, it is always a good idea to verify benefits. The selection of location(s) involves an assessment of the relative strengths and weaknesses of alternate locations. Evaluation criteria should include the following:

Available utilities

Operational requirements and hazards

Interface with ongoing projects or operations

Construction/operations and maintenance access

Security constraints (consider separation of construction workers from operations, construction access and so forth)

Regulatory/social constraints

Orientation of project to facilitate future expansion

Other (user defined).

B. PROJECT PERFORMANCE REQUIREMENTS

The elements in this category address high-level requirements informing the basis of design. These elements should define success criteria.

B.1 Products

Product(s) to be manufactured and/or the specifications and tolerances that the project is intended to deliver have been documented. Issues to consider should include the following:

Chemical composition; physical form/properties; allowable impurities

Raw materials and packaging specification

Intermediate/final product form

By-products and wastes

Hazards associated with products

Other (user defined).

B.2 Capacities

Design output or benefits to be gained from this project have been documented. Capacities should be defined in terms of the following:

Yield; design rate or output

Increase in storage

Regulation- or environment-driven requirements

Product quality or process efficiency improvement

Other (user defined).

B.3 Processes

A particular, specific sequence of steps to change the raw materials, intermediates, or sub-assemblies in the finished product or outcome, has been documented. The organization's experience with the process steps should be considered. Evaluation criteria should include the following:

Proven, new, and/or experimental elements of the process

Scale-up from bench or pilot application to commercial scale

Potential impacts to other process steps from proposed change

Other (user defined).

B.4 Technology

The technology(ies) being used in this project to gain the desired results should be documented. Technologies may include chemical, biological, or mechanical processes, and information technology (i.e., software development/upgrade). Evaluation criteria should include the following:

Existing/proven or duplicate

New or experimental

Scale-up from bench or pilot application to commercial scale

Organization's (or industry's) experience with the technology

Licensing or development implications of chosen technology(ies)

Other (user defined).

**** Additional items to consider for renovation & revamp projects****

Integration of new technology with existing systems, including interface/safety issues.

B.5 Physical Site

Permanent physical systems that support or drive the need for the project have been documented. Physical parameters should be defined in terms of the following:

Excavation or remediation

Fencing and security

Structural

Utilities/infrastructure

Access

Buildings

Other (user defined).

SECTION II – BASIS OF DESIGN

C. DESIGN GUIDANCE

The elements in this category identify items required to support detailed design.

C.1 Lead/Discipline Scope of Work

A complete, generally discipline-oriented, narrative description of the project should be documented that lays out the major components of work to be accomplished. This narrative should be tied to a high-level work breakdown structure (WBS) for the project. Items to consider should include the following:

Sequencing of both product and project work, including engineering deliverables supporting pre-commissioning, commissioning, and expedited start-up

Interface issues for various contractors, contracts, or work packages

Any ancillary or temporary equipment required for installation and commissioning, regulatory compliance, or reporting

Other (user defined).

**** Additional items to consider for renovation & revamp projects****

Identification of specific interface or coordination efforts with operations and owner's staff

C.2 Project Design Criteria

The codes, standards, and guidelines that govern the project design should be identified and documented, as well as evaluated for schedule impact. Items to consider should include the following:

National, local, or corporate codes

Local, state/provincial, and federal government permits:

- ☐ Construction, building, and occupancy
- ☐ Transportation, including highway, railroad, or levee board
- ☐ Security and fire
- ☐ Air and water

Utilization of engineering standards (e.g., owner's, contractor's, or other)

Alignment of criteria between the project and existing system/facilities

Health, safety, and environment (HSE)

Electrical area classifications

Value engineering plan

Future expansion considerations

Level of automation

Other (user defined).

**** Additional items to consider for renovation & revamp projects****

Evaluation of original intent of codes and regulations, and any "grandfathered" requirements

Setting design goals to take advantage of outages and plant down-time

Electrical area reclassification impact on existing access and operating areas

Verification of accuracy of as-built or existing 3D models

**** If this is an instance of a repetitive program****

Applicability of existing criteria and permits for this project.

C.3 Project Site Assessment

The actual conditions pertaining to the project site should be identified and documented. The team should identify the availability/non-availability or redundancy of site utilities needed to operate the unit/facility and equipment. Items to consider should include the following:

Survey and benchmark (coordinate and elevation) control system
Geotechnical report
Soil treatment or removal/replacement requirements
Environmental permits currently in force
Existing environmental problems with the site
Other factors such as light, dust, noise, emissions, or erosion control
Fluid/gas utility sources with supply conditions (including temperature, pressure, and quality)
Power sources with supply conditions (including location, voltage level, available power, reliability, and electrical power quality)
Other (user defined).

**** Additional items to consider for renovation & revamp projects****

Field verification of the condition of isolation and tie-in points, including operational approval
Field verification of the condition of existing or reused equipment
Existing horizontal and vertical position analysis (e.g., use of laser scanning).

C.4 Specifications

Project-specific specifications for the design, performance, manufacturing, and material requirements should be identified and documented. Items to consider should include the following:

Mechanical (e.g., classes of equipment, piping, tracing requirements, protective coating, and insulation)
Instrument & electrical (e.g., classes of equipment, power and control, protection, security, heat tracing, and installation standards)
Automation/process control

Civil/Structural (e.g., dimensions, seismic, boundary, fireproofing, protective coatings, and wind loads)

Architectural (e.g., acoustical, finishes, specialty coatings, "cleanability," accessibility of occupants, and voice/data)

Heating, ventilation and air conditioning along with indoor air quality (e.g., equipment, ducting, filtration, air changes, and emissions)

Other (user defined).

**** Additional items to consider for renovation & revamp projects****

Reconciliation of as-built specifications with current specifications

**** If this is an instance of a repetitive program****

Compatibility of this project's specifications with program's specifications.

C.5 Construction Input

A structured process for constructability analysis should be documented. This process should be initiated in front end planning and include early identification of project team participants for constructability analysis. Elements of constructability to consider should include the following:

Construction knowledge/experience involved in project planning and design, including contracting strategy, value engineering, and WBS development

Developing a construction-sensitive project schedule

Considering construction methods in design (e.g., modularization/pre-assembly, and off-site fabrication)

Developing site layouts for construction infrastructure and logistics, including laydown areas and hoisting requirements (e.g., crane placement and assembly/disassembly, lift paths, rigging, and line of sight)

Developing a detailed traffic/routing plan for oversized loads and equipment inside the plant boundaries

Other (user defined).

**** Additional items to consider for renovation & revamp projects****

"Installability" (e.g., small components/modules/pre-assembly to facilitate installation in congested areas)

Opportunities to perform as much work as possible outside shutdowns and outages

Development of an operations-sensitive schedule (e.g., minimization of shutdown/turnaround work and hot work in operating areas).

D. PROCESS/PRODUCT DESIGN BASIS

The elements in this category focus on the process and mechanical design. It should be noted that on some small projects, none of the elements in this category may be applicable; however, in other situations these may be the key items driving the project.

(For more information on process/mechanical issues, see Category G in the PDRI -- Industrial Projects.)

D.1 Process Safety Management

A formal process safety management (PSM) plan is in place to identify, evaluate, and mitigate potential risks of injury to the environment or populace. The team should develop the PSM plan to address the specific scope of the project appropriately. The important issues are, first, whether the owner has clearly communicated the requirements, methodology, and responsibility for the various activities to project participants and, second, whether this information is incorporated into the project plans. Each national government (or organization) will have its specific PSM compliance requirements. (For example, in the U.S., OSHA Regulation 1910.119 compliance is required.) If a PSM plan is not in place, the team should consider the potential for risks that could affect the schedule and cost of the project.

**** Additional items to consider for renovation & revamp projects****

Compatibility of this project with existing PSM documentation

**** If this is an instance of a repetitive program****

Compatibility of this project with program's PSM documentation.

D.2 Process Flow Diagrams along with Heat & Material Balance

The process flow diagrams, along with the heat and material balance, have been created or updated to accurately reflect the process conditions required to support operating conditions. Evaluation criteria should include the following:

Major equipment items
Flow of materials and heat to and from the major equipment items
Sufficient information to allow sizing of all process lines
Other (user defined).

**** Additional items to consider for renovation & revamp projects****

Definition of owner's requirements for updating existing process flow diagrams and heat and material balance.

D.3 Piping and Instrumentation Diagrams

Piping and instrumentation diagrams (P&IDs) may be referred to with the following other terms:

- Engineering Flow Diagrams (EFDs)
- Mechanical Flow Diagrams (MFDs)
- Process & Mechanical Control Diagrams (PMCDs).

In general, P&IDs are considered to be a critical element within the scope definition package of an industrial project. For small projects, utility flow diagrams (UFDs) will be included. P&IDs must be complete enough to support the required accuracy of estimate and the development of the project's detailed design. P&IDs are traditionally completed in the following iterations or issues:

Preliminary issue – comments and work input from other disciplines and the owner's representatives

Issue for approval – incorporation of all critical information, including lines sized, specifications developed, equipment identified, and blocks completed for owner approval

Issue for design – incorporation of all owner comments, and readiness of P&IDs for the appropriate level of process safety management (PSM) review

Issue as basis of estimate – completion of entire process safety review and incorporation of all comments.

**** Additional items to consider for renovation & revamp projects****

Field verification of existing P&IDs for accuracy

Clear identification of scope of work on the new or existing P&IDs
*(clouding or shading that indicates, e.g., new, refurbished, modified, and/or relocated equipment; utilities; piping; tie-in points; and other items)

Completion of demolition P&IDs to define equipment, piping, and supporting utilities removal scope.

D.4 Piping System Stress Analysis

Piping system stress guidelines and requirements should be documented. The owner must communicate the standards, methodology, and record documentation required to support the piping systems design effort.

**** Additional items to consider for renovation & revamp projects****

Verification of existing conditions (e.g., hangers, supports, anchors, and wall thickness); assurance that lines are functioning, available, and active

Field verification (back to anchor points) of existing lines that will be modified and require stress analysis.

D.5 Equipment Location Drawings

Equipment location/arrangement drawings, which identify the specific location and elevation of each item of equipment in the project, should be developed; key stakeholders should review and approve these drawings.

**** Additional items to consider for renovation & revamp projects****

Identification of any equipment to be removed or rearranged; assurance that equipment is sufficient for continued use, including any necessary retrofitting.

D.6 Critical Process/Product Items Lists

Critical items lists should be developed and documented. Many of these critical items can be extracted from the P&IDs, and they will form the basis for procurement and discipline design. All lists should be in accordance with owner/engineer organization standards. Critical items lists should include the following:

Mechanical equipment list should identify all equipment by tag number,

Instrument index should identify all instruments by tag number (e.g., control valves, relief devices, motor operated valves, and tagged instruments).

The line list should designate all piping in the project (including utilities). It should include items such as the following:

- ☐ Unique number for each line, with size/termination/origin/reference drawing
- ☐ Operating and design temperature and pressure
- ☐ Test pressure requirements and method
- ☐ Pipe specifications
- ☐ Insulation/tracing and paint requirements

Tie-in list should identify all new lines connecting to existing lines. It should include items such as the following:

- ☐ Existing/new line numbers
- ☐ Reference drawings
- ☐ Pipe specifications
- ☐ Types of tie-in/size
- ☐ Structured process to validate tie-ins and tie-in strategy

The piping specialty items list should specify in-line piping items not covered by piping material specifications (e.g., strainers, steam traps, flex hoses, and expansion joints).

Other (user defined).

**** Additional items to consider for renovation & revamp projects****

Identification of existing components to relocate, modify, refurbish, or dismantle.

E. ELECTRICAL AND INSTRUMENTATION SYSTEMS

The elements in this category are focused on electrical design and control. It should be noted that, while none of the elements in this category may be applicable on some small projects, they may be the key items driving the project in other situations.

E.1 Control Philosophy

A control philosophy that describes the general nature of the process and identifies overall control systems hardware, software, simulation, and testing requirements should be documented in a functional specification. Items to consider should include the following:

Continuous or batch

Cyber security

Redundancy requirements

Block diagrams

Input/output (I/O) list

Manual or automatic controls

Safety instrumented systems (SIS) requirements

Classification of interlocks (i.e., process safety)

Alarm conditions and emergency shut down

Start-up controls

Other (user-defined).

**** Additional items to consider for renovation & revamp projects****

Existing specifications, owner preferences and agreements, and compatibility

**** If this is an instance of a repetitive program****

Compatibility of this project with program's control philosophy.

E.2 Functional Descriptions and Control Narratives

Functional descriptions and control narratives should be documented, providing a method of depicting interlock and sequencing systems for the start-up, operation, alarm, and shutdown of new equipment and processes.

**** Additional items to consider for renovation & revamp projects****

Field verification of functional descriptions and control narratives to ensure that they are correct and have been maintained to reflect the actual or current operating scenarios.

E.3 Electric Single Line Diagrams

Electric single line diagrams that document the components, devices, or parts of an electrical power distribution system should be documented. These diagrams portray the system layout, from the public utility's incoming supply to the internal electrical power distribution system. Depending on the size of the electrical system, the single line diagrams may include several levels of distribution. Items to consider should include the following:

Incoming utility with owner substation/distribution to high- and medium-voltage motors and substations

Electrical load list

Unit substations and switch gear

Motor control centers with distribution to motors and lighting panels

Other (user-defined).

**** Additional items to consider for renovation & revamp projects****

Field verification of existing single line diagrams to ensure that they are correct and have been maintained to reflect the actual site conditions

Verification of locations and availability of power for new or relocated equipment.

E.4 Critical Electrical Items Lists

Critical items lists, most of which are extracted from the single line diagrams, need to be developed and documented. These lists will form the basis for procurement and discipline design. All lists should be in accordance with owner/engineer organization standards. Critical items lists should include the following:

Unit substations and switch gear

Transformers

Motor control centers (MCC)

Uninterruptable power supplies (UPS)

Power conditioning equipment

Power factor correction equipment

High-voltage cable

Other (user-defined).

**** Additional items to consider for renovation & revamp projects****

Identification of existing components to relocate, modify, refurbish, or dismantle.

F. GENERAL FACILITY REQUIREMENTS

The elements in this category focus on balance of plant. It should be noted that, while some of the elements in this category may not be applicable on small projects, they may be the key items driving the project in other situations.

F.1 Site Plan

The site plan (also known as the plot plan) identifies the location of new work in relation to adjoining units or facilities. In many cases, the existing facility site plan will be updated to show the location affected by the project. Items to consider should include the following:

Plant grid system with coordinates and work limits

Gates, fences, and/or barriers

Temporary facilities (e.g., construction/fabrication/laydown areas)

Roads/rail facilities/access ways

Green space/buffer zones

Buildings

Other (user-defined).

F.2 Loading/Unloading/Storage Requirements

Permanent loading/unloading/storage facility requirements should be documented; this documentation should identify the raw materials to be unloaded and stored, and the products to be loaded (along with their specifications and hazardous handling requirements, i.e., safety data sheets). Items to consider should include the following:

Instantaneous and overall loading/unloading rates

Storage facilities to be provided and/or utilized

Specification of any required special environmental isolation provisions (e.g., dikes, leak detection devices)

Essential security considerations (e.g., inspection requirements, secure storage, authorized deliveries, access/egress control)

Other (user-defined).

F.3 Transportation Requirements

Document requirements for permanent “in-plant” transportation (e.g., roadways or conveyance systems), as well as methods for receiving/shipping/storing materials (e.g., truck, rail, and/or marine).

F.4 Additional Project Requirements

Additional project requirements define items of scope that require special considerations and documentation. Items to consider should include the following:

Dismantling and demolition requirements (e.g., timing/sequencing, contamination, remediation, hazards, purge requirements, and temporary protection of existing equipment or spaces)

Fire protection and safety considerations (e.g., alarm systems, eye wash stations/safety showers, fire monitors, hydrants, and evacuation and escape routes)

Civil/structural requirements (e.g., structures, buildings, columns, pipe racks, foundations, materials of construction, sewers, and future expansion considerations)

Architectural requirements (e.g., building use, space requirements, safety vulnerability assessment, service, storage, maintenance, parking, accessibility, and noise)

Mechanical/heating, ventilation and air conditioning (HVAC) requirements (e.g., equipment, ducting, controls, cleanrooms, air filtration, and special containments/negative air spaces needed during or after construction)

Water treatment requirements (e.g., process and sanitary waste water treatment, waste disposal, and storm water containment)

Containment (e.g., diking and secondary/double containment)

Other (user-defined).

**** Additional items to consider for renovation & revamp projects****

Interruption or interface to any existing fire and life safety systems (with appropriate contingency planning)
Assessment of existing structural conditions (e.g., foundations, building framing, pipe racks, harmonics/vibrations)
Potential effect of noise vibration and restricted headroom in installation of piling and on existing operations
Underground interference (i.e., utilization of shallow-depth designs)
Transition plan/swing space for people, materials, and processes.

(For more information on architectural requirements, see CII IR 113-2, *PDRI – Industrial Projects,* or CII IR 155-2, *PDRI – Building Projects*.)

SECTION III – EXECUTION APPROACH

G. EXECUTION REQUIREMENTS

The elements in this category focus on ensuring a successful project execution phase.

G.1 Procurement Plan

A procurement plan that, first, identifies all equipment and materials to be delivered to the site and, then, validates and documents that it can be delivered in the required timeframe and at the required quality level should be developed. The team should also consider streamlining procurement processes to address the short duration of small projects. The identification and delivery of long lead/critical equipment and materials are especially important for shutdowns/turnarounds. Issues to consider should include the following:

Long lead time equipment and materials that may impact engineering or construction schedule, including vendor data to support design
Equipment or materials to be reused, including requirements for and timing of inspections/refurbishment
Procurement procedures and guidelines, including responsibilities and impact to schedule
Appropriate specifications and quality requirements of materials/services, including factory acceptance testing and onsite vendor support services

Field procurement of materials and services, including expediting

Procurement of professional services (e.g., design, consulting, testing)

Identification of approved/preferred service suppliers and equipment vendors, with buy-in from key stakeholders

Bid evaluation, terms, and conditions and selection of vendors/suppliers

Spare parts requirements, including consideration to match existing equipment

Inspection, receiving, and warehousing, including reservation of existing equipment/materials

Other (user-defined).

**** Additional items to consider for renovation & revamp projects****

Identification of delivery dates in advance of shutdown/turnaround, to support preparations for pre-outage activities

Availability of procurement support during time-constrained R&R work, especially where expedited material services are required

Procurement for repair, refurbishment, and relocation of existing equipment, materials, lines, electrical, and instrumentation

Retrofit kits (i.e., for non-standard connections and obsolete equipment that may require adaptors).

G.2 Owner Approval Requirements

Owner approval requirements have been developed and documented. Owner approval requirements typically are an important part of the project execution plan, especially the timing of necessary approvals. Document formatting and delivery procedures should also be determined (i.e., specific software used for submission). Items to consider should include the following:

Project document review and approval process

Approval process for changes or modifications

Drawings and drawing revisions

Schedule and schedule changes

Purchasing/invoicing

Other (user-defined).

**** If this is an instance of a repetitive program****

Compatibility of this project with program's owner approval process.

G.3 Distribution Matrix

A distribution matrix (document control system) should be developed that identifies required correspondence and deliverables. It denotes who is required to receive copies of all documents at the various stages of the project, and it ensures the proper distribution of documentation (including methods of distribution and retrieval). Some documents may be restricted due to their proprietary nature.

G.4 Risk Management Plan

A system should be in place to ensure that the team has identified, evaluated, and documented significant risks unique to the project. Mitigation plans should also be developed, with appropriate contingencies included in the project budget and schedule. Risk ownership has been determined. Typical risk issues include the following:

Design issues (e.g., technology maturity, site location, performance of installed equipment)

Construction delivery (e.g., availability of crafts/labor, site discovery, procurement, environmental/regulatory, site logistics, impact on/from operations)

Management performance (e.g., project, construction)

Business conditions/requirements

Other (user-defined).

**** Additional items to consider for renovation & revamp projects****

Unforeseen issues related to the unique characteristics of renovations projects (e.g., hazardous materials unknown underground structures or utilities)

Security clearance/access control in operating areas during project execution

Safety of occupants during emergency conditions related to renovation activities.

G.5 Shutdown/Turnaround Requirements

Required shutdowns/turnarounds have been identified and documented. In the event that this project falls within a shutdown/turnaround, or is the driver for the shutdown/turnaround, special effort should be made to contact the shutdown/turnaround manager for “customer” requirements related to the unique issues surrounding the process. In the event there is no such individual, special care should be made to ensure the site/plant manager is part of the planning process for the project. Issues to consider should include the following:

Scopes of work to be accomplished prior to and during the shutdown/turnaround
Schedule development, including timing of outages
Labor resources
Contingency planning:

- ☐ Unexpected delays (e.g., weather, faulty equipment, unforeseen conditions)
- ☐ Unintended consequences

Considerations given to impacts on operating facilities
Progress measurement and reporting specifically to production/operations
Coordination meetings and planning
Identification of unique risks
Potential impact due to multiple projects working concurrently
Shutdown/turnaround communications plan
Other (user-defined).

G.6 Pre-Commissioning, Start-up, & Turnover Sequence Requirements

Most small projects have some element of pre-commissioning, start-up, and turnover. The owner’s requirements for this completion activity should be reviewed, documented, and incorporated into the planning sequence. Issues to consider should include the following:

Contractor/Engineer/Owner roles and responsibilities:

- ☐ Leadership responsibility
- ☐ Pre-commissioning, training, testing, and start-up

- ☐ Definition of mechanical/electrical acceptance/approvals

Sequence of start-up and turnover, including system identification requirements and pre-start-up safety review (PSSR)

Workforce/technology requirements

Start-up requirements identified (e.g., quality documentation requirements, run uptime, rate, performance requirements, commissioning spares, and feedstock)

Training requirements:

- ☐ Information systems, technology, and controls
- ☐ Equipment operation and maintenance
- ☐ Training materials and equipment (e.g., instructional videos, manufacturer/supplier-specific training)
- ☐ Safety systems

Other (user-defined).

H. Engineering/Construction Plan & Approach

The elements in this category focus on ensuring successful construction and closeout phases.

H.1 Engineering/Construction Methodology

The methodology for engineering and constructing the project has been documented. Items to consider should include the following:

Establishment of contracting plan

Engineering/construction staffing requirements:

- ☐ Identification of requisite project team experience, including seniority, experience with project type, and previous working relationships with the team/owner
- ☐ Ensuring that the organization can staff the project with a team of appropriately experienced individuals, or identify where hiring should occur
- ☐ Determination of necessary availability (e.g., part-time or full-time) of project team members
- ☐ Design and contractor licensure and registrations
- ☐ Union considerations

Identification, documentation, and clear communication of responsibilities among parties

Identification and incorporation of construction sequencing of events into the schedule/work package

Review of control of work plan (e.g., work permits, access, critical lifts)

Quality assurance and quality control (QA/QC) plans

Understanding and documentation of any variance from standard operating procedures regarding health, safety, environmental, security, and communication between engineering and construction

Clear identification of delivery gates/docks/doors and receiving hours to be used by contractors

Other (user-defined).

**** Additional items to consider for renovation & revamp projects****

Consideration of flexible contracting arrangements for renovation projects, such as a combination of unit price, cost reimbursable, and lump sum

Identification of appropriate contingency for unforeseen conditions

Identification of specialized contractors for R&R activities, such as hazardous abatement or heavy haulers

Acknowledgement of responsibility for critical maintenance activities in the existing facility (i.e., routine maintenance that is necessary during construction)

Identification of permits and approvals for work in or near continuing operations (e.g., hot work permitting, confined space, lift plans, environmental remediation)

Planning for coordination between multiple contractors and/or maintenance activities

Coordination of equipment and material movement for renovation work with operations to ensure no unplanned impacts.

**** If this is an instance of a repetitive program****

Compatibility of this project with program’s engineering/construction plan and approach

H.2 Project Cost Estimate

The project cost estimate should address all costs and work hours necessary to complete the project. This cost estimate should include the following:

Design costs

Construction/demolition costs, including labor, materials, and equipment

Professional/service fees

Contingencies

Start-up and commissioning costs, including raw materials, utilities, and consumables

Construction management costs

Owner costs

Taxes and insurance

Project specific safety costs

Costs for such exigencies as currency exchange, import/export fees, and transoceanic shipping

Other overhead costs

Other (user-defined).

H.3 Project Accounting and Cost Control

Project-specific accounting requirements have been identified, documented, and responsibility assigned. A method for measuring and reporting progress on meeting these requirements has been established, documented and responsibilities assigned in accordance with organizational requirements. These requirements should take into consideration any joint ventures or special contracting/funding arrangements. Shutdowns/turnarounds/outages may require a much more detailed project control system. Issues to consider should include the following:

Budget established

Internal cost reporting requirements (e.g., phasing or area sub-accounting, capital versus non-capital funds)

Client or regulatory reporting/billing requirements

Payment schedules

Cost control reporting requirements

Cost control procedures, including cash flow projections and reporting requirements

Percent complete control procedures, including lien waivers

Change management procedures, including interfaces with information systems

Integration of multiple projects

Other (user-defined).

**** Additional items to consider for renovation & revamp projects****

Additional communication may be required to coordinate contractor activities with ongoing owner maintenance and plant operations.

H.4 Project Schedule and Schedule Control

An appropriately detailed project schedule has been developed, documented, and analyzed. A method for measuring and reporting progress should be established and documented, with responsibilities assigned in accordance with organizational requirements. Key stakeholders should agree upon this schedule. Schedule and control requirements should include the following:

Early input from the following:

- ☐ Owner/operations
- ☐ Design/engineering
- ☐ Construction/estimating
- ☐ Procurement
- ☐ Environmental and permitting
- ☐ Shutdown/turnaround manager (if applicable)

Milestones, unusual schedule considerations, appropriate master schedule contingency time (float), procurement of long lead items, and required submissions and approvals

Schedule control procedures, including clearly defined outage dates, constraints, and detailed hourly schedule (if appropriate for the scope of work)

Reporting requirements

Other (user-defined).

**** Additional items to consider for renovation & revamp projects****

Communication of the schedule to coordinate contractor activities with owner maintenance and plant operations, and integration of multiple projects

Milestone schedule should involve obtaining early input from the Shutdown/turnaround manager, due to time and space constraints that require very detailed plans and schedules.

H.5 Project Change Control

A process has been established and documented that identifies and manages changes to project scope and/or construction changes, in accordance with organizational requirements. The process should include an assessment and approval process, and should take the following into consideration:

Level of approval necessary, including identification of party(ies) responsible for authorizing change

Time required for approvals

Documentation required

Impact on project:

- ☐ Schedule
- ☐ Quality
- ☐ Budget

Other (user-defined).

**** If this is an instance of a repetitive program****

Compatibility of this project with program's change management process

H.6 Deliverables for Design and Construction

A list detailing the required deliverables for the project has been developed. Items to consider should include the following:

Written scope of work

Drawings such as the following:

- ☐ P&IDs
- ☐ Isometrics/field erection details

- ☐ Site or plot plans
- ☐ Piping
- ☐ Civil/structural/architectural/electrical/instrumentation
- ☐ Other (user-defined).

Vendor documentation and certifications (e.g., positive material identifications (PMIs), material test reports (MTRs).

Models (level of modeling and specific modeling software requirements defined)

Project correspondence

Project process safety management (PSM) documents (project hazards analysis (PHA) resolution report complete):

- ☐ Alarm set points
- ☐ Operational guidelines for new equipment
- ☐ Other (user-defined).

Regulatory permits

Procurement documents (purchase orders, material registers, contract)

Other (user-defined)

**** If this is an instance of a repetitive program****

Compatibility of this project with program's design and construction deliverables.

H.7 Deliverables for Project Commissioning/Closeout

A list detailing the required deliverables for commissioning/closeout of the project has been developed. Items to consider should include the following:

Design calculations, equipment folders, and project data books (quantity, format, contents, and completion date)

Operations, training, and maintenance manuals

As-built drawings

Quality assurance documents

Spare parts documentation

Preventative maintenance plan/operability and reliability requirements

Commissioning documentation requirements

Other (user-defined).

**** Additional items to consider for renovation & revamp projects****

Requirements to update existing (legacy) documentation/models and as-built drawings, including equipment folders/asset management systems

Procedures for retiring an asset including the documentation requirements, spare parts inventory, and accounting requirements

**** If this is an instance of a repetitive program****

Compatibility of this project with program's commissioning/closeout deliverables

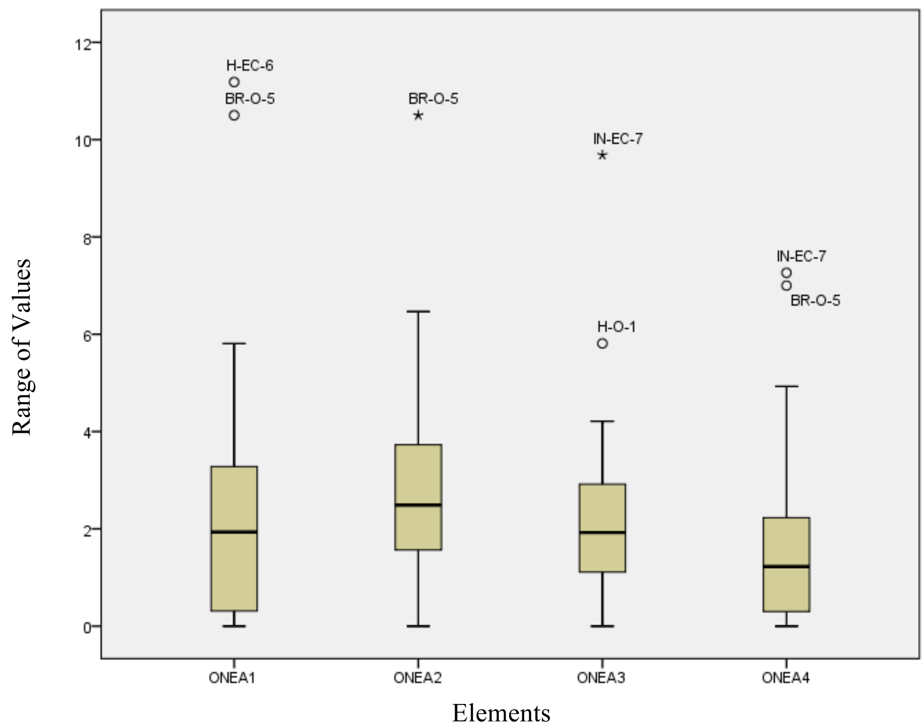
APPENDIX C

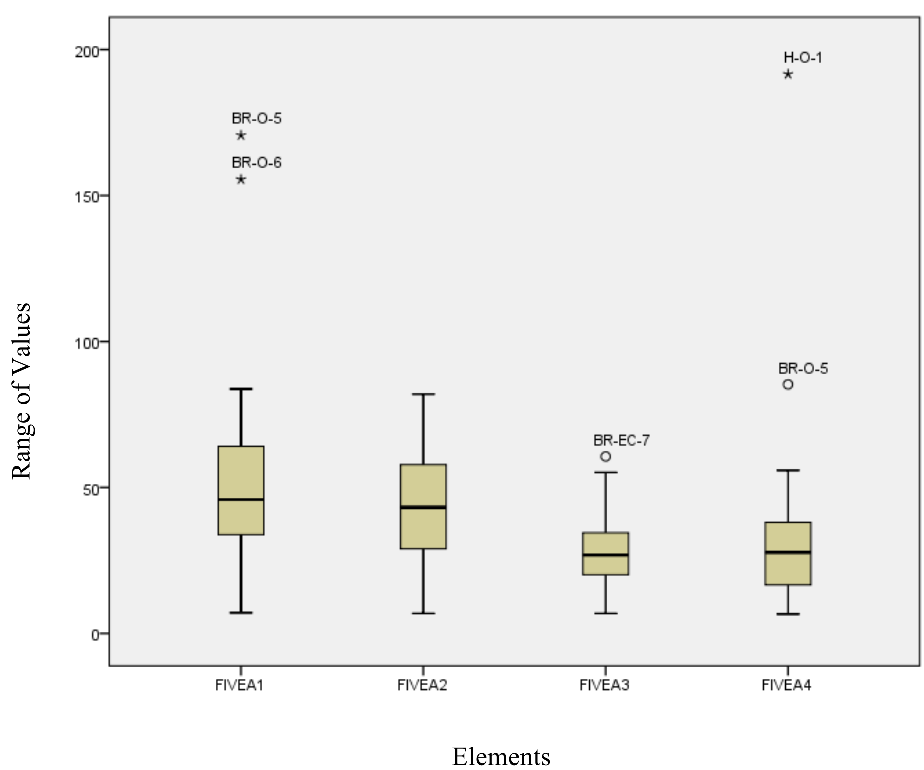
DESCRIPTIVE STATISTICS FROM WEIGHTING WORKSHOPS

DESCRIPTIVE STATISTICS FOR ELEMENTS A.1 – A.4

	A.1		A.2		A.3		A.4	
	LEV. 1	**LEV. 5**	**LEV. 1**	**LEV. 5**	**LEV. 1**	**LEV. 5**	**LEV. 1**	**LEV. 5**
Mean	2.18	48.47	2.68	45.79	1.89	26.12	1.93	33.30
Standard Deviation	2.56	30.99	1.94	19.82	1.71	11.10	1.90	30.22
Minimum	0.00	7.09	0.00	6.83	0.00	4.85	0.00	6.62
Q1	0.00	27.73	1.47	29.70	0.96	19.20	0.43	17.77
Median	1.57	43.24	2.36	45.39	1.76	24.90	1.42	27.93
Q3	3.05	61.59	3.36	57.83	2.33	30.57	2.82	38.75
Maximum	11.18	170.65	10.50	101.26	9.68	60.61	7.26	191.60
Range	11.18	163.56	10.50	94.42	9.68	55.75	7.26	184.98
IQR	3.05	33.87	1.88	28.13	1.37	11.37	2.38	20.98
Mode	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A
Skewness	1.92	1.83	1.38	0.27	2.07	0.79	1.16	3.93
Kurtosis	4.24	5.27	3.66	-0.11	7.16	1.26	1.03	19.65
Upper Extreme Value	12.19	163.19	9.00	142.24	6.45	64.69	9.97	101.70
Upper Outlier Value	7.62	112.39	6.18	100.03	4.39	47.63	6.39	70.22
Lower Outlier Value	-4.57	-23.07	-1.35	-12.51	-1.10	2.13	-3.14	-13.70
Lower Extreme Value	-9.14	-73.87	-4.17	-54.71	-3.16	-14.93	-6.72	-45.17

BOXPLOTS FOR ELEMENTS A.1 – A.4 (LEVEL 1 AND LEVEL 5)

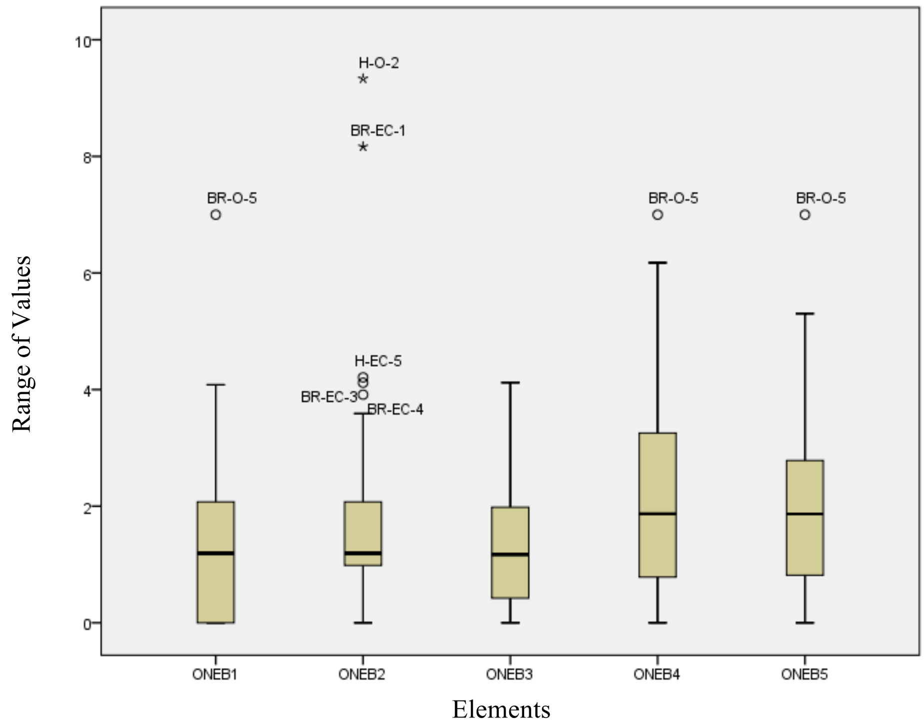


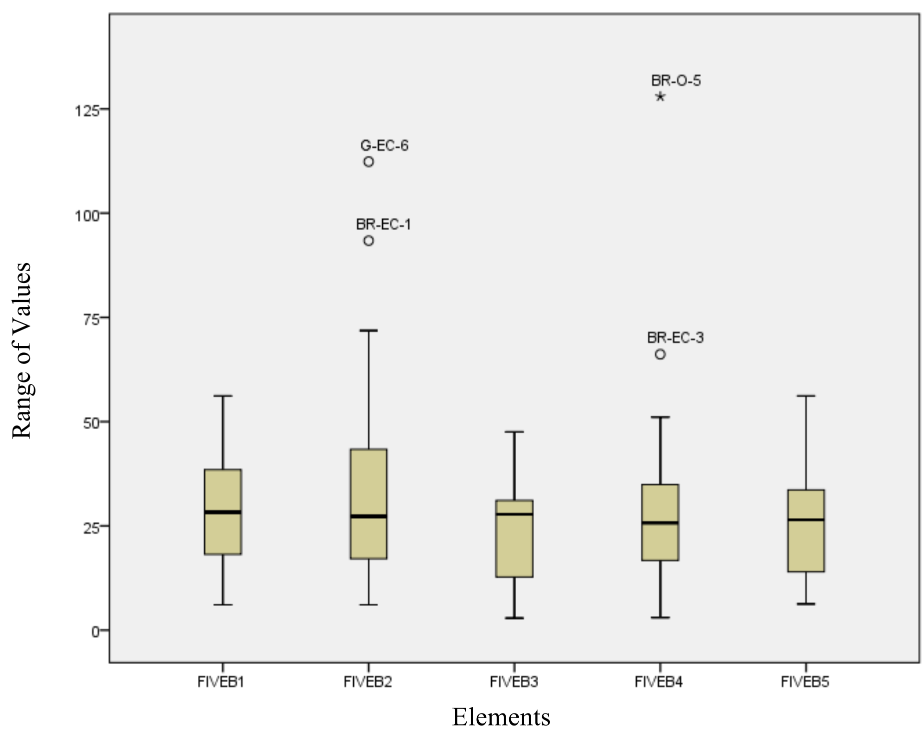


DESCRIPTIVE STATISTICS FOR ELEMENTS B.1 – B.5

	B.1		B.2		B.3		B.4		B.5	
	LEV. 1	LEV. 5	LEV. 1	LEV. 5	LEV. 1	LEV. 5	LEV. 1	LEV. 5	LEV. 1	LEV. 5
Mean	1.52	29.00	1.89	32.87	1.38	22.79	1.95	28.02	2.01	25.95
Standard Deviation	1.63	13.13	1.99	22.17	1.13	10.97	1.81	19.45	1.54	14.88
Minimum	0.00	6.06	0.00	0.00	0.00	2.89	0.00	3.03	0.00	1.32
Q1	0.00	19.10	0.68	17.70	0.50	12.72	0.49	16.87	0.94	14.28
Median	1.19	28.09	1.28	27.05	1.20	25.55	1.54	25.97	2.02	25.62
Q3	2.08	37.64	2.68	38.11	2.08	30.17	2.89	34.56	2.80	33.07
Maximum	7.00	56.18	9.33	112.36	4.12	47.57	7.00	127.99	7.00	83.68
Range	7.00	50.12	9.33	112.36	4.12	44.68	7.00	124.96	7.00	82.36
IQR	2.08	18.54	2.00	20.42	1.58	17.45	2.39	17.69	1.86	18.78
Mode	0.00	27.78	0.00	#N/A	0.00	27.78	0.00	#N/A	0.00	#N/A
Skewness	1.52	0.37	1.83	1.48	0.57	-0.05	1.00	2.94	0.90	1.19
Kurtosis	2.74	-0.67	4.16	2.65	-0.39	-0.67	0.39	13.61	1.15	3.14
Upper Extreme Value	8.34	93.25	8.68	99.37	6.82	82.53	10.07	87.64	8.38	89.42
Upper Outlier Value	5.21	65.44	5.68	68.74	4.45	56.35	6.48	61.10	5.59	61.24
Lower Outlier Value	-3.13	-8.70	-2.33	-12.93	-1.87	-13.47	-3.10	-9.67	-1.84	-13.90
Lower Extreme Value	-6.25	-36.51	-5.33	-43.55	-4.24	-39.65	-6.69	-36.20	-4.63	-42.07

BOXPLOTS FOR ELEMENTS B.1 – B.5 (LEVEL 1 AND LEVEL 5)

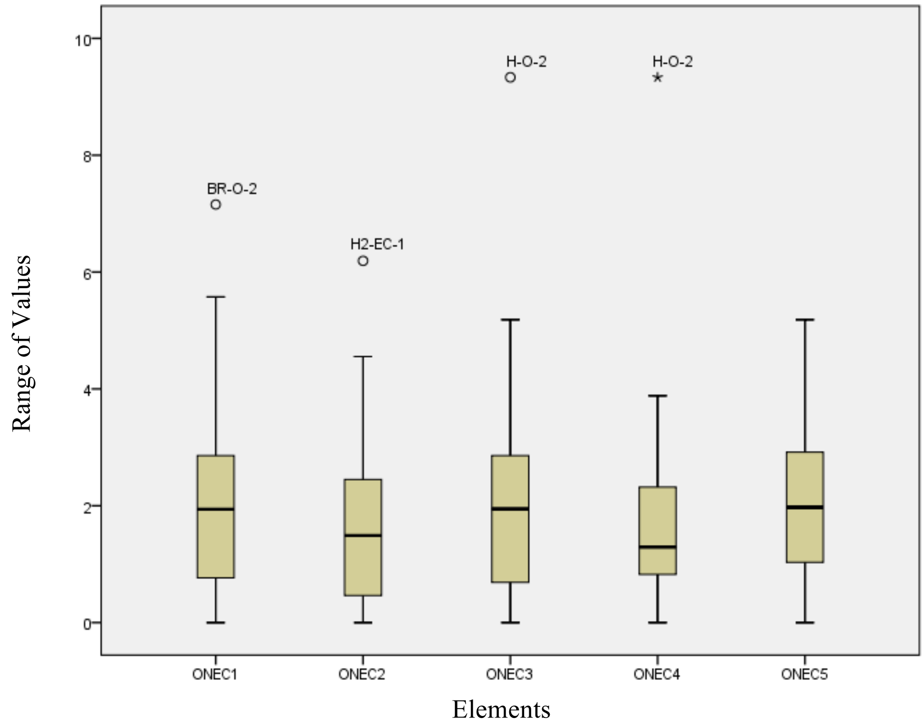


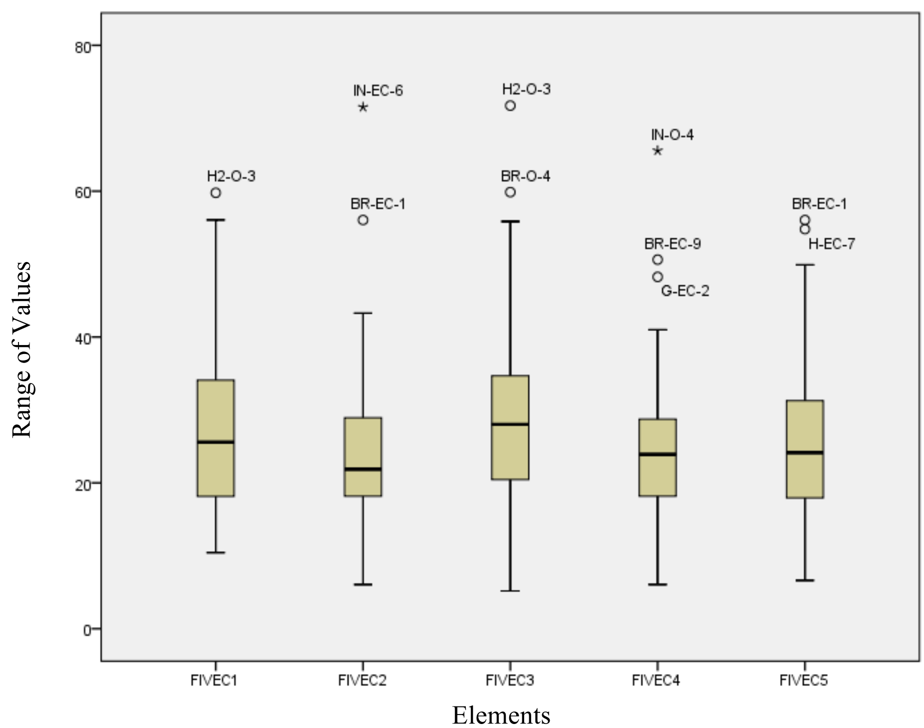


DESCRIPTIVE STATISTICS FOR ELEMENTS C.1 – C.5

	C.1		C.2		C.3		C.4		C.5	
	LEV. 1	LEV. 5	LEV. 1	LEV. 5	LEV. 1	LEV. 5	LEV. 1	LEV. 5	LEV. 1	LEV. 5
Mean	1.98	27.66	1.69	24.57	2.03	29.03	1.62	24.93	2.05	26.14
Standard Deviation	1.67	13.24	1.43	11.79	1.75	13.67	1.53	10.89	1.35	11.02
Minimum	0.00	7.15	0.00	6.06	0.00	5.17	0.00	6.06	0.00	6.62
Q1	0.94	17.11	0.53	17.92	0.72	20.18	0.82	18.71	1.04	17.92
Median	1.92	25.57	1.53	21.82	1.95	27.90	1.29	23.91	2.04	24.64
Q3	2.87	34.85	2.47	28.94	2.84	34.62	2.32	28.86	2.92	31.50
Maximum	7.16	59.77	6.19	71.53	9.33	71.73	9.33	65.57	5.19	56.05
Range	7.16	52.62	6.19	65.47	9.33	66.55	9.33	59.51	5.19	49.43
IQR	1.93	17.74	1.94	11.02	2.12	14.44	1.50	10.15	1.89	13.58
Mode	0.00	27.78	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	27.78
Skewness	0.91	0.71	1.05	1.48	1.49	0.68	2.41	1.19	0.26	0.82
Kurtosis	0.77	-0.24	1.80	3.86	4.41	0.87	10.82	2.82	-0.43	0.51
Upper Extreme Value	8.67	88.06	8.30	61.98	9.19	77.95	6.83	59.32	8.58	72.25
Upper Outlier Value	5.77	61.46	5.39	45.46	6.02	56.28	4.58	44.09	5.75	51.88
Lower Outlier Value	-1.96	-9.49	-2.38	1.40	-2.46	-1.49	-1.43	3.48	-1.79	-2.45
Lower Extreme Value	-4.85	-36.10	-5.29	-15.13	-5.63	-23.15	-3.69	-11.75	-4.62	-22.83

BOXPLOTS FOR ELEMENTS C.1 – C.5 (LEVEL 1 AND LEVEL 5)

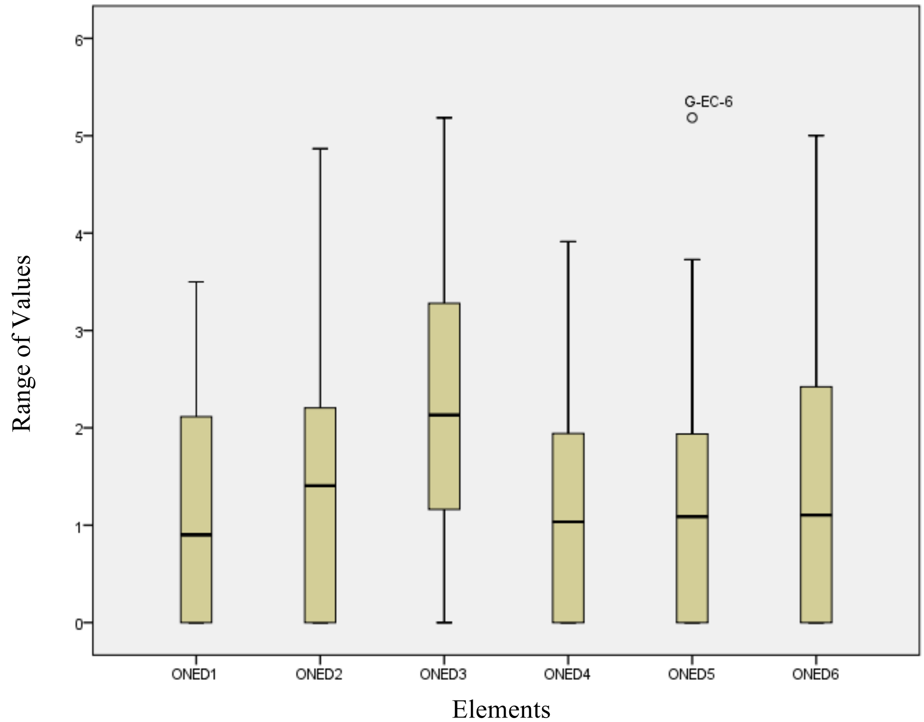


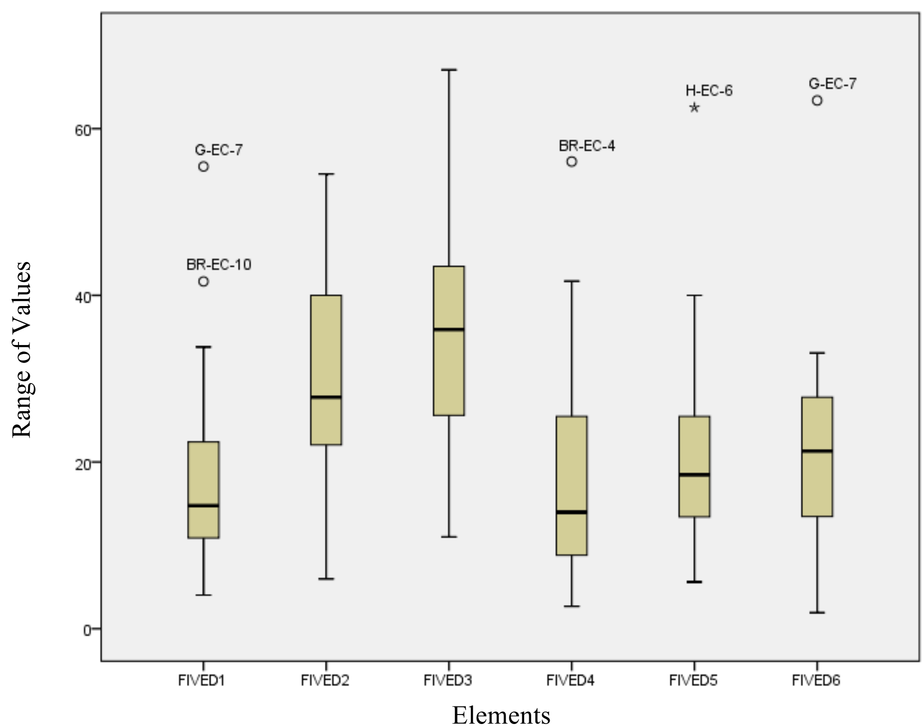


DESCRIPTIVE STATISTICS FOR ELEMENTS D.1 – D.6

	D.1		D.2		D.3Q		D.4		D.5		D.6	
	LEV. 1	**LEV. 5**	**LEV. 1**	**LEV. 5**	**LEV. 1**	**LEV. 5**	**LEV. 1**	**LEV. 5**	**LEV. 1**	**LEV. 5**	**LEV. 1**	**LEV. 5**
Mean	1.13	17.56	1.35	28.40	2.26	35.45	1.31	18.18	1.31	21.99	1.42	22.19
Standard Deviation	1.03	9.79	1.21	13.77	1.73	17.64	1.28	13.08	1.18	11.84	1.23	11.71
Minimum	0.00	4.04	0.00	5.98	0.00	9.28	0.00	2.69	0.00	0.00	0.00	1.92
Q1	0.00	10.94	0.00	19.13	1.15	20.54	0.00	8.77	0.10	13.57	0.42	14.58
Median	0.93	14.76	1.27	27.30	2.06	34.09	1.06	13.98	1.14	20.83	1.18	21.63
Q3	2.07	22.14	2.08	38.85	3.13	42.58	2.01	25.81	1.94	30.06	2.07	28.37
Maximum	3.50	55.46	4.87	64.89	9.30	87.46	5.57	60.75	5.19	62.54	5.00	63.38
Range	3.50	51.42	4.87	58.91	9.30	78.18	5.57	58.06	5.19	62.54	5.00	61.47
IQR	2.07	11.20	2.08	19.72	1.98	22.04	2.01	17.04	1.84	16.50	1.65	13.79
Mode	0.00	#N/A	0.00	27.78	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A
Skewness	0.43	1.70	0.72	0.44	1.43	0.76	1.08	1.47	1.07	0.74	0.88	0.69
Kurtosis	-1.03	4.40	0.27	-0.10	4.23	0.27	1.38	2.45	1.47	1.37	0.52	1.65
Upper Extreme Value	8.29	55.73	8.34	98.00	9.06	108.71	8.03	76.92	7.47	79.56	7.03	69.74
Upper Outlier Value	5.18	38.94	5.21	68.42	6.10	75.65	5.02	51.36	4.70	54.81	4.55	49.06
Lower Outlier Value	-3.11	-5.85	-3.13	-10.45	-1.82	-12.52	-3.01	-16.79	-2.67	-11.18	-2.05	-6.11
Lower Extreme Value	-6.22	-22.65	-6.25	-40.03	-4.79	-45.58	-6.02	-42.34	-5.43	-35.93	-4.53	-26.80

BOXPLOTS FOR ELEMENTS D.1 – D.6 (LEVEL 1 AND LEVEL 5)

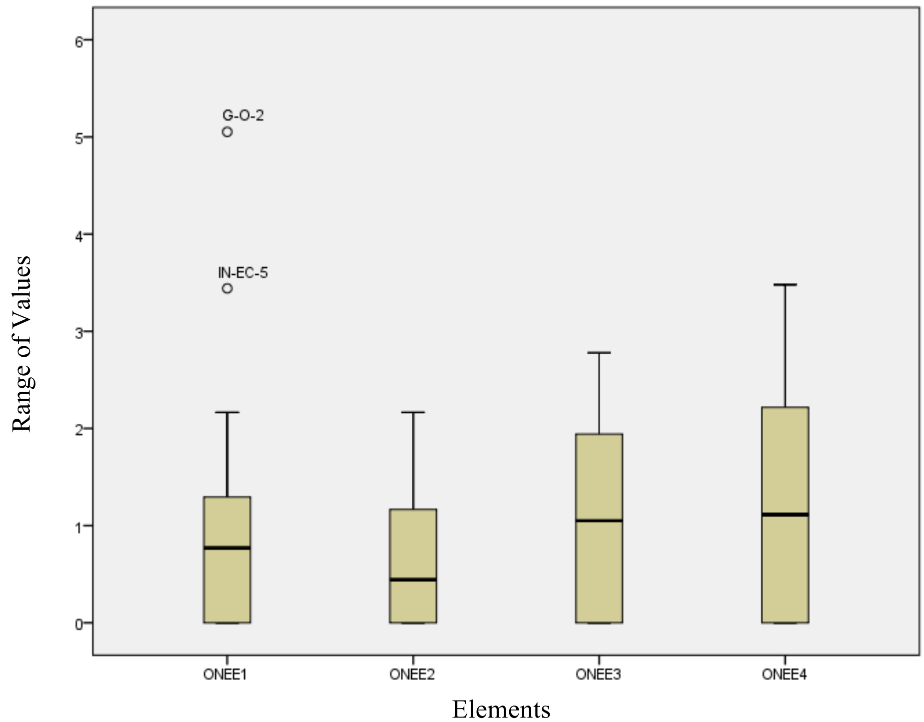


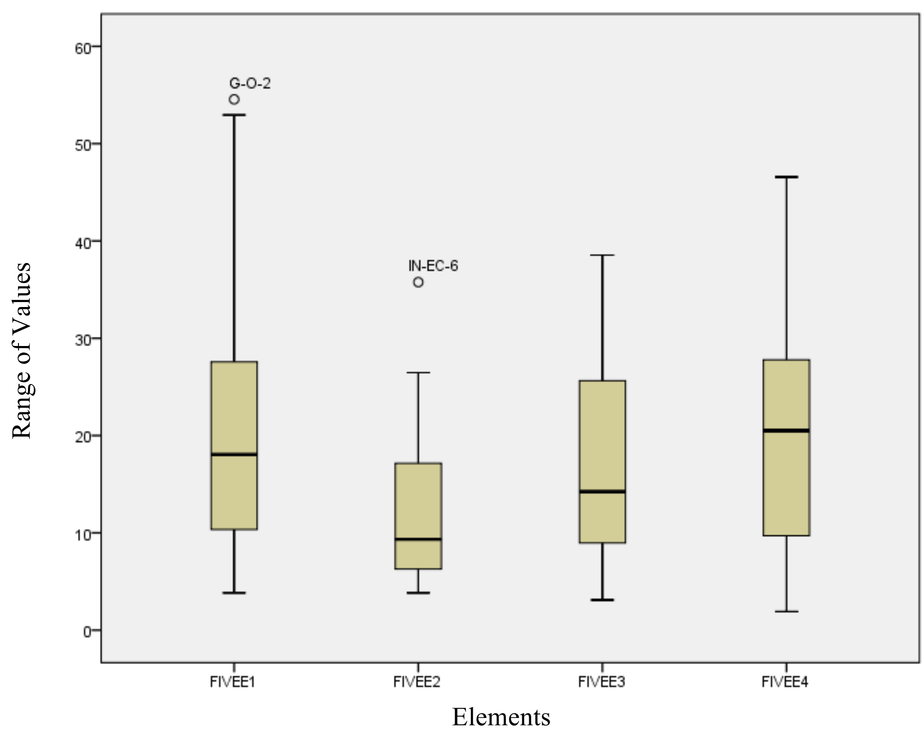


DESCRIPTIVE STATISTICS FOR ELEMENTS E.1 – E.4

	E.1		E.2		E.3		E.4	
	LEV. 1	LEV. 5	LEV. 1	LEV. 5	LEV. 1	LEV. 5	LEV. 1	LEV. 5
Mean	1.23	20.53	0.81	12.67	1.03	16.54	1.11	17.81
Standard Deviation	1.47	12.33	0.95	8.13	0.94	10.07	1.02	11.04
Minimum	0.00	3.83	0.00	3.83	0.00	2.86	0.00	0.00
Q1	0.00	11.78	0.00	6.23	0.00	8.35	0.00	9.34
Median	1.05	18.71	0.61	10.02	0.99	13.65	1.00	16.39
Q3	1.62	27.04	1.23	18.71	1.97	25.51	1.79	26.83
Maximum	7.16	54.55	4.77	36.29	2.78	40.98	3.48	46.57
Range	7.16	50.72	4.77	32.46	2.78	38.12	3.48	46.57
IQR	1.62	15.26	1.23	12.48	1.97	17.16	1.79	17.49
Mode	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A
Skewness	2.10	1.21	1.99	1.23	0.38	0.68	0.57	0.40
Kurtosis	5.61	1.32	5.98	1.23	-1.27	-0.50	-0.68	-0.42
Upper Extreme Value	6.46	72.83	4.92	56.15	7.88	76.99	7.15	79.30
Upper Outlier Value	4.04	49.94	3.08	37.43	4.93	51.25	4.47	53.06
Lower Outlier Value	-2.42	-11.11	-1.85	-12.50	-2.96	-17.39	-2.68	-16.90
Lower Extreme Value	-4.85	-34.01	-3.69	-31.22	-5.91	-43.13	-5.36	-43.14

BOXPLOTS FOR ELEMENTS E.1 – E.4 (LEVEL 1 AND LEVEL 5)

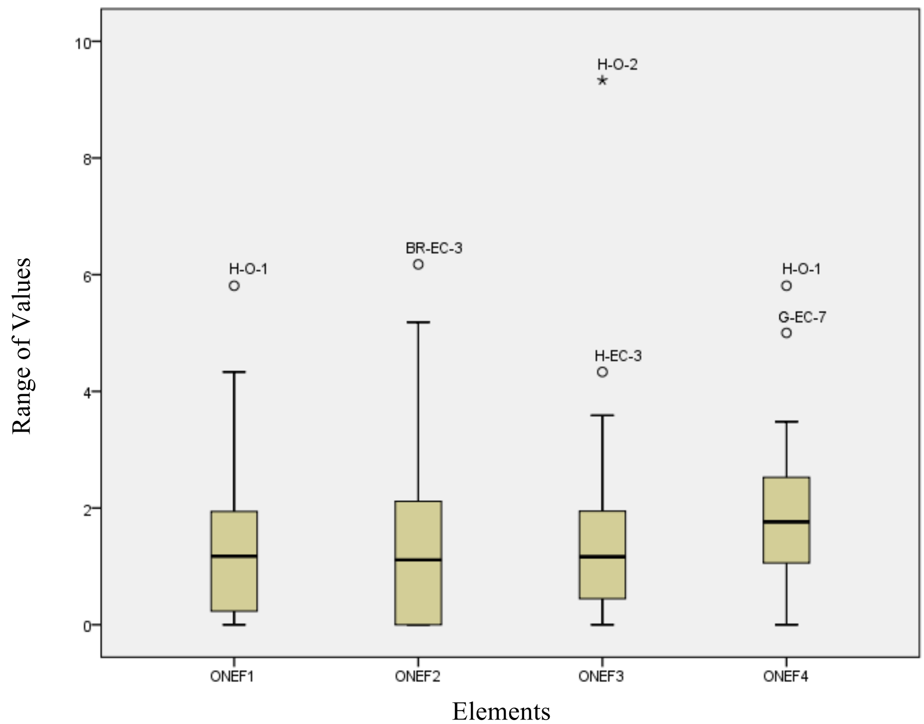


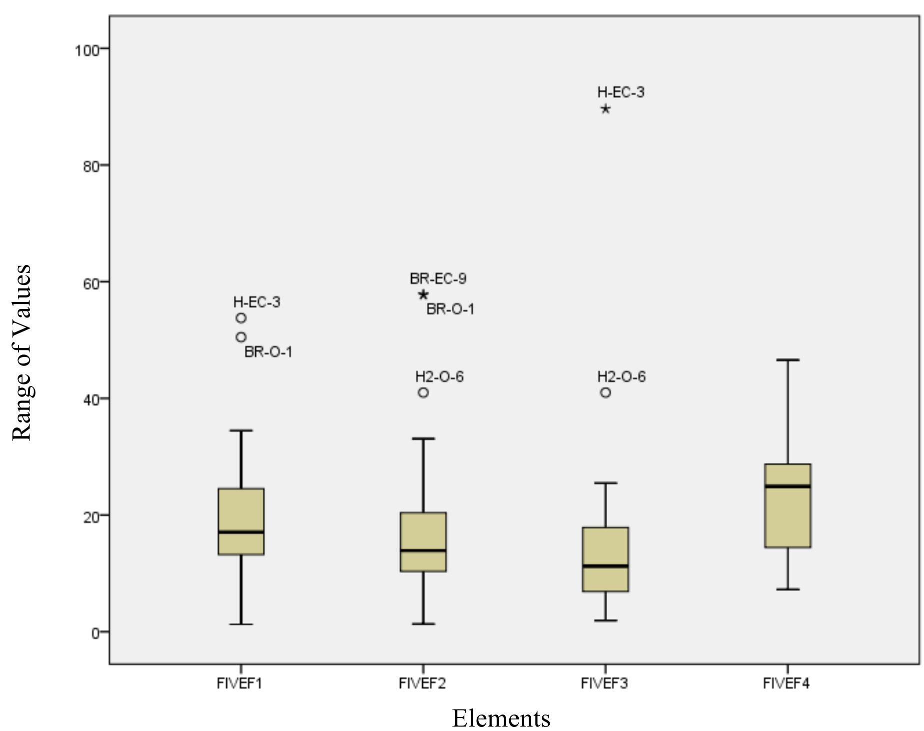


DESCRIPTIVE STATISTICS FOR ELEMENTS F.1 – F.4

	F.1		F.2		F.3		F.4	
	LEV. 1	**LEV. 5**	**LEV. 1**	**LEV. 5**	**LEV. 1**	**LEV. 5**	**LEV. 1**	**LEV. 5**
Mean	1.13	18.89	1.43	16.70	1.42	14.57	2.02	24.30
Standard Deviation	1.22	12.82	1.55	12.52	1.68	14.73	1.40	12.23
Minimum	0.00	1.26	0.00	1.32	0.00	1.92	0.00	4.47
Q1	0.00	10.41	0.00	10.04	0.43	6.86	1.07	14.23
Median	0.99	16.60	1.11	13.89	1.07	10.90	1.95	24.60
Q3	1.60	23.10	2.07	17.14	1.94	17.24	2.56	30.39
Maximum	5.81	58.25	6.18	57.84	9.33	89.62	5.81	59.87
Range	5.81	56.99	6.18	56.52	9.33	87.71	5.81	55.40
IQR	1.60	12.70	2.07	7.10	1.51	10.38	1.49	16.16
Mode	0.00	#N/A	0.00	13.89	0.00	#N/A	0.00	#N/A
Skewness	1.67	1.30	1.47	1.94	3.00	3.77	0.91	0.84
Kurtosis	3.91	1.93	1.91	4.31	12.59	17.93	0.97	1.12
Upper Extreme Value	6.39	61.20	8.30	38.44	6.47	48.38	7.03	78.86
Upper Outlier Value	3.99	42.15	5.19	27.79	4.21	32.81	4.79	54.63
Lower Outlier Value	-2.40	-8.64	-3.11	-0.61	-1.83	-8.72	-1.17	-10.01
Lower Extreme Value	-4.79	-27.69	-6.22	-11.26	-4.09	-24.29	-3.41	-34.25

BOXPLOTS FOR ELEMENTS F.1 – F.4 (LEVEL 1 AND LEVEL 5)

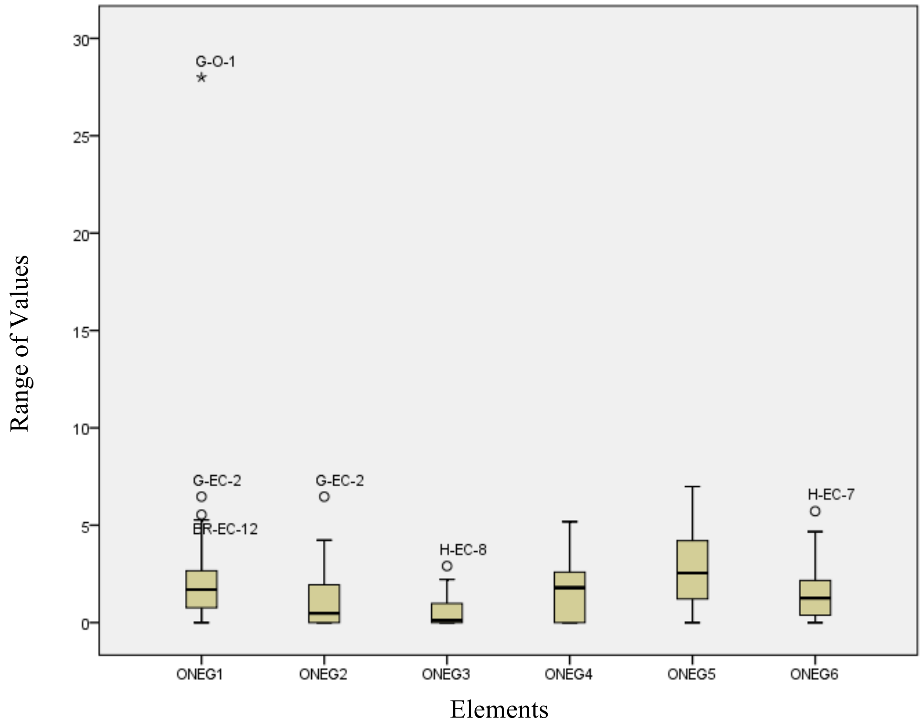


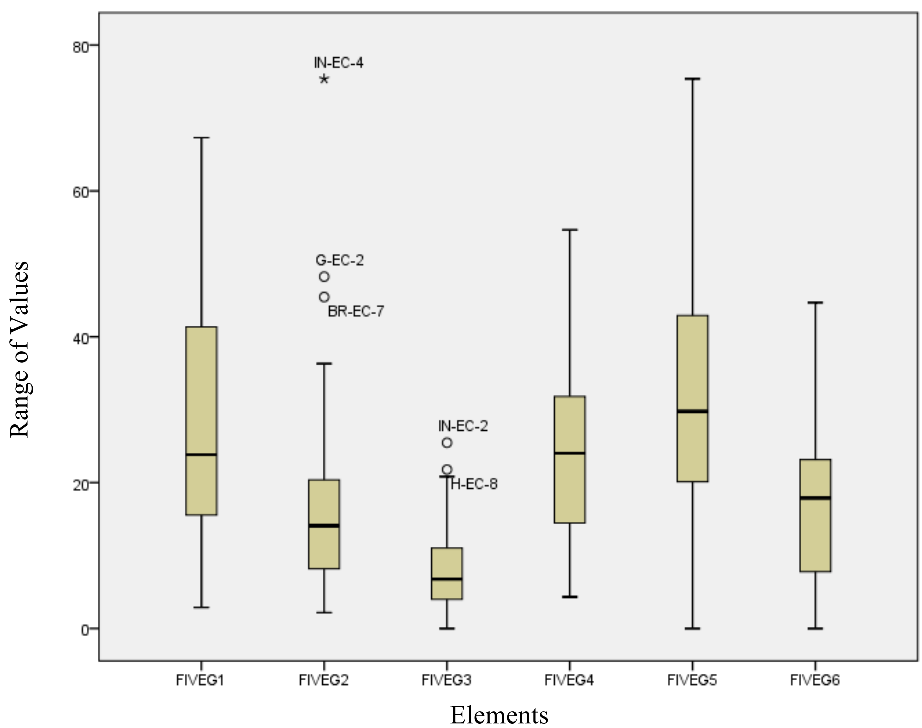


DESCRIPTIVE STATISTICS FOR ELEMENTS G.1 – G.6

	G.1		G.2		G.3		G.4		G.5		G.6	
	LEV. 1	**LEV. 5**	**LEV. 1**	**LEV. 5**	**LEV. 1**	**LEV. 5**	**LEV. 1**	**LEV. 5**	**LEV. 1**	**LEV. 5**	**LEV. 1**	**LEV. 5**
Mean	2.49	28.65	1.10	16.61	0.47	7.81	1.56	23.58	2.76	33.07	1.74	20.14
Standard Deviation	3.96	16.97	1.32	12.93	0.67	5.90	1.38	12.83	1.87	18.16	1.44	12.99
Minimum	0.00	2.87	0.00	2.16	0.00	0.00	0.00	4.33	0.00	0.00	0.00	0.00
Q1	0.77	15.01	0.00	8.28	0.00	3.99	0.00	13.54	1.38	20.80	0.51	9.71
Median	1.70	24.41	0.76	13.89	0.00	6.41	1.33	22.91	2.58	30.56	1.76	20.70
Q3	2.69	41.36	2.02	20.04	0.82	10.73	2.56	30.59	4.23	42.91	2.55	26.83
Maximum	28.00	71.53	6.47	75.38	2.90	25.47	5.19	54.67	6.99	92.78	5.72	54.55
Range	28.00	68.66	6.47	73.21	2.90	25.47	5.19	50.35	6.99	92.78	5.72	54.55
IQR	1.92	26.36	2.02	11.75	0.82	6.74	2.56	17.05	2.85	22.10	2.04	17.12
Mode	0.00	#N/A	0.00	#N/A	0.00	0.00	0.00	#N/A	0.00	#N/A	0.00	#N/A
Skewness	5.13	0.65	1.65	2.27	1.70	1.15	0.53	0.39	0.25	0.88	0.75	0.80
Kurtosis	32.07	-0.38	3.89	7.35	2.94	0.92	-0.54	-0.53	-0.75	1.45	0.32	0.29
Upper Extreme Value	8.46	120.43	8.08	55.29	3.27	30.95	10.25	81.75	12.79	109.22	8.65	78.18
Upper Outlier Value	5.57	80.90	5.05	37.66	2.04	20.84	6.40	56.17	8.51	76.07	5.60	52.50
Lower Outlier Value	-2.12	-24.52	-3.03	-9.34	-1.23	-6.12	-3.84	-12.04	-2.90	-12.35	-2.54	-15.97
Lower Extreme Value	-5.00	-64.06	-6.06	-26.97	-2.45	-16.23	-7.68	-37.61	-7.18	-45.51	-5.60	-41.65

BOXPLOTS FOR ELEMENTS G.1 – G.6 (LEVEL 1 AND LEVEL 5)

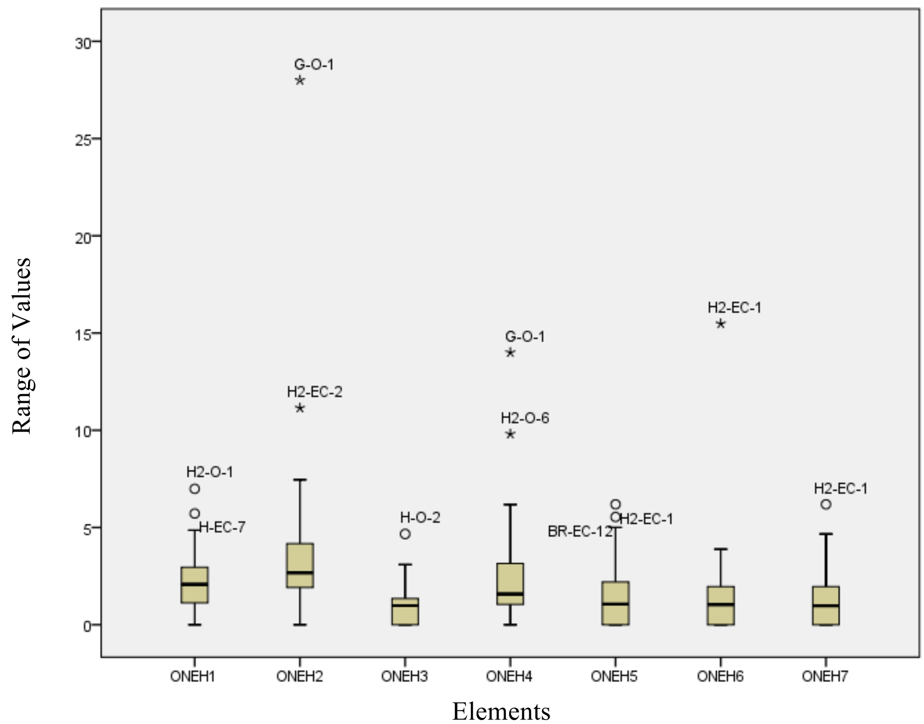


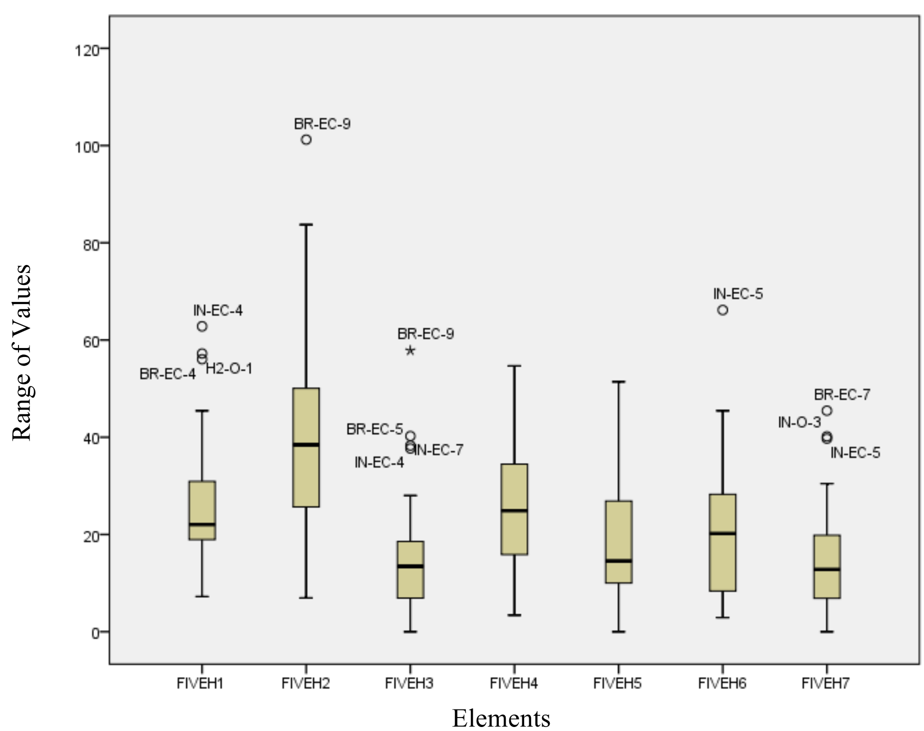


DESCRIPTIVE STATISTICS FOR ELEMENTS H.1 – H.7

	H.1		H.2		H.3		H.4		H.5		H.6		H.7	
	LEV. 1	LEV. 5	LEV. 1	LEV. 5	LEV. 1	LEV. 5	LEV. 1	LEV. 5	LEV. 1	LEV. 5	LEV. 1	LEV. 5	LEV. 1	LEV. 5
Mean	2.13	25.22	3.53	40.56	0.97	14.37	2.36	25.16	1.27	18.53	1.38	20.32	1.26	14.89
Standard Deviation	1.57	12.55	3.90	20.51	0.99	10.64	2.50	13.05	1.44	12.36	2.18	13.12	1.33	10.43
Minimum	0.00	7.23	0.00	6.94	0.00	0.00	0.00	3.41	0.00	0.00	0.00	2.89	0.00	0.00
Q1	1.11	18.11	1.95	25.77	0.00	6.87	1.03	16.04	0.00	10.03	0.00	8.67	0.00	6.86
Median	2.02	21.98	2.72	40.18	0.95	12.71	1.57	23.63	1.06	14.69	1.02	20.56	0.97	12.82
Q3	2.95	30.75	4.15	49.98	1.32	18.55	3.12	34.00	2.18	26.84	1.95	28.42	1.96	19.83
Maximum	6.99	62.81	28.00	101.22	4.67	57.84	14.00	54.67	6.19	51.43	15.48	66.18	6.19	45.45
Range	6.99	55.58	28.00	94.28	4.67	57.84	14.00	51.26	6.19	51.43	15.48	63.29	6.19	45.45
IQR	1.84	12.64	2.20	24.21	1.32	11.67	2.10	17.97	2.18	16.81	1.95	19.75	1.96	12.96
Mode	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A
Skewness	0.74	1.00	4.72	0.66	1.29	1.82	2.43	0.26	1.51	0.76	5.06	0.85	1.39	0.97
Kurtosis	0.65	1.00	28.63	0.55	2.43	4.58	8.41	-0.68	2.65	0.06	32.17	1.33	2.47	0.59
Upper Extreme Value	8.45	68.65	10.73	122.61	5.28	53.56	9.41	87.90	8.73	77.29	7.79	87.68	7.83	58.71
Upper Outlier Value	5.70	49.70	7.44	86.30	3.30	36.05	6.27	60.95	5.46	52.06	4.87	58.05	4.89	39.27
Lower Outlier Value	-1.64	-0.84	-1.34	-10.54	-1.98	-10.63	-2.12	-10.91	-3.27	-15.20	-2.92	-20.96	-2.94	-12.58
Lower Extreme Value	-4.40	-19.80	-4.64	-46.86	-3.96	-28.14	-5.26	-37.86	-6.55	-40.42	-5.84	-50.59	-5.87	-32.02

BOXPLOTS FOR ELEMENTS H.1 – H.7 (LEVEL 1 AND LEVEL 5)





APPENDIX D

WEIGHTING WORKSHOP PRESENTATION AND EVALUATION FORMS

Small Industrial PDRI Workshop

CII Research Team 314

Baton Rouge, Louisiana
April 10, 2014

CII

Workshop Agenda

April 10, 2014 Baton Rouge, LA, (Ford, Bacon & Davis)

Time	Agenda Item
9:00 – 9:30 am	Continental Breakfast & Networking
9:30 – 10:15 am	Introductions & Background Information
10:15 – 10:30 am	Break
10:30 – 11:45 am	PDRI Tool Evaluation/Prioritization/Input
11:45 – 12:30 am	Lunch Provided
12:30 – 1:45 pm	PDRI Tool Evaluation/Prioritization/Input
1:45 – 2:00 pm	Conclusion & Wrap-up

CII

1

Introductions

- Briefly
  - Name
  - Organization
  - Experience with front end planning and small industrial projects

Workshop Objectives

- Provide background of Research Team 314 efforts to participants
- Participants “get to know” the Small Industrial PDRI
- Weight (prioritize) the PDRI elements
- Critique the PDRI structure & elements
- Provide a copy of the draft PDRI for participants reference/use
- Solicit help in tool testing/validation

2

CII Mission

Add value for members by enhancing the business effectiveness and sustainability of the capital facility life cycle through CII research, related initiatives, and industry alliances.

Expand the global competitive advantage realized through active involvement and effective use of research findings, including CII Best Practices.

RT 314, Project Definition Rating Index (PDRI) for Small Industrial Projects

1. Enhance or supplement current CII FEP documentation to focus on small industrial projects including definitions of types of small industrial projects and specific risk issues
2. Produce a tool to assist project teams in effective front-end planning for small industrial projects, including identifying project objectives, strategies, and philosophies, systems parameters, project requirements, risk identification and assessment, and mitigation methods
3. Identify and synthesize preferred methods for optimizing front-end planning for safely and efficiently constructing new small industrial projects and renovating existing assets, including design guidance criteria, owner requirements, procurement of necessary labor, materials, and equipment, contracting approaches, quality, cost and schedule assurance/control

3

Research Team 314 Members

Scott Penrod, Co-Chair	Walbridge
Brad Lynch, Co-Chair	TransCanada

G. Edward Gibson, Jr.	Arizona State University
Kristen Parrish	Arizona State University

Jeffrey Allen	Burns & McDonnell
Jere Brubaker	Wood Group Mustang
Amy Busse	Air Products and Chemicals
David Buttrum	Technip
Don Cooley	CH2M Hill
Thea Cummings	Anheuser-Busch InBev
Wesley DuBois	SABIC
Gregory Duffy	Pioneer Natural Resources
John Fish	Ford, Bacon & Davis

Doug Helmann	Architect of the Capitol
Arno Jansen	Power Engineers
Paul Katers	American Transmission Company
Stephanie Quinn	Pioneer Natural Resources
Brett Smedley	Eli Lilly
David Sonntag	DTE Energy
Julia Speed	Audubon Engineering
Graham Targett	Irving Oil Refining
William Thornton	Hargrove Engineers + Constructors

Wes Collins, Student	Arizona State University

Confidentiality

- Responses coded
- Only ASU team members know who filled out
- Not attributable to any individual
- If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

4

RT 314 Milestones

- 05/20/13 Team kick-off
- 02/07/14 Draft PDRI complete
- 04/10/14 Workshop - Baton Rouge
- 05/09/14 Workshop - Houston
- 06/06/14 Workshop - Washington D.C.
- 07/01/14 Workshop - United Kingdom
- 07/24/14 Workshop - Indianapolis
- 07/24/14 Workshops Complete
  - Minimum 60 qualified responses
  - Planned 5 sessions
- 4Q, 2015 Publish PDRI

Typical Small Industrial Projects

Total Installed Cost	Less than $10 Million
Construction Duration	Less than 7 months
Funding Decisions	Typically plant/local approvals as opposed to corporate
Engineering Effort	Less than 7,000 man-hours
Impact to Operations	Project dependent, can range from minimal to significant
Visibility to Owner Management	Project dependent, depends on physical location, scope of the project, potential for adverse consequences
Team Resources Availability	Organization dependent, mix of full/part-time to dedicated full-time
Core Team Resources Numbers	Less than 12 individuals/firms
Experience with Project Characteristics	Depends on complexity/level of rigor along with experience

These can/will vary from organization to organization, and from project to project

These attributes may be more "consequences" of projects being small as opposed to differentiators between large and small projects

5

Examples of Typical Small Industrial Projects

- Oil/Gas Refining Facilities
  - ex. Stack monitoring and flare line replacement
- Breweries
  - ex. Replacement of cooker coils, upgrade ink coders on can line
- Power Generation Plants
  - ex. Addition of a motor control center, replacement of constant speed electric feed-water pumps with variable frequency driven pumps
- Manufacturing Facilities
  - ex. Installation of new packaging line, modifications to existing packaging line
- Plant upgrade/retrofit
  - ex. Installation of new dust collection equipment and ducting, installation of environmental monitoring or noise abatement equipment
- General
  - ex. Replacement of existing elevators, replacement of existing HVAC equipment, tuckpointing of existing masonry structures

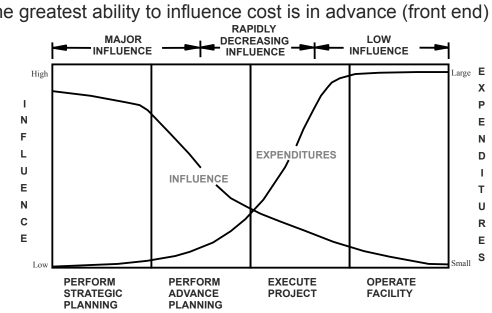
BACKGROUND

What is Front End Planning?

6

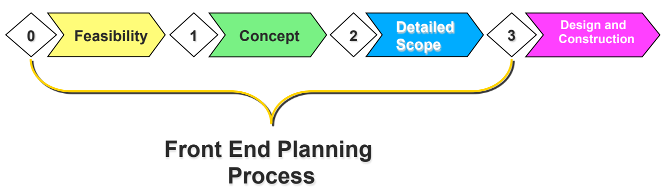
BACKGROUND (1)

The greatest ability to influence cost is in advance (front end) planning



Influence and expenditures curve for the project life cycle

Front End Planning Defined (2)



7

BACKGROUND (3)

- Tools have been developed and widely used for industrial, building and infrastructure projects during front end planning phase: Project Definition Rating Index (PDRI)
- Greater advance planning efforts = greater project success
  - Lower cost variance
  - Less schedule slippage
  - Fewer change orders

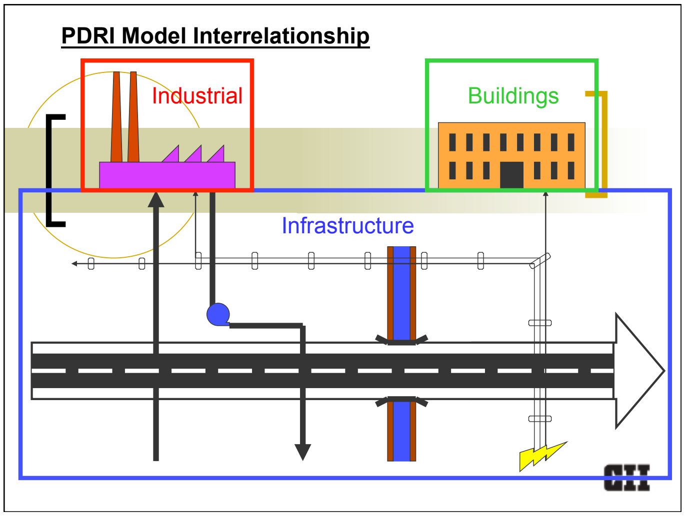
CII

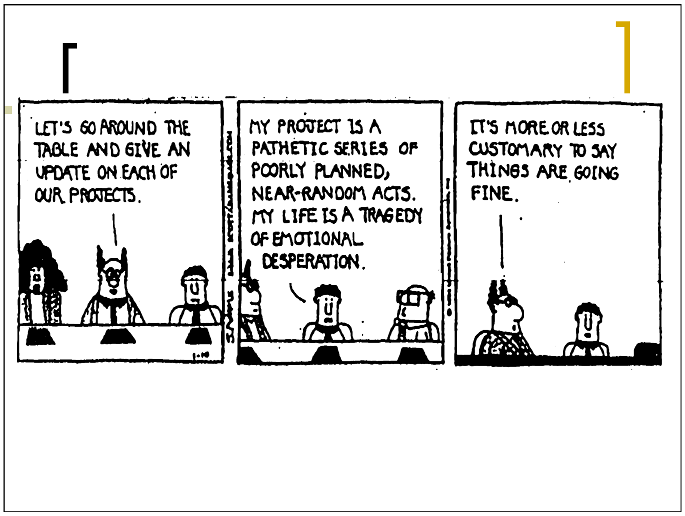
PDRI – The Definition

- An Acronym
  - Project Definition Rating Index
- An Index
  - Score along a continuum representing the level of scope definition
- A Risk Management Tool
  - Identifies and measures risks related to project scope definition

CII

8


PDRI Model Interrelationship
Industrial
Buildings
Infrastructure

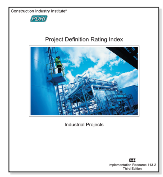

LET'S GO AROUND THE TABLE AND GIVE AN UPDATE ON EACH OF OUR PROJECTS.
MY PROJECT IS A PATHETIC SERIES OF POORLY PLANNED, NEAR-RANDOM ACTS. MY LIFE IS A TRAGEDY OF EMOTIONAL DESPERATION.
IT'S MORE OR LESS CUSTOMARY TO SAY THINGS ARE GOING FINE.

9

BACKGROUND (4)

Tool Format-- Project Definition Rating Index

*The crucial elements that need to be included in a scope definition for **industrial** projects.*



Composition:
- 3 Sections
  - 15 Categories
    - 70 Elements

34 pages of detailed element descriptions;
Rate each of the 70 elements to obtain a project score of up to 1000 points--the lower the better.

CII

Weighted Score Sheet (5)

(Example)

See page 37 of IR 113-2

SECTION I - BASIS OF PROJECT DECISION							
	Definition Level						
CATEGORY Element	0	1	2	3	4	5	Score
A. MANUFACTURING OBJECTIVES CRITERIA (Maximum Score = 45)							
A1. Reliability Philosophy	0	1	5	9	14	20	
A2. Maintenance Philosophy	0	1	3	5	7	9	
A3. Operating Philosophy	0	1	4	7	12	16	
CATEGORY A TOTAL							
B. BUSINESS OBJECTIVES (Maximum Score = 213)							
B1. Products	0	1	11	22	33	56	
B2. Market Strategy	0	2	5	10	16	26	
B3. Project Strategy	0	1	5	9	14	23	
B4. Affordability/Feasibility	0	1	3	6	9	16	
B5. Capacities	0	2	11	21	33	55	
B6. Future Expansion Considerations	0	2	3	6	10	17	
B7. Expected Project Life Cycle	0	1	2	3	5	8	
B8. Social Issues	0	1	2	5	7	12	
CATEGORY B TOTAL							
C. BASIC DATA RESEARCH & DEVELOPMENT (Maximum Score = 94)							
C1. Technology	0	2	10	21	39	54	
C2. Processes	0	2	8	17	28	40	
CATEGORY C TOTAL							
D. PROJECT SCOPE (Maximum Score = 120)							
D1. Project Objectives Statement	0	2	8	14	19	25	
D2. Project Design Criteria	0	3	6	11	16	22	
D3. Site Characteristics Available vs. Req'd	0	2	9	16	22	29	
D4. Dismantling and Demolition Req'mts	0	2	5	8	12	15	
D5. Lead/Discipline Scope of Work	0	1	4	7	10	13	
D6. Project Schedule	0	2	6	9	13	16	
CATEGORY D TOTAL							
E. VALUE ENGINEERING (Maximum Score = 27)							
E1. Process Simplification	0	0	2	4	6	8	
E2. Design & Material Alts. Considered/Rejected	0	0	2	4	5	7	
E3. Design For Constructability Analysis	0	0	3	5	8	12	
CATEGORY E TOTAL							
Section I Maximum Score = 499	**SECTION I TOTAL**						

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

10

PDRI Element Descriptions (6)
(Example)

A2. Maintenance Philosophy
A list of the general design principles to be considered to achieve dependable operating performance from the unit/facility or upgrades instituted for this project. Evaluation criteria should include:

- ❑ Justification of spare equipment
- ❑ Control, alarm, security and safety systems redundancy, and access control
- ❑ Extent of providing surge and intermediate storage capacity to permit independent shutdown of portions of the plant
- ❑ Mechanical/structural integrity of components (metallurgy, seals, types of couplings, bearing selection)
- ❑ Identify critical equipment and measures to be taken to prevent loss due to sabotage or natural disaster
- ❑ Other

** Additional items to consider for Renovation & Revamp projects **

- ❑ Maintenance impact of renovation projects
- ❑ Common/ spare parts (repair vs. replace existing components)
- ❑ Interruptions to existing and adjacent facilities during R&R work
- ❑ Compatibility of maintenance philosophy for new systems and equipment with existing use and maintenance philosophy
- ❑ Coordination of the project with any maintenance projects

IR 113-2, 3rd Edition; Each element can be considered a written deliverable

Tool Format
Project Definition Rating Index (7)

*The crucial elements that need to be included in a scope definition for **building** projects.*

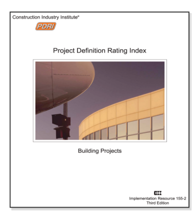
Composition:

3 Sections

11 Categories

64 Elements

37 pages of detailed element descriptions;



Building PDRI

Rate each of the 64 elements to obtain a project score of up to 1000 points--the lower the better.

Tool Format
Project Definition Rating Index (8)

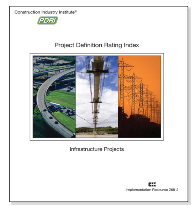
*The crucial elements that need to be included in a scope definition for **infrastructure** projects.*

Composition:

- 3 Sections
  - 13 Categories
    - 68 Elements

71 pages of detailed element descriptions;

Rate each of the 68 elements to obtain a project score of up to 1000 points--the lower the better.



Infrastructure PDRI

Weighting Small Industrial PDRI Elements

PDRI INFORMATION PACKAGE*

*Color Coded

- Brief introduction to the PDRI (White)
- Instructions for evaluating the PDRI elements (White)
- Background information (Yellow)
- PDRI element descriptions (White)
- PDRI weighting factor evaluation forms (Pink)
- Detailed project information sheets (Blue)
- Suggestions for improvement (Green)
- Un-weighted project score sheet (later)

WE NEED YOUR HELP...

- Research team identified 41 risk issues, grouped into 8 categories and 3 sections
- Not all elements are equally important

Therefore:

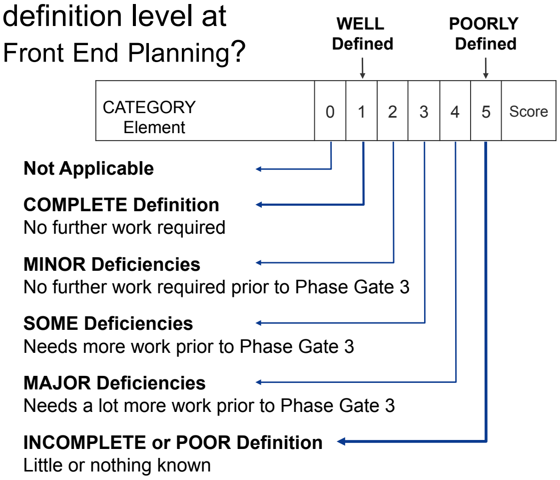
- We desire to prioritize or "weight" the issues according to their relative importance
- We need input from experienced project managers and project development subject experts to help us determine the issues' "weights"
- Then, we need to test the PDRI on real projects to assess its validity

13

WEIGHTING THE PDRI ELEMENTS (1)

- Consider a typical project (type and size) for your organization; on your background sheet
- Evaluate the *level of definition* of each element in the PDRI and apply an appropriate **contingency** to that element **(i.e., its individual impact on TIC stated as a percentage of the overall estimate)**
- Consider:
  - When detailed design is about to commence (**end of FEP**)
  - **Consider both cost and time impacts**
  - Two levels of definition:
    - 1 = Complete Definition
    - 5 = Incomplete or Poor Definition

Which definition level at end of Front End Planning?



What is N/A?

- Not Applicable to the specific "Typical Project" you chose for this work shop
- If you are unsure
  - Rely on your experience
  - Estimate a weight
  - Don't check N/A

CII

WEIGHTING THE PDRI ELEMENTS (2)

Example:

CATEGORY Element	Definition Level						Comments
	N/A	1	2	3	4	5	
C. Design Guidance							
C4. Specifications							

Definition Levels:

1 = Complete Definition

5 = Incomplete or Poor Definition

15

PDRI Element Description

C4. Specifications
Project specific specifications for the design, performance, manufacturing, and material requirements should be identified and documented. Items to consider should include:

- ❑ Mechanical (e.g., classes of equipment, piping, tracing requirements, protective coating and insulation)
- ❑ Instrument & electrical (e.g., classes of equipment, power and control, protection, security, heat tracing, installation standards)
- ❑ Automation/process control
- ❑ Civil/Structural (e.g., dimensions, seismic, boundary, fireproofing, protective coatings, wind loads)
- ❑ Architectural (e.g., acoustical, finishes, accessibility of occupants, voice/data)
- ❑ Other user defined

**** Additional items to consider for Renovation & Revamp projects****

- ❑ Reconciliation of as-built specifications with current specifications

**** If this is an instance of a Repetitive Program****

- ❑ Compatibility of this project's specifications with program's

WEIGHTING THE PDRI ELEMENTS (3)

Example:

CATEGORY Element	Definition Level						Comments
	N/A	1	2	3	4	5	
C. Design Guidance							
C4. Specifications		2%				30%	

Definition Levels:

1 = Complete Definition

5 = Incomplete or Poor Definition

2,3,4 = Interpolated Later

16

Path Forward

- Incorporate your comments and input
- Normalize input from all respondents
- Develop "weighted" score sheet
- Test on:
  - On-going projects
  - After the fact projects
- Develop Excel Spreadsheet
- Deploy

CII

Questions?

CII

17

A. Background Information					
Name					
Date					
Company					
Company Position					
Department/Division					
Company Address					
City		State		Zip	
Phone					
Email					
Years of Project Management/Estimating Experience					
Please describe some projects that you have recently completed					
Percentage of Experience Spent on the Following Types of Projects					
Industrial		Commercial Buildings			
Infrastructure		Other (Please Specify)			
What percentage of your experience has been spent on small projects?					
Annual dollar value of projects worked on or estimated over the last 3 years:					
What percentage of your experience has been spent on the following types of projects:					
New Construction					
Renovation/Revamp/Add-on					

B. Typical Small Project For Your Company and Your Basis for PDRI Weighting	
Name of Project	
Brief Project Description	
Total installed dollar value of the project (in US Dollars)	
Total construction duration of the project (in Months)	
Did the project involve renovation/revamp/add-on work? (costs greater than 50% of total installed cost for the project)	
On a scale of 1 to 5, how successful do you feel that the project was? (1 = complete failure, 3 = average, 5 = complete success)	

PDRI WEIGHTING FACTOR EVALUATION FORM - PROJECT DEFINITION RATING INDEX (PDRI)
FOR SMALL INDUSTRIAL PROJECTS

NAME: ______________________ DATE: ______________________

SECTION I - BASIS OF PROJECT DECISION							
	Definition Level						
CATEGORY Element	n/a	1	2	3	4	5	Comments
A. PROJECT ALIGNMENT							
A1. Project Objectives Statement							
A2. Project Strategy and Scope of Work							
A3. Project Philosophies							
A4. Location							
B. PROJECT PERFORMANCE REQUIREMENTS							
B1. Products							
B2. Capacities							
B3. Processes							
B4. Technology							
B5. Physical Site							

Definition Levels
N/A = Not Applicable 1 = Complete Definition 2 = Minor Deficiencies 3 = Some Deficiencies 4 = Major Deficiencies 5 = Missing or Very Poor Definition

NAME: ______________________ DATE: ______________________

SECTION II - BASIS OF DESIGN							
	Definition Level						
CATEGORY Element	n/a	1	2	3	4	5	Comments
C. DESIGN GUIDANCE							
C1. Lead/Discipline Scope of Work							
C2. Project Design Criteria							
C3. Project Site Assessment							
C4. Specifications							
C5. Construction Input							
D. PROCESS/PRODUCT DESIGN BASIS							
D1. Process Safety Management (PSM)							
D2. Process Flow Diagrams along with Heat and Material Balance							
D3. Piping and Instrumentation Diagrams (P&ID's)							
D4. Piping System Stress Analysis							
D5. Equipment Location Drawings							
D6. Critical Process/Product Items Lists							
E. ELECTRICAL AND INSTRUMENTATION SYSTEMS							
E1. Control Philosophy							
E2. Functional Descriptions and Control Narratives							
E3. Electric Single Line Diagrams							
E4. Critical Electrical Items Lists							
F. GENERAL FACILITY REQUIREMENTS							
F1. Site Plan							
F2. Loading/Unloading/Storage Requirements							
F3. Transportation Requirements							
F4. Additional Project Requirements							

Definition Levels
N/A = Not Applicable 1 = Complete Definition 2 = Minor Deficiencies 3 = Some Deficiencies 4 = Major Deficiencies 5 = Missing or Very Poor Definition

NAME: ______________________ DATE: ______________________

SECTION III - EXECUTION APPROACH							
	Definition Level						
CATEGORY Element	**n/a**	**1**	**2**	**3**	**4**	**5**	**Comments**
G. EXECUTION REQUIREMENTS							
G1. Procurement Plan							
G2. Owner Approval Requirements							
G3. Distribution Matrix							
G4. Risk Management Plan							
G5. Shutdown/Turnaround Requirements							
G6. Precomissioning, Startup, & Turnover Sequence Requirements							
H. ENGINEERING/CONSTRUCTION PLAN AND APPROACH							
H1. Engineering/Construction Methodology							
H2. Project Cost Estimate							
H3. Project Accounting and Cost Control							
H4. Project Schedule and Schedule Control							
H5. Project Change Control							
H6. Deliverables for Design and Construction							
H7. Deliverables for Project Comissioning/Closeout							

Definition Levels
N/A = Not Applicable   1 = Complete Definition   2 = Minor Deficiencies   3 = Some Deficiencies   4 = Major Deficiencies   5 = Missing or Very Poor Definition

SUGGESTIONS FOR IMPROVEMENT

Name:____

Date:____

Please answer the following questions regarding the PDRI.

Is the list of elements complete? If not, please list all others that should be added.

Are any of the elements redundant?
If so, please list and provide any recommended changes.

Are any of the definitions unclear or incomplete?
If so, please list and provide any recommended changes.

Do you have any other suggestions for improving the PDRI or the instruction sheet?

Please answer the following questions regarding the Background Information Sheet.

Are any of the questions unclear? If so, which ones and how should they be reworded?

Are there any other questions not included in the information sheet that may provide the research team with important information regarding the experience of the project managers and estimators? If so, please list the ones that should be added.

General Comments:

Sample SMALL Project Information Sheet

Your Name	
Name of Project	
Industry (e.g., oil/gas production or refining, chemical plant, power plant, manufacturing, other)	
Type of work (e.g., new construction, renovation/revamp, combination of both)	
Briefly describe the scope of the project	
Total installed cost of Project (in US $)	
Total project contingency carried on this project (in US dollars)	
Total project contingency used on this project (in US dollars)	
Construction duration of project (in months)	
Level of funding approval required (e.g., local, regional, corporate, board of directors)	
Number of different engineering specialties required to design the project	
Impact on facility operations/production (e.g., minimal, significant)	
Was a production shutdown required (Yes/No)	
Visibility of project to owner management (e.g., none, minimal, significant)	
Number of core team members Involved (e.g., project managers, estimators, engineers, production managers)	
Availability of core team resources throughout project (e.g., part-time, full-time, combination of both)	
Organizational experience with scope of project (e.g., unfamiliar, somewhat familiar, completely familiar)	
Was a new or unfamiliar technology involved (yes/no)	
What level of permitting was required (e..g., none, minimal, significant)	
Was types of permits were required (e.g., none, local, national, combination)	
Number of separate trade contractors involved with the project	
What type of project delivery method was used (e.g., design-bid-build, EPC, other)	
How would you describe the planning processes used by your organization for projects of this type (e.g., none, ad-hoc, structured)	
What amount of time was spent planning this project (in weeks)	
How many individuals were involved in the planning of this project?	
On a scale of 1 to 5, how successful would you say this project was? (1 = Failure, 3 = Average, 5 = Complete Success)	

Sample LARGE Project Information Sheet	
Your Name	
Name of Project	
Industry (e.g., oil/gas production or refining, chemical plant, power plant, manufacturing, other)	
Type of work (e.g., new construction, renovation/revamp, combination of both)	
Briefly describe the scope of the project	
Total installed cost of Project (in US $)	
Total project contingency carried on this project (in US dollars)	
Total project contingency used on this project (in US dollars)	
Construction duration of project (in months)	
Level of funding approval required (e.g., local, regional, corporate, board of directors)	
Number of different engineering specialties required to design the project	
Impact on facility operations/production (e.g., minimal, significant)	
Was a production shutdown required (Yes/No)	
Visibility of project to owner management (e.g., none, minimal, significant)	
Number of core team members Involved (e.g., project managers, estimators, engineers, production managers)	
Availability of core team resources throughout project (e.g., part-time, full-time, combination of both)	
Organizational experience with scope of project (e.g., unfamiliar, somewhat familiar, completely familiar)	
Was a new or unfamiliar technology involved (yes/no)	
What level of permitting was required (e..g., none, minimal, significant)	
Was types of permits were required (e.g., none, local, national, combination)	
Number of separate trade contractors involved with the project	
What type of project delivery method was used (e.g., design-bid-build, EPC, other)	
How would you describe the planning processes used by your organization for projects of this type (e.g., none, ad-hoc, structured)	
What amount of time was spent planning this project (in weeks)	
How many individuals were involved in the planning of this project	
On a scale of 1 to 5, how successful would you say this project was? (1 = Failure, 3 = Average, 5 = Complete Success)	

APPENDIX E

EXAMPLE OF COMPLETED WEIGHTING WORKSHOP ASSESSMENT

BRO2

PDRI WEIGHTING FACTOR EVALUATION FORM - PROJECT DEFINITION RATING INDEX (PDRI)
FOR SMALL INDUSTRIAL PROJECTS

NAME: [redacted] DATE: 4-9-14

SECTION I - BASIS OF PROJECT DECISION							
	Definition Level						
CATEGORY Element	n/a	1	2	3	4	5	Comments
A. PROJECT ALIGNMENT							
A1. Project Objectives Statement		2				50	
A2. Project Strategy and Scope of Work		5				25	
A3. Project Philosophies		3				15	
A4. Location		1				5	
B. SYSTEMS PARAMETERS							
B1. Products		0				20	
B2. Capacities		0				10	
B3. Processes		0				5	
B4. Technology		10				30	
B5. Physical Site		5				15	

Definition Levels
N/A = Not Applicable 1 = Complete Definition 5 = Incomplete or Poor Definition

Baton Rouge Workshop - 4/10/14

NAME: [redacted] DATE: 4-9-14

SECTION II - BASIS OF DESIGN							
	Definition Level						
CATEGORY Element	n/a	1	2	3	4	5	Comments
C. DESIGN GUIDANCE							
C1. Lead/Discipline Scope of Work		15				30	
C2. Project Design Criteria		5				15	
C3. Project Site Assessment		0				5	
C4. Specifications		2				8	
C5. Construction Input		10				25	
D. PROCESS/PRODUCT DESIGN BASIS							
D1. Process Safety Management (PSM)		5				15	
D2. Process Flow Diagrams along with Heat and Material Balance		0				35	
D3. Piping and Instrumentation Diagrams (P&ID's)		2				10	
D4. Piping System Stress Analysis		5				20	
D5. Equipment Location Drawings		0				5	
D6. Critical Process/Product Items List		0				5	
E. SYSTEMS CONTROL							
E1. Control Philosophy		15				35	
E2. Logic Diagrams		10				25	
E3. Electric Single Line Diagrams	N/A						
E4. Critical Electrical Items List	N/A						LOW POWER & UPS ?
F. GENERAL FACILITY REQUIREMENTS							
F1. Plot Plan		0				5	
F2. Loading/Unloading/Storage Requirements		5				20	
F3. Transportation Requirements	NA						OWNER & VENDOR LIMITS
F4. Additional Project Requirements	NA						INTERNAL STD'S & EXTERNAL REQUIREMENTS

Definition Levels
N/A = Not Applicable 1 = Complete Definition 5 = Incomplete or Poor Definition

Baton Rouge Workshop - 4/10/14

NAME: [redacted] DATE: 4-9-14

CATEGORY Element	n/a	1	2	3	4	5	Comments
	SECTION III - EXECUTION APPROACH						
	Definition Level						
G. EXECUTION REQUIREMENTS							
G1. Procurement Plan		2				10	
G2. Owner Approval Requirements		0				5	UPPER MANAGEMENT IMPACT ON SCH/COST
G3. Distribution Matrix		0				5	
G4. Risk Management Plan		5				30	
G5. Shutdown/Turnaround Requirements		5				40	
G6. Precomissioning, Startup, & Turnover Sequence Requirements		0				5	
H. ENGINEERING/CONSTRUCTION PLAN AND APPROACH							
H1. Engineering/Construction Methodology		0				10	
H2. Project Cost Estimate		8				25	DEMOLITION COST (EXPENSE COST)
H3. Project Accounting and Cost Control		0				5	
H4. Project Schedule and Schedule Control		10				30	
H5. Change Management Control		5				20	
H6. Deliverables for Design and Construction		0				15	
H7. Deliverables for Project Comissioning/Closeout		0				5	

Definition Levels
N/A = Not Applicable
1 = Complete Definition
5 = Incomplete or Poor Definition

Baton Rouge Workshop - 4/10/14

APPENDIX F

PDRI TESTING QUESTIONNAIRES

COMPLETED PROJECTS QUESTIONNAIRE

Ira A. Fulton Schools of Engineering
ARIZONA STATE UNIVERSITY

September 10, 2014

Thank you for agreeing to assess the scope definition of your project with the new Project Definition Rating Index (PDRI) tool for small industrial projects. The Construction Industry Institute (CII) established a research team in the summer of 2013 to create this PDRI specifically for small industrial projects, which make up 70-90% of all completed projects in the industrial sector. We have been working diligently since that time to develop a tool that will accurately gauge how well a project team has defined an upcoming project, outlining certain elements that should be considered during the front end planning process. Our goal is to produce a tool that will be just as effective as the previously developed PDRI's, which have improved cost and schedule performance on an array of projects. We thank you for your help in this endeavor.

At this time, we would like to collect project data from recently completed small industrial construction projects as part of the testing process for the new tool. We are looking for both projects that you view as successful and unsuccessful and would like projects that meet our definition of what constitutes a "small" project (see attachment). The research hypothesis is that the more completely the project scope is defined, the higher the probability of project success. The enclosed questionnaire is designed to test the PDRI by measuring the level of project scope definition at the end of the front end planning (FEP) phase, and then comparing the scope definition level to various management success metrics.

Several items are attached: (1) PDRI For Small Industrial Projects Research Introduction, (2) Definitions, (3) Instructions for Evaluating the PDRI, (4) PDRI for Small Industrial Projects Element Descriptions, (5) Validation Questionnaire, and (6) Un-Weighted PDRI Project Score Sheet. Please take a few minutes to familiarize yourself with these materials prior to the assessment. **We ask that once the assessment is complete, you please return copies of the Project Background Information Sheet, Project Score Sheet, Action Items List, and Suggestions for Improvement to Wes Collins at wes.collins@asu.edu. Either scanned copies of the documents or the Excel file completed with all pertinent information will suffice. All of the information gathered will be held in the strictest confidence.** Your company will also be credited as a participant in the research effort and will receive copies of the research summary and implementation resource when published in 2015 at no charge. If you have questions regarding the PDRI testing or this package, please contact myself, Edd Gibson, at (480) 965-7972, edd.gibson@asu.edu, Kristen Parrish at (480) 727-6363, kristen.parrish@asu.edu, or Wes Collins at (937) 610-6212, wes.collins@asu.edu.

Sincerely,

G. Edward Gibson, Jr., Ph.D., P.E.
Director, School of Sustainable Engineering and the Built Environment
Professor and Sunstate Chair of Construction Management and Engineering
Arizona State University

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Project Definition Rating Index (PDRI) for Small Industrial Projects
Research Introduction

Introduction

The construction industry is in need of a user-friendly tool to assist in defining project scope and maximizing the chance of project success for small industrial projects. These projects, which make up a majority of those completed (by count) in the industrial sector each year, frequently suffer from poor or incomplete project scope definition. Early planning of small projects may be inadequate or may not be performed at all because there is no perceived reason to expend the resources required for planning. A quantitative understanding of scope definition issues during front end planning (FEP) has not yet been studied. A multi-disciplinary research team at the Construction Industry Institute (CII) representing all the key participants in the small industrial project process--including owners, engineers and constructors--is working to develop a PDRI that is both user-friendly and effective. The work completed in this research should significantly enhance the project environment by improving the predictability of project parameters, reducing the cost of design and construction, preserving schedule, reducing risk during project execution, improving project team alignment and communication, assuring customer satisfaction, and improving the probability of a successful project.

Although recent CII research has raised the awareness of FEP and its benefits, there is still not a publicly available tool that specifically assesses the adequacy of scope definition for small industrial projects. Accordingly, the fundamental objective of this research investigation centers on developing a PDRI for Small Industrial Projects. The format of the tool will be similar to the PDRI for Industrial Projects (outlined in CII Implementation Resource 113-2), the PDRI for Building Projects (outlined in CII Implementation Resource 155-2), and the PDRI for Infrastructure Projects (outlined in CII Implementation Resource 268-2). It is intended to be a general-use, scope definition tool that addresses an array of small industrial projects, including, but not limited to:

- Oil/Gas Refining Facilities
    - ex. Stack monitoring and flare line replacement
- Breweries
    - ex. Replacement of cooker coils, upgrade ink coders on can line
- Power Generation Plants
    - ex. Addition of a motor control center, replacement of constant speed electric feed-water pumps with variable frequency driven pumps
- Manufacturing Facilities
    - ex. Installation of a new packaging line, modifications to existing packaging line
- Plant Upgrade/Retrofit
    - ex. Installation of new dust collection equipment and ducting, installation of environmental monitoring or noise abatement equipment
- General
    - ex. Replacement of existing elevators, replacement of existing HVAC equipment, tuckpointing of existing masonry structures

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ARIZONA STATE UNIVERSITY

Value-Added Benefits

The team expects the benefits of this effort will be similar to benefits realized by development of the PDRIs for Industrial, Buildings, and Infrastructure projects. Results from use of the existing PDRIs indicate 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 results are real cost savings of greater than 10% per project. With the volume of small industrial projects constructed each year, the potential for savings from better scope definition through PDRI use is substantial. PDRI use facilitates a better understanding of what constitutes a well-defined scope and correspondingly improves the alignment and communication among project stakeholders, in turn reducing cost overruns and disputes.

Methodology

The methodology for producing the PDRI tool was developed and proven in previous research. The final draft of the PDRI for Small Industrial Projects has been developed and is currently being evaluated by industry participants through application to completed and in-process projects. The final draft of the PDRI comprises a score sheet and element descriptions. The PDRI is organized into three main sections, which are broken down into eight categories that are then further broken down into forty-one elements. The un-weighted score sheet lists sections, categories and elements contained in the PDRI, each of which are described in detail in the element descriptions document.

Steps remaining in the development effort include:

1. Evaluating the tool through testing on sample projects
2. Linking scope definition elements in the PDRI to a logic flow diagram
3. Developing publications and deploying to industry

Products of the Research

A research report, research summary, and implementation resource of the PDRI for Small Industrial Projects will be completed in spring 2015. A CII annual conference presentation is anticipated for August 2015. For more information, please reference www.construction-institutue.org.

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DEFINITIONS

"Small" Industrial Project

To ensure applicability and correct usage of the new tool, the research team sought to determine an appropriate definition of what constitutes a "small project" in the industrial sector. The matrix below details the results of a survey (created by the research team and completed by over 90 industrial sector practitioners) that highlights some of the typical attributes of small industrial projects. We feel that projects that closely meet these attributes (both process and non-process related) will best be evaluated using the new tool.

Total Installed Cost	Less than $10 Million
Construction Duration	Less than 7 months
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Visibility to Owner Management	Project dependent, depends on physical location, scope of the project, potential for adverse consequences
Team Resources Availability	Organization dependent, mix of full/part-time to dedicated full-time
Core Team Resources Numbers	Less than 12 individuals/firms
Experience with Project Characteristics	Depends on project complexity/level of rigor along with experience

Process vs. Non-Process Related Projects

The PDRI for Small Industrial Projects is intended for use on both process and non-process related projects.

A "process" related project is defined as any project in an industrial facility related to constructing or refurbishing the systems, equipment, utilities, piping, and/or controls that directly affect the production rate, efficiency, quantity, or quality of the product being produced. These projects would typically have a stated Return on Investment (ROI) expectation to be met directly related to improved production factors, and may affect how the product is marketed to consumers (e.g., higher quality than before, increase in quantities available). In most cases, documents pertaining to the ongoing operations of the facility (e.g., Piping and Instrumentation Diagrams, Process Safety Management Plans) would need to be created, or existing documents updated.

A "non-process" related project is defined as any project in an industrial facility that is ancillary to production processes, but does not directly affect the quantity or quality of the product being produced. Examples of these types of projects include additions to or expansion of the infrastructure that supports a facility, facility updates necessary for environmental or safety compliance, replacement-in-kind of facility components (e.g., equipment, structural, piping) that do not directly affect the nature of the

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DEFINITIONS (cont.)

product being produced. If an ROI is required on these projects, it will typically be attributed to improving the operating efficiencies of the facility that are not directly related to production, such as increased energy efficiency related to installing Variable Frequency Drives (VFD's) on HVAC equipment, or installing solar panels to lessen the amount of power needed from a public utility provider. Documents pertaining to the ongoing operations of the facility (e.g., Piping and Instrumentation Diagrams, Process Safety Management Plans) may or may not need to be created or updated.

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INSTRUCTIONS FOR EVALUATING THE PDRI

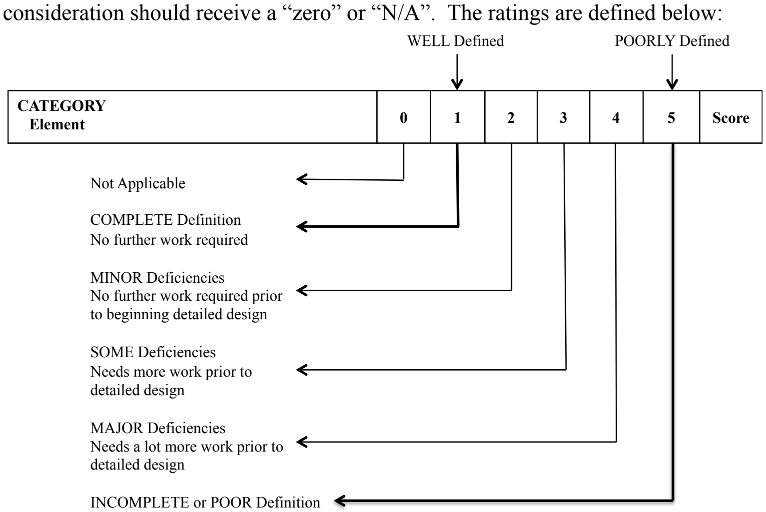
Who should evaluate the PDRI?

An individual (or group of individuals) with knowledge of the planning aspects of the nominated project should complete the Un-Weighted PDRI Project Score Sheet. The project managers from the owner, contractor, and engineering organizations responsible for completing the project would most likely have the most knowledge of this information. Other individuals, such as procurement staff, operations staff, estimators, and construction supervisors involved in the project could also provide insight.

How to evaluate the PDRI

To perform this assessment, the person (or persons) should remember back to the point in time when the project was entering the detailed design phase. At this point, the project team should have had an understanding of the project's detailed scope.

The PDRI consists of three main sections, each of which is broken down into a series of categories, which, in turn, are broken down into sections and elements. Scoring is performed by evaluating and rating the individual elements. Elements should be rated from 1 to 5 based on its level of definition at the point in time prior to beginning detailed design for the project. Think of this as a "zero defects" type of evaluation. Elements that were as well-defined as possible should receive a perfect rating of "one". Elements that were completely undefined should receive a rating of "five". At this stage in the planning progress you had a certain level of "scope definition"; many or all issues may have been well defined or not. All other elements should receive a "two", "three", or "four" depending on their levels of definition. Those elements deemed not applicable for the project under consideration should receive a "zero" or "N/A". The ratings are defined below:



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Using the list of 41 elements that are defined in the PDRI Element Descriptions, please mark your opinion of the project's level of definition for each element at this point (just prior to detailed design). Consider each element *individually*. If the entire element is not applicable to your project check "N/A" and do not rate the element.

To rate an element, first read its definition in the PDRI Element Descriptions. Some elements contain a list of items to be considered when evaluating their levels of definition. These lists may be used as checklists, but note that some of these items may not be applicable to your project. Next, refer to the Un-Weighted PDRI Project Score Sheet and locate the element. Please choose only one definition level (N/A, 1, 2, 3, 4, 5) for that element based on your perception of how well it was defined when the project was moving in to detailed design. Once you have chosen the appropriate definition level, please check (☑) the corresponding box. Do this for each of the 41 elements starting with element A1. **Please be sure to rate each element**.

Example, Assessing Element C3

The completed project that I am assessing was the installation of a new packaging line. I have addressed all of the elements up to C3. Reading the definition of element C3 Project Site Assessment on page 7 in the PDRI Element Descriptions, I felt that the site assessment for my project had some deficiencies since a comprehensive assessment had not been completed, and some conflicts between the intent of the proposed design and the actual site conditions were thought to exist at that time.

C3. Project Site Assessment

The actual conditions pertaining to the project site should be identified and documented. Availability/non-availability or redundancy of site utilities needed to operate the unit/facility and equipment should be identified. Items to consider should include the following:

- ☐ Survey and benchmark (coordinate and elevation) control system
- ☐ Geotechnical report
- ☐ Soil treatment or removal/replacement requirements
- ☐ Environmental permits now in force
- ☐ Existing environmental problems with the site
- ☐ Other factors such as light, dust, noise, emissions, or erosion control
- ☐ Fluid/gas utility sources with supply conditions (including temperature, pressure, and quality)
- ☐ Power sources with supply conditions (including location, voltage level, available power, reliability, and electrical power quality)
- ☐ Other user defined

**** Additional items to consider for Renovation & Revamp projects****

- ☐ Field verify condition of isolation and tie-in points, including operational approval
- ☐ Field verify condition of existing or reused equipment
- ☐ Existing horizontal and vertical position analysis (e.g., use of laser scanning)

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Therefore I checked level 3 "Some Deficiencies" in the score sheet below. Note that this uncertainty manifested itself during the design phase and caused some conflict during construction.

Example

CATEGORY Element	**Definition Level**					
	N/A	**1**	**2**	**3**	**4**	**5**
SECTION II - BASIS OF DESIGN						
C. DESIGN GUIDANCE						
C3. Project Site Assessment				✓		

1 = Complete Definition **2 = Minor Deficiencies** **3 = Some Deficiencies**
4 = Major Deficiencies **5 = Missing or Very Poor Definition**

We sincerely appreciate your help in developing this new PDRI tool. If you have any questions about the research project or this assessment, feel free to contact us at:

Dr. G. Edward Gibson, Jr.
Arizona State University
(480) 965-0557
edd.gibson@asu.edu

Dr. Kristen Parrish
Arizona State University
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VALIDATION QUESTIONNAIRE

Company Information					
Date					
Company Name					
Company Contact					
Company Position					
Department/Division					
Company Address					
City		State/Province		Zip	
Phone					
Email					

Assessed Project Background Information					
Name of Project (Optional)					
Project Address					
City		State/Province		Zip	
Please provide a brief project description:					
Type of Facility (e.g., refinery, petrochemical, manufacturing, power generation)					
Was the project new construction, renovation/revamp, or both?					
Would the project be considered process or non-process, based on the definitions given?					
Please describe what the driver was for this project (e.g., necessary maintenance or replacement, improvement to a production process, innovation, technology upgrade, governmental regulation, other)					

Project Schedule Information		
Please provide the following schedule information (if known)		
Item	**Planned (Date - Day/Month/year)**	**Actual (Date - Day/Month/year)**
Start Date of Detailed Design		
Completion Date of Detailed Design		
Start Date of Construction		
Date of Mechanical Completion		
Do you have any comments regarding any causes or effects of schedule changes (e.g., special causes, freak occurances, etc.?)		

Project Cost Information		
Please provide the following schedule information (if known)		
Item	**Budgeted Costs at Start of Detailed Design**	**Actual Costs at End of Project**
Total Design Costs*		
Construction Costs		
Owner's Contingency		
Other**		
Total Installed Cost		
Please describe any 'Other' costs listed above that were realized on the project		
** - Total design costs include all engineering and architect fees, including any feasibility studies, planning, programming, etc.*		
*** - Other costs may include major equipment procurement, owner's project management costs, etc.*		

Project Change Information	
What were the total number of change orders issued (during both detailed design and construction)?	
What was the total dollar amount (US Dollars) of all positive dollar amount change orders?	
What was the total dollar amount (US Dollars) of all negative dollar amount change orders?	
Did change orders increase or decrease the duration of the project (i.e., schedule)?	
If so, what was the net project duration change resulting from change orders? (in days)	
Do you have any comments regarding any causes or effects of significant change orders (e.g., special causes, freak occur	

Operating Information	
Since completion of the project, has the operational performance (which includes capacity and availability) met the expectations as set forth in the project plan prior to detailed design? (Yes/No)	
If no, please describe	
Since completion of the project, has the operations and maintenance costs of the project met the expectations as set forth in the project plan prior to detailed design? (Yes/No)	
If no, please describe	

Financial Information	
What level of approval was required for the project? (e.g., local, regional, corporate, board of directors, other)	
What specific financial measurement was used to authorize the project? (e.g., return on assets, internal rate of return, benefit/cost ratio, payback period, none, other)	
On a scale of 1 to 5 (1 being fallen far short of expectations, 5 being far exceeded expectations at authorization), how well has the actual financial performance of the project matched expectations?	

Customer Satisfaction	
Reflecting on the overall project, rate the success of the project using a scale of 1 to 5, with 1 being very unsuccessful and 5 being very successful	
Do you have any additional comments regarding customer satisfaction?	

PROJECT SCORE SHEET - UNWEIGHTED

CATEGORY Element	Definition Level n/a	1	2	3	4	5
SECTION I - BASIS OF PROJECT DECISION						
A. PROJECT ALIGNMENT						
A1. Project Objectives Statement						
A2. Project Strategy and Scope of Work						
A3. Project Philosophies						
A4. Location						
B. PROJECT PERFORMANCE REQUIREMENTS						
B1. Products						
B2. Capacities						
B3. Processes						
B4. Technology						
B5. Physical Site						
SECTION II - BASIS OF DESIGN						
C. DESIGN GUIDANCE						
C1. Lead/Discipline Scope of Work						
C2. Project Design Criteria						
C3. Project Site Assessment						
C4. Specifications						
C5. Construction Input						
D. PROCESS/PRODUCT DESIGN BASIS						
D1. Process Safety Management (PSM)						
D2. Process Flow Diagrams along with Heat and Material Balance						
D3. Piping and Instrumentation Diagrams (P&ID's)						
D4. Piping System Stress Analysis						
D5. Equipment Location Drawings						
D6. Critical Process/Product Items Lists						
E. ELECTRICAL AND INSTRUMENTATION SYSTEMS						
E1. Control Philosophy						
E2. Functional Descriptions and Control Narratives						
E3. Electric Single Line Diagram						
E4. Critical Elecrical Items Lists						
F. GENERAL FACILITY REQUIREMENTS						
F1 Site Plan						
F2. Loading/Unloading/Storage Requirements						
F3. Transportation Requirements						
F4. Additional Project Requirements						

Definition Levels
N/A = Not Applicable 1 = Complete Definition 2 = Minor Deficiencies 3 = Some Deficiencies
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SECTION III - EXECUTION APPROACH						
G. EXECUTION REQUIREMENTS						
G1. Procurement Plan						
G2. Owner Approval Requirements						
G3. Distribution Matrix						
G4. Risk Management Plan						
G5. Shutdown/Turnaround Requirements						
G6. Precomissioning, Startup, & Turnover Sequence Requirements						
H. ENGINEERING/CONSTRUCTION PLAN AND APPROACH						
H1. Engineering/Construction Methodology						
H2. Project Cost Estimate						
H3. Project Accounting and Cost Control						
H4. Project Schedule and Schedule Control						
H5. Project Change Control						
H6. Deliverables for Design and Construction						
H7. Deliverables for Project Comissioning/Closeout						

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IN-PROGRESS PROJECTS QUESTIONNAIRE

Ira A. Fulton Schools of Engineering
ARIZONA STATE UNIVERSITY

September 10, 2014

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Prior to fully deploying the tool, we feel it paramount to ensure that what we have developed is complete, accurate in assessing the scope definition of a small industrial project, and sufficiently detailed for use in industry. Along with helping you assess your current project, we are very interested in your feedback. Any suggestions or thoughts that you have after completing the assessment would be greatly appreciated. If you are unfamiliar with facilitating PDRI assessments, our team is available to provide a pre-assessment training session via telephone at your convenience.

Several items are attached: (1) Definitions, (2) PDRI for Small Industrial Projects Element Descriptions, (3) Project Background Information Sheet, (4) Project Score Sheet – Unweighted, (5) Action Items List, and (6) Suggestions for Improvement. Please take a few minutes to familiarize yourself with the material prior to the assessment. **We ask that once the assessment is complete, you please return copies of the Project Background Information Sheet, Project Score Sheet, Action Items List, and Suggestions for Improvement to Wes Collins at wes.collins@asu.edu. Either scanned copies of the documents or the Excel file completed with all pertinent information will suffice. All of the information gathered will be held in the strictest confidence.** Your company will also be credited as a participant in the research effort and will receive copies of the research summary and implementation resource when published in 2015 at no charge. If you have questions regarding the PDRI testing or this package, please contact myself, Edd Gibson, at (480) 965-7972, edd.gibson@asu.edu, Kristen Parrish at (480) 727-6363, kristen.parrish@asu.edu, or Wes Collins at (937) 610-6212, wes.collins@asu.edu.

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DEFINITIONS

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To ensure applicability and correct usage of the new tool, the research team sought to determine an appropriate definition of what constitutes a "small project" in the industrial sector. The matrix below details the results of a survey (created by the research team and completed by over 90 industrial sector practitioners) that highlights some of the typical attributes of small industrial projects. We feel that projects that closely meet these attributes (both process and non-process related) will best be evaluated using the new tool.

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DEFINITIONS (cont.)

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PROJECT BACKGROUND INFORMATION SHEET

Company Information					
Date					
Company Name					
Company Contact					
Company Position					
Department/Division					
Company Address					
City		State/Province		Zip	
Phone					
Email					

Assessed Project Background Information					
Name of Project (Optional)					
Project Address					
City		State/Province		Zip	
Please provide a brief project description:					

Estimated total installed cost of Project (in US $)	
Estimated construction duration of project (in months)	
Is this project new construction, renovation/revamp, or both?	
Would this project be considered process or non-process, based on the definitions given?	

PROJECT SCORE SHEET - UNWEIGHTED

CATEGORY Element	Definition Level n/a	1	2	3	4	5
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H2. Project Cost Estimate						
H3. Project Accounting and Cost Control						
H4. Project Schedule and Schedule Control						
H5. Project Change Control						
H6. Deliverables for Design and Construction						
H7. Deliverables for Project Comissioning/Closeout						

Definition Levels
N/A = Not Applicable 1 = Complete Definition 2 = Minor Deficiencies 3 = Some Deficiencies
4 = Major Deficiencies 5 = Missing or Very Poor Definition

ACTION ITEMS LIST	
Element (e.g., A1, E4, G3)	**Actions to be Completed Prior to the Start of Detailed Design**

SUGGESTIONS FOR IMPROVEMENT

Please answer the following questions regarding the PDRI for Small Industrial Projects

Is the list of elements complete and sufficient to assess a small industrial project?

Yes			No	

If not, please list any additional elements that you feel should be added

Are any of the elements redundant?

Yes			No	

If so, please list and provide any recommended changes

Are any of the definitions unclear or incomplete?

Yes			No	

If so, please provide any recommended changes

Do you have any other suggestions for improving the PDRI for Small Industrial Projects?

SUGGESTIONS FOR IMPROVEMENT

Please answer the following questions regarding the project assessment

How long did the assessment take (in hours)?

How many people were involved in the assessment?

Please list the positions of the participants (e.g., Project Manager, Piping Engineer, Owner's Representative)

Was value added during the assessment?

Yes		No	

Have you previously used the PDRI for Industrial Projects?

Yes		No	

Have you previously used the PDRI for Industrial Projects to assess a small project?

Yes		No	

If so, please describe the benefits of using this tool as compared to used the PDRI for Industrial Projects to assess a small project

Would you use this tool on a future project?

Yes		No	

SUGGESTIONS FOR IMPROVEMENT

During the front end planning process of a typical small industrial project, how many times would your organization use this tool to assess the level of project scope definition?

1		2		3 or More	

General Comments

PDRI for Small Industrial Projects
In-Process Project Testing Packet
9/10/14

APPENDIX G

PROJECT COMPLEXITY LITERATURE REVIEW

G.1 Project Complexity Definitions

Merriam-Webster's dictionary defines complex as "a group of obviously related units of which the degree and nature of the relationship is imperfectly known" (Merriam-Webster 2014). Complexity is the quality or state of being complex. Many authors have expanded this basic definition to address project complexity in construction, shown in Table G-1.

Table G-1. Project Complexity Definitions from Literature

Reference	Definition
Baccarini (1996)	Consisting of many interrelated parts and can be operationalized in terms of differentiation and interdependency.
Gidado (1996)	A construction production process is 'complex' only if the difficulty of producing individual parts and/or bringing these parts together influence one or a number of or all of the set managerial objectives focused towards project success. Usually, these managerial objectives are the control of cost, time quality, avoidance of conflict and functionality of the finished product.
Vidal and Marle (2008), Vidal et al. (2011, 2011b)	The property of a project which makes it difficult to understand, foresee and keep under control its overall behavior, even when given reasonably complete information about the project system.
Remington et al. (2009)	One that demonstrates a number of characteristics to a degree, or level of severity, that makes it extremely difficult to predict project outcomes, to control or manage the project. These characteristics include high levels of interconnectedness, nonlinearity, adaptiveness, and emergence.
Brockman and Kahkonen (2012)	Number of elements, their interactions and the strength of impacts of a defined system with regard to decision-making.
Lu et al. (2015)	Consisting of many varied interrelated parts, and has dynamic and emerging features.

G.2 Factors Affecting Project Complexity

The literature suggests that, however defined, many individual factors combine to create overall project complexity. Baccarini (196) specified two types of complexity: organizational and technological. Organizational complexity deals with the allocation of responsibilities, tasks, and authority for decision-making within the temporary multi-organizational structures created to manage construction projects. The greater the differentiation between units (e.g., departments, groups, occupational specializations, levels of hierarchy) within the multi-organizational structure, and the greater the operational interdependency and interaction between the units, the more complex the project will be. Technological complexity deals with the transformational process of changing inputs to outputs, including the material means, techniques, knowledge, and skills utilized within the project production systems. The greater the number, diversity, and interdependence of the inputs and outputs, actions or tasks, and specialties (e.g., subcontractors or trades) to produce the end product of a project, the more complex the project will be. Baccarini (1996) also cites Thompson (1967) regarding three types of interdependencies between organizational units, namely pooled (i.e., each part provides a discrete contribution to the project, irrespective of other parts), sequential (i.e., the output from one organization becomes the input for another organization), and reciprocal (i.e., each organization involved provides inputs and receives outputs from every other organization.)

Gidado (1996) researched how project complexity affects production planning, and found that "complexity factors influencing the managerial objectives in construction originate from a number of sources, namely the employed resources, the environment, the level of scientific knowledge required and the number and interaction of different parts in the work flow." The employed resources and environment are constrained by inherent complexity and uncertainty factors. Inherent complexity is scaled between three divisions, including technical complexity (i.e., that which is understood by current advances in construction technology, but requires the skills, knowledge, and attention of those involved), analyzability (i.e., that which is not understood by current advances in construction technology and requires all the skills, knowledge, and attention of those involved), and task difficulty (i.e., that which is understood by current advances in construction technology and does not require special skills or knowledge, but requires the use of unusual processes due to environmental constraint). Uncertainty factors associated with the task include the lack of complete specifications for the activities to be executed, unfamiliarity of the inputs and/or environment by management, lack of uniformity of work, and unpredictability of the environment. The workflow complexity was classified into three divisions, including the number of technologies involved in a task, repetition of their roles and their interdependencies, the rigidity of sequence between the various main operations, and the overlap of stages or elements of construction. Project managers can influence project complexity, both as a positive failure (inadequate planning and control leading to overruns of production time and cost) and negative failures (too much planning and control leading to decreased profit margins due to excessive overhead costs). He also states that "Among the managerial functions in construction, planning is considered as the most important function that brings success for any given process (but on if it is done well and at the right time.)"

Vidal and Marle (2008) and Vidal et al. (2011, 2011b) stated that ever-growing project complexity is an ever-growing source of project risk, and that, as a whole, project complexity results in damages or failures for projects. Interdependencies and all notions related with them such as interactions, interrelationships or interfaces are likely to be the greatest drivers of project complexity. Project complexity was classified into four families, including project size (i.e., the size of the elementary objects (stakeholders) which exist within the project system based on a quantitative measure), project variety (i.e., the diversity of the elementary objects which exist within the project system), project interdependence (i.e., the existence of relationships/interactions between elementary objects within the project system), and project context-dependence (i.e., the environment within which a project is undertaken the context and practices that apply to one project are not directly transferable to other projects with different institutional and cultural configurations).

Remington et al. (2009) determined through literature review and structured interviews of 25 individuals experienced with complex projects in Australia that project complexity is affected by five characteristics (e.g., goals, means to achieve goals, number of interdependent elements, timescale of project, environment), where each characteristic becomes more complex depending on certain levels severity (e.g., difficulty, non-linearity, uncertainty, uniqueness, communication, context dependent, clarity, trust, capability).

Wood and Ashton (2010) determined through literature review and structured interviews of 16 individuals experienced with complex projects in England project complexity is made up of five main factors, including organizational (people involved/relationships), operational and technological, planning and management environmental, and uncertainty. A common theme amongst the interviewees was that issues relating to the people working on a project (e.g., poor communication between stakeholders, large number of different stakeholders with differing interests and aspirations) are the biggest driver of project complexity, and also the most difficult to predict and manage. Interactions and interdependencies between project elements, a high degree of leading-edge technology, and issues concerning the environment in which the project is carried out (e.g., physical characteristics, market conditions, legal environment) were also highly cited as driving project complexity. Wood and Ashton (2010) concluded that "…the complexity in a project needs to be identified at the earliest stage in order to be able to manage it appropriately" and that identifying where complexity lies in a project is a critical factor for project success.

Bosch-Rekveldt et al. (2011) determined through literature review and structured interviews of 18 individuals involved with six large engineering projects (one project manager, one team member, and one owner representative per project) in England that 50 specific elements drive project complexity, which were broken down into three categories: technical (e.g., the project goals, scope, tasks, experience, risk), organizational (e.g., project size, resources, team, trust, risk), and environmental (e.g., project stakeholders, location, risk). The authors developed a framework, namely the TOE (technical, organizational, environmental) framework, for use in determining project complexity of large engineering projects. The purpose of the framework is to provide a method for determining the "footprint" of project complexity, allowing project teams to "further adapt the front end development phase of these projects to the particular project complexity with the aim to better manage the project." The authors also state that "Assessing a project's complexity is a subjective process by nature, in which perceived complexity based on previous experiences play an important role."

Lebcir and Choudrie (2011) stated that project complexity includes four factors: infrastructure size (i.e., the size of the infrastructure to be delivered at the end of the project based on the number of components, parts, functions, tasks, and specialists), infrastructure interconnectivity (i.e., the degree of "integration" and "linkages" between the different elements of the infrastructure), infrastructure newness (i.e., the portion of the infrastructure to be innovated from previous projects delivering the same types of infrastructures), and project uncertainty (i.e., the level and extent of the gap between the knowledge required to perform the project tasks and the knowledge available to the project team at the beginning of the project). The authors utilized a System Dynamics (SD) simulation model, and found that project complexity has an "inflating effect" on project cycle time (i.e., schedule), where projects with higher levels of complexity had more cycle time than less complex projects based on their four factors. (Note: "infrastructure" as referred to by Lebcir and Choudrie (2011) is a generic term used for any construction project, not specifically infrastructure construction projects).

Puddicombe (2012) determined through a study of 1,300 completed process-engineering projects that technical complexity and novelty affect project performance, specifically project schedule and cost. Technical complexity was defined to have four dimensions, including project size, physical characteristics of the process, operating characteristics of the process, and project content. Novelty was also defined to have four dimensions, including process newness, product newness, customization, and execution newness.

Xia and Chan (2012) determined through a delphi survey of 20 individuals experienced with building projects in China that six complexity measures (i.e., factors) drive project complexity, including building function and structure, construction method, urgency of the project schedule, project size/scale, geological condition, and neighboring environment, with building function and structure being the most critical factor.

Gransberg et al. (2013) found that (regarding transportation projects) there are five sources of complexity, including: technical (i.e., all the typical engineering requirements including scope of design and construction, quality, and need for integrated delivery), schedule (i.e., the calendar-driven aspects of the project), cost (i.e., quantifying the scope of work in monetary terms), context (i.e., external influences impacting project development and progress), and financing (i.e., not project cost, but the sources of the project's funding)

He et al. (2015) found that (regarding mega-projects in China) there are six categories of complexity, including technological (e.g., building type, overlapping of design and construction work, dependency on project operation, diversity of technology in project, dependence on technological processes, interaction between the technology system and the external environment, risk of highly difficult technology), organizational (e.g., members experience, number of hierarchies, departments of organizational structure), goal (e.g., various project participants requirements, project task complexity, limited resources, and structural complexity as projects have many objectives, and the ambiguity of interpretations of goals and objectives amongst stakeholders), environmental (e.g., context where a project operates such as natural market, political, and regulatory environment), cultural (e.g., diversity of the cultural software in the human mindset, which is manifested by a number of factors such as team trust, cognitive flexibility, emotional quotient and system thinking. Three levels of culture exist, including national culture, industrial culture, organizational culture.), and information complexity (e.g., complicated communication among a great number of project stakeholders under complicated contractual arrangements throughout the whole project delivery process. Influenced by several factors such as information systems, the degree of obtaining information, levels of processing, and transmission of information).

Nguyen et al. (2015) found (regarding transportation projects in Vietnam) six components of project complexity, including sociopolitical complexity (e.g., administrative policies and procedures, number of applicable laws/regulations, local experience expected from parties, influence of politic), environmental complexity (e.g., local climatic conditions, geological/hydrological conditions, environmental risks), organizational complexity (e.g., contractual conditions, number of contract/work packages, coordination of stakeholders, project planning and scheduling), infrastructural complexity (e.g., site compensation and clearance, transportation systems near project site, qualifications required for contractors), technological complexity (e.g., variety of technologies employed, technological newness of the project), and scope complexity (e.g., ambiguity of the project scope, project size in terms of capital).

Lu et al. (2015) stated that project complexity is based on task complexity and organizational complexity. Task complexity consists of seven factors, including technological complexity, goal uncertainty, environmental complexity, openness of elements, dynamics of process, resource availability, and information completeness. Organizational complexity consists of three factors, including the number of organizational members, complexity of organizational members (e.g., leadership skill, technological skill, coordination skill, working background, working experience), and complexity of organizational structure (e.g., degree of centralization, degree of formalization, degree of matrixing.)

G.3 Methods to Measure Project Complexity

Two authors have developed methods for measuring project complexity. Gidado (1996) asserted that project complexity is manifested through longer project schedules and increased project costs. He proposed a simple model where a multiplier is applied to the sum of the schedule durations of task items to create a contingency that would account for project complexity. Cost items were applied contingency using the same method, though the multiplier was different. He stated that the success of the models depends on the reliability and accuracy of the "k" components (i.e., multipliers) of the models and the availability of data and information used as baselines for the production rates and costs. No universal "k" values exist for all contractors, and "every contractor will have to gear up to establish their own applicable and realistic values in line with their experience and capabilities."

Gransberg et al. (2013) developed a two-step "mapping" technique where spider diagrams are utilized to measure project complexity on transportation projects. The first step entails a project team to rank (from one to five) each of the sources of complexity (e.g., technical, schedule, cost, context, financing). The second step entails assigning a "dimensional impact rating" to each of the sources of complexity. The impact ratings are scaled from 10 to 100, with a rating of 55 being considered a typical, routine project. A score greater than 55 would indicate a project that is more complex than a typical project, and a score less than 55 would indicate a project with lower complexity than a typical project. The dimensional impact ratings would then be mapped onto a five-factor spider diagram (as shown in Figure 2-12), and the area inside of the five-sided map would be calculated to determine a 'footprint area." The maximum map area equals 23,776 units (based on all ratings equaling 100), and the average map area equals 7,192 units (based on all ratings equaling 55.)

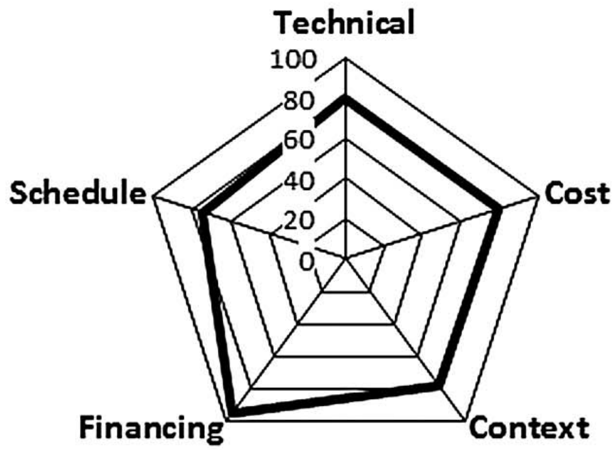


Figure G-1. Project Complexity Map (Taken from Gransberg et al. 2013)

G.4. Summary

The six definitions of project complexity provided in Table 2-1 highlights that complexity within the field of construction is driven by the uncertainty of how the disparate individual project parts will interact, even when reasonably complete information about the project system is known, and how these interactions effect project success. The intensity of interaction uncertainty, or relational uncertainty, is based on the amount of differentiation and interdependence between the individual project parts. Project complexity is a dynamic project trait, necessitating constant adaptation of project tasks to address emerging conditions.

The literature provided 49 total factors that effect project complexity, shown in Table G-2. Three factors were most predominant, including technical/technological/task (Baccarini 1996, Wood and Ashton 2010, Bosch-Rekveldt et al. 2011, Puddicombe 2012, Gransberg et al. 2013, He et al. 2015, Lu et al. 2015, Nguyen et al. 2015), organizational (Baccarini 1996, Wood and Ashton 2010, Bosch-Rekveldt et al. 2011, He et al. 2015, Lu et al. 2015, Nguyen et al. 2015), and environmental (Remington et al. 2009, Wood and Ashton 2010, Bosch-Rekveldt et al. 2011, Gransberg et al. 2013, He et al. 2015). Table G-3 summarizes the separate characterizations of the technical, organizational, and environmental complexity described in the literature, which ranged from very high-level descriptions, such as the characterization of technical complexity provided by Baccarini (1996), to very detailed, such as the characterization of organizational complexity provided by Lu et al. (2015).

Table G-2. Project Complexity Factors from Literature

Reference	Factors
Baccarini (1996)	Organizational
	Technological
Vidal and Marle (2008), Vidal et al. (2011, 2011b)	Size of project system
	Variety of project system
	Interdependencies within project system
	Context dependent
Remington et al. (2009)	Goals
	Means to achieve goals
	Number of interdependent elements
	Timescale of project
	Environment
Wood and Ashton (2010)	Organizational
	Operational and technological
	Planning and management
	Environmental
	Uncertainty
Bosch-Rekveldt et al. (2011)	Technical
	Organizational
	Environmental
Lebcir and Choudrie (2011)	Infrastructure size
	Infrastructure connectivity
	Infrastructure newness
	Project uncertainty
Puddicombe (2012)	Technical
	Novelty
Xia and Chan (2012)	Building function and structure
	Construction method
	Urgency of project schedule
	Project size/scale
	Geological condition
	Neighboring environment
Gransberg et al. (2013)	Technical
	Schedule
	Cost
	Context
	Financing
He et al. (2015)	Technological
	Organizational
	Goal
	Environmental
	Cultural
	Information
Lu et al. (2015)	Task
	Organizational
Nguyen et al. (2015)	Sociopolitical
	Organizational
	Infrastructural
	Technological
	Scope

Table G-3. Project Complexity Factors from Literature

Reference	Technical	Organizational	Environmental
Baccarini (1996)	Transformational process of changing inputs to outputs	Allocation of responsibilities, tasks, and authority for decision making	
Wood and Ashton (2010)	Degree of technology, high number of installations, regulations, physical size, number of trades	Poor relationships, large number of stakeholders, poorly defined project roles	Physical site characteristics, market conditions, legal environment, international projects
Bosch-Rekveldt et al. (2011)	Number of goals, goal alignment, goal clarity, scope largeness, number of tasks, conflicting norms and standards	Project duration, amount of CAPEX, team size, engineering hours, size of site, number of resources, availability of resources, trust	Variety of stakeholder perspectives, political influence, internal support, site conditions, remoteness of site, experience in country
Puddicombe (2012)	Project size, physical characteristics of the process, operating characteristics of the process, project content		
Gransberg et al. (2013)	Typical engineering requirements including scope of design and construction, quality, and need for integrated delivery		External influences impacting project development and progress
He et al. (2015)	Building type, overlapping of design and construction work, dependency on project operation, diversity of technology, dependence on technological processes, interaction between technology system and external environment, risk of highly difficult technology	Members experience, number of hierarchies, departments of organizational structure	Context where a project operates such as natural market, political, regulatory environment
Lu et al. (2015)	Technological complexity, goal uncertainty, environmental complexity, openness of elements, dynamics of process, resource availability, and information completeness.	Number of organizational members, complexity of organizational members, and complexity of organizational structure	
Nguyen et al. (2015)	Variety of technologies employed, technological newness of the project	Contractual conditions, number of contract/work packages, coordination of stakeholders, project planning and scheduling	Local climatic conditions, geological/hydrological conditions, environmental risks

Several authors also noted project size as a factor of project complexity (Vidal and Marle 2008, Vidal et al. 2011, 2011b, Lebcir and Choudrie 2011, Xia and Chan 2012). Lebcir and Choudrie (2011) stated "Size makes the project more complex as there is an increased volume of work and the need to coordinate the different elements of the projects." Xia and Chan (2012) stated "Larger project size does not necessarily lead to higher degree of complexity, but it usually calls for multiple contracts, various subcontractors and suppliers, and complex coordination systems", and "As the size of the project increases, difficulties in coordination work among all participants increase, affecting the project complexity in terms of management." Several authors also noted novelty (e.g., newness, unfamiliarity, experience) as complexity factors (Lebcir and Choudrie 2011, Puddicombe 2012), or as aspects of other complexity factors (Wood and Ashton 2010, Bosch-Rekveldt et al. 2011, Lu et al. 2015, Nguyen et al. 2015).

Other project complexity factors proposed in the literature could be considered subsets of the technical, organizational, and environmental complexity factors. For example, goal complexity cited by Remington et al. (2009) and He et al. (2015) could be considered part of organizational complexity, where a project would be considered more complex if differences existed between the goals of project stakeholders within the project structure. Schedule complexity, cited by Remington et al. (2009), Xia and Chan (2012), and Gransberg et al. (2013), could be a subset of either technical, organizational, or environmental complexity. For example, technical complexity could influence schedule if lead times for critical items specified on a project were unknown at the outset of a project. Organizational complexity could influence schedule if the availability of critical personnel was unknown at the outset of a project. Environmental complexity could influence schedule if market conditions necessitated a decrease to the overall project schedule so that a project owner could be “first to market” with a new product that could not be produced until construction has been completed. Novelty or infrastructure newness complexity cited by Lebcir and Choudrie (2011) and Puddicombe (2012) could also be a subset of either technical, organizational, or environmental complexity, where project scope, organizational structure, or project environment that is novel to the project team could influence how complex a project potentially is.

A common theme throughout the literature is that project complexity has a negative effect on project success, and/or meeting project objectives. Gidado (1996) asserted that complexity is inherent in every project, and that project managers effect project success through either insufficient planning, or excessive planning. Wood and Ashton (2010) state that project complexity needs to be identified as early as possible in the project life cycle if it is to be managed appropriately to meet project objectives. Bosch-Rekveldt et al. (2011) posited that measuring project complexity is very subjective, and is based on previous experiences of those who are providing the measurement. Methods for measuring project complexity provided by Gidado (1996) and Gransberg et al. (2013) are both very subjective, where projects teams measure project complexity through adding contingency to project schedule and cost factors, or benchmarking projects against “typical” projects.

APPENDIX H

INDUSTRIAL PDRI SELECTION GUIDE

Construction Industry Institute®

Industrial Project Definition Rating Index (PDRI) Selection Guide

Project ________________________________ Date ________________

The Construction Industry Institute (CII) has developed two separate tools for assessing the level of scope definition on Industrial construction projects: PDRI for Industrial Projects and the PDRI for Small Industrial Projects. The purpose of the selection guide is to aid you and your organization in choosing the appropriate tool to assess your upcoming project. The selection guide is meant to be used at the beginning of the Front End Planning process.

Please answer the following nine questions to the best of your ability regarding your upcoming project, and select the numerical value that coincide with you answers. Record these values in the "Your Score" box. Estimated values are suitable for this evaluation. After answering each of the nine questions, sum the "Your Score" boxes to determine a total score. Use the information at the end of this tool to determine which PDRI tool is most appropriate for use on your project.

1 What will be the total installed cost of the project (in US Dollars)?

≤ $5 Million	0
$5.01 - $10 Million	2
$10.01 - $15 Million	4
$15.01 - $20 Million	6
$20.01 - $25 Million	8
> $25 Million	12

Your Score

2 What will be the construction schedule duration of the project?

≤ 3 Months	0
3.01 - 6 Months	2
6.01 - 9 Months	4
9.01 - 12 Months	6
12.01 - 15 Months	8
> 15 Months	11

Your Score

3 What will be the highest level of funding approval necessary for the project?

No approval needed	0
Local	3
Regional	6
Corporate	9
Board of Directors	11

Your Score

4 How visible (i.e., "on the radar") will this project be to the corporate management of the project owner's organization?

Not at all	0
Minimal visibility	4
Moderate visibility	8
Significant visibility	11

Your Score

Construction Industry Institute®

5 How many core team members (engineers/designers, design project managers, owner project managers, trade project managers, etc.) will be needed to complete this project?

		Your Score
≤ 3 Individuals	0	
4 - 6 Individuals	2	
7 - 9 Individuals	4	
10 - 12 Individuals	6	
13 - 15 Individuals	8	
> 16 Individuals	11	

6 What will be the necessary availability of the core team members to complete the project?

		Your Score
No core team members needed	0	
Part-time availability	4	
Combination of part-time and full-time availability	8	
Full-time availability	11	

7 How extensive will the permitting be on this project?

		Your Score
No permitting necessary	0	
Minimal amount of permitting	6	
Significant amount of permitting	11	

8 What types of permits will be necessary to complete the project?

		Your Score
No permits necessary	0	
Local and state permits only	4	
National permits only	8	
Combination of local/state and national permits	11	

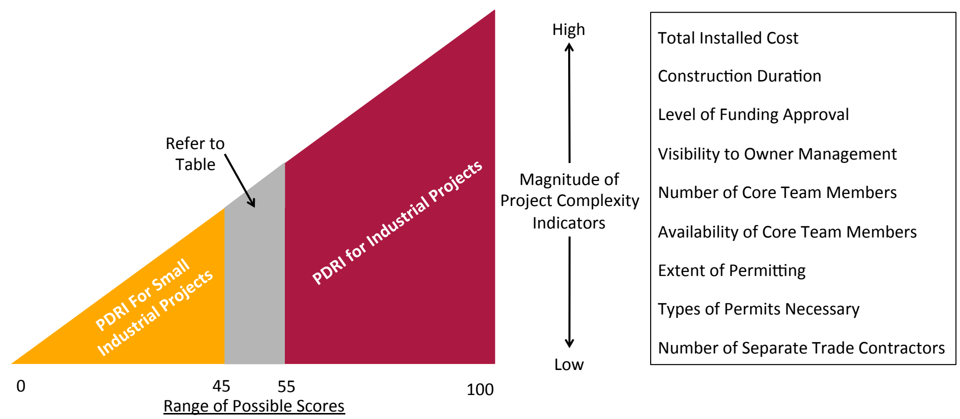
9 How many separate trade contractors will be necessary to complete the project?

		Your Score
≤ 2 Separate contractors	0	
3 - 4 Separate contractors	2	
5 - 6 Separate contractors	4	
7 - 8 Separate contractors	6	
9 - 10 Separate contractors	8	
> 11 Separate contractors	11	

What is your total score? >>>>>>>>>>>>>>

How to analyze your score

Based on an analysis of typical projects in the industrial construction sector, projects that score in the range of 0 to 44 are best assessed by using the PDRI for Small Industrial Projects, and projects that score in the range of 56-100 are best assessed with the PDRI for Industrial Projects. Projects that score in the lower range are typically less complex than those projects in the higher range. Due to their characteristics, these projects, sometimes referred to as "small projects", can be assessed with an abbreviated PDRI tool and still achieve the same level of project success as a more complex project that is assessed with the mor robust version of the PDRI.



What to do if your project score is between 45 and 55

If your project score isbetween 45 and 55, review the table shown below and compare your individual answers to those of typical projects that are assessed with each of the tools. By comparing your individual answers, you should be able to determine which tool will be best suited to assess your project. For example, if your answers to a majority of the questions align with projects that score below a 44, then most likely the PDRI-Small Industrial Projects will be appropriate for use. If your answers to a majority of the questions align with projects that score above a 56, then the PDRI-Industrial Projects would be most appropriate.

Project Complexity Indicator	PDRI for Small Industrial Projects	PDRI for Industrial Projects
Total Installed Cost	Less than $10 Million (US Dollars)	More than $10 Million (US Dollars)
Construction Duration	Between 3 and 6 months	Between 9 and 15 months
Level of Funding	Between regional and corporate	Between corporate and Board of Directors
Project Visibility	Moderate	Significant
Number of Core Team Members	Between 7 and 9 individuals	Between 10 and 15 individuals
Availability of Core Team Members	Part-time availability	Between a combination of part-time and full-time to completely full time
Extent of Permitting	Between none and minimal permitting	Between minimal and significant permitting
Types of Permits	Between none to local/state permits	Between local/state to national permits
Number of Trade Contractors	Between 3-4 separate trade contractors	Between 7-8 separate trade contractors