First International Conference on Construction in the 21st Century (CITC2002)
"Challenges and Opportunities in Management and Technology"
25-26 April, 2002, Miami, Florida, USA

SCOPE DEFINITION AND PROJECT RISK ANALYSIS

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ABSTRACT
The Project Definition Rating Index (PDRI) is a project scope definition tool developed under the guidance of Construction Industry Institute (CII). The PDRI allows a project team to evaluate the completeness of scope definition prior to detailed design or construction. It also helps the project team quickly analyze the scope definition package and predict factors that may impact project risk. This paper will summarize the application of the PDRI in the project risk management process. Data from 78 building projects representing approximately $1.1 billion were collected and the relationship between PDRI scores and project performance will be demonstrated. Used in a project team environment the PDRI facilitates discovery of project risk areas and related potential cost escalation, allowing generation of risk control measures. The use of the PDRI as a project risk management tool will be demonstrated.

KEYWORDS
Scope Definition, Project Definition Rating Index (PDRI), Project Risk, Risk Management

1. INTRODUCTION

Pre-project planning is "….the process of developing sufficient strategic information with which owners can address risk and decide to commit resources to maximize the chance for a successful project" (CII, 1995). Specifically, a complete scope definition improves project performance in the areas of cost, schedule, quality, and operational characteristics. Extraordinary risks are results of unresolved scope issues or unforeseen conditions (Smith and Bohn 1999). For example, according to a national survey of top 100 U.S. large contractors, Kangari (1995) identified 'defective design' as one of the most important risks ranked by the survey participants. Poor scope definition often results in delayed design and in some cases contributes to poor design.

Inadequate or poor scope definition, which negatively correlates to the project performance, is recognized by many as the most serious problem on a construction project (Smith and Tucker, 1983). As stated in the Business Roundtable's Construction Industry Cost Effectiveness (CICE) Project Report A-6 (Business Roundtable, 1982), two of the most frequent contributing factors to cost overrun are: poor scope definition at the estimate (budget) stage and loss of control of project scope. Therefore, the result of a poor scope definition is that final project costs can be expected to be higher because of the inevitable changes which interrupt project rhythm, cause rework, increase project time, and lower the productivity as well as the morale of the work force (O'Connor and Vikroy, 1986). Success during the detailed design, construction, and start-up phases of a project highly depends on the level of effort expended during the scope definition phase as well as the integrity of project definition package (Gibson and Dumont, 1996). Several studies focusing on project performance and success have identified the major factors that cause project failure. These studies suggest that poor scope definition is one of the primary causes of unsuccessful projects (Merrow et al., 1981; Myers and Shangraw, 1986; Merrow, 1988; Gibson and Hamilton, 1994; and Broaddus, 1995). According to these studies, cost growth and inaccurate cost estimates, as well as schedule slippage on many projects are due to inadequate scope definition. These studies further conclude that the more time and effort invested in scope definition prior to authorization, the more accurate the construction estimation and scheduling (Wang, 2002).

The Project Definition Rating Index (PDRI) is a project scope definition tool developed under the guidance of Construction Industry Institute (CII) and is a powerful, yet simple-to-use tool that offers a method to measure project scope definition for completeness. It is a weighted scope definition checklist developed to assist the project team in defining the scope of a building project (CII, 1999). Research has shown that the PDRI allows a project team to evaluate the completeness of scope definition prior to detailed design or construction and helps a project team to quickly analyze the scope definition package and predict factors that may impact project risk (Gibson and Dumont 1996, Cho and Gibson 2001).

Poorly defined scope definition elements are identified during the PDRI evaluation process with the project team. These poorly defined elements should be treated as potential risk factors that might cause negative impact to project outcomes. This paper will outline data collection and analysis of 78 building construction projects representing approximately $1.1 billion. A correlation analysis is shown that indicates the significance of risk impact (PDRI scores) on project success. A systematic risk management approach incorporating the PDRI in the risk management process will be presented.

2. SCOPE DEFINITION AND PRE-PROJECT PLANNING

Pre-project planning is a major component of the project planning process. This phase begins after a decision is made by the business unit to proceed with a project concept and continues until the detailed design is developed. The pre-project planning process can be summarized into four major steps: organization for pre-project planning, selection of project alternative(s), development of a project definition package (which is the detailed scope definition of the project), and decision on whether to proceed with the project (Gibson et al., 1995). Figure 1 shows this pre-project planning process map. Project scope definition is the process where projects are defined and prepared for execution and is a key component of pre-project planning.

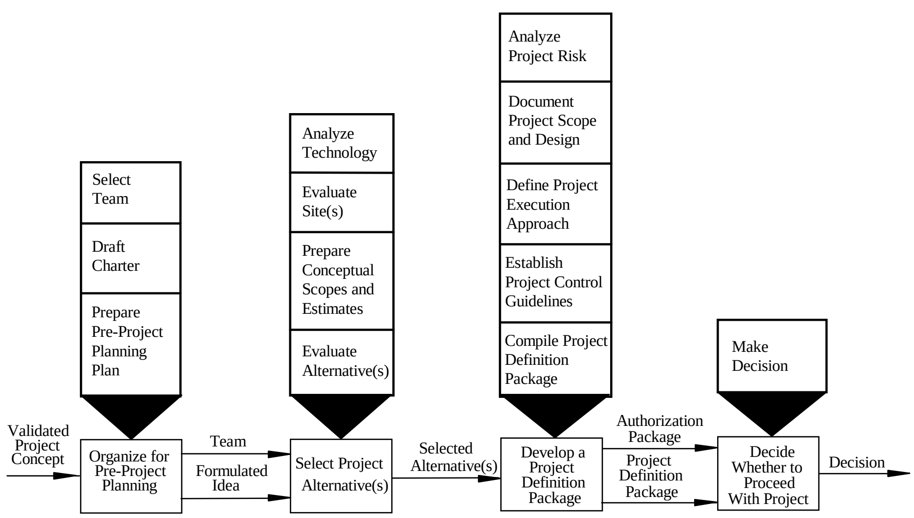


Figure 1: Pre-Project Planning Process

As defined by the Project Management Institute (PMI), project scope definition occurs early in the project life cycle when the major project deliverables are decomposed into smaller, more manageable components in order to provide better project control (PMI, 2000). During this process, information such as general project requirements, necessary equipment and materials, construction methods or procedures are identified and compiled in the form of a project definition package for a capital project. This package consists of a detailed formulation of continuous and systematic strategies to be used during the execution phase of the project to accomplish the project objectives for a capital project. This package also includes sufficient supplemental information to permit effective and efficient detailed engineering to proceed (Gibson et al., 1993).

The development of the Project Definition Rating Index (PDRI) addressed the need for better pre-project planning effort on capital projects. Developed by CII, the PDRI serves as a scope definition tool for industrial project (CII, 1996). In responding to the needs of the building industry, CII developed the PDRI for Building Projects in 1999 (CII, 1999). The PDRI for building projects is a weighted checklist that identifies and describes each critical element in a project scope definition package to assist project managers in understanding the scope of work. It provides a means for an individual or team to evaluate the status of a building project during pre-project planning with a score corresponding to the project's overall level of definition. The PDRI helps the stakeholders of a project to quickly analyze the scope definition package and to predict factors that may impact project risk specifically with regard to buildings (CII, 1999; Cho, 2000). For illustration purposes, Section I – Category A of the PDRI for building projects (both elements and their weights) is shown in Figure 2. This is one category of 11 in the PDRI for buildings and encompasses eight of 64 scope definition elements (Cho and Gibson 2001). Each element has a corresponding detailed description. Please refer to CII (1999) for detailed information on development of the tool, element descriptions and application of the PDRI.

Table1: PDRI-Buildings Category A

SECTION I - BASIS OF PROJECT DECISION							
	Definition Level						
CATEGORY Element	**0**	**1**	**2**	**3**	**4**	**5**	**Score**
A. BUSINESS STRATEGY (Maximum = 214)							
A1. Building Use	0	1	12	23	33	44	
A2. Business Justification	0	1	8	14	21	27	
A3. Business Plan	0	2	8	14	20	26	
A4. Economic Analysis	0	2	6	11	16	21	
A5. Facility Requirements	0	2	9	16	23	31	
A6. Future Expansion/Alteration Considerations	0	1	7	12	17	22	
A7. Site Selection Considerations	0	1	8	15	21	28	
A8. Project Objectives Statement	0	1	4	8	11	15	

3. CONSTRUCTION PROJECT RISK AND MANAGEMENT

The construction business is an inherently risky business for both owners of facilities and contractors. Often times, risk is interpreted in association with uncertainty. In this sense, risk implies that there is more than one possible outcome for the event, where the uncertainty of outcomes is expressed by probability (Al-Bahar, 1988). Al-Bahar defined risk as "the exposure to the chance of occurrences of events adversely of favorable affecting project objectives as a consequence of uncertainty". In project management of capital projects, risks are typically associated with cost, schedule, safety and technical performance (Rao et al., 1994). Risk management is a quantitative and systematic approach used to manage risks faced by project participants. It deals with both foreseeable as well as unforeseeable risks and the choice of the appropriate technique(s) for treating those risks. The process of risk management includes three phases: risk identification, risk quantification, and risk control. This process is a continuous cycle that consists of risk analysis, strategy implementation, and monitoring (Minato and Ashley, 1998).

Risk identification is the first risk management process that involves the investigation of all possible potential sources of project risks and their potential consequences. Several studies have been conducted to identify and categorize construction risk factors and allocate the ownership of risk (Ashley et al., 1988; Al-Bahar and Crandall, 1990; Kangari, 1995; Smith and Bohn, 1999). A survey of the top 100 U.S. construction contractors allocated ownership of the risk under three categories: owner, contractor, and shared risk (Kangari, 1995). In this survey study, 23 risk factor descriptions were identified, including permits and ordinances, site access/right of way, defective design, changes in work, labor, equipment and material availability, safety, quality of work, and financial failure of any party. The PDRI includes these risk factors descriptions in its element descriptions as well as several others. The 64 scope definition elements in the PDRI have been shown to be a comprehensive list of potential risk factors for capital facility project developments (Cho and Gibson, 2001).

The next risk management process step is risk quantification. Risk quantification is needed to determine the potential impact of the risk. This process tries to quantitatively analyze uncertainty in order to evaluate the potential impact of risk. In this process, an analyst integrates information from numerous sources through quantitative and/or qualitative modeling, while preserving the uncertainty and the complex relationships between the elements of information (Rao et al., 1994). By identifying the relationship between PDRI scores and project performance, PDRI scores can be used as an indicator for possible project outcomes (ranges of cost and schedule performance) (Cho and Gibson, 2001).

The third phase of the risk management process is risk control. Risk control involves measures aimed at avoiding or reducing the probability and/or potential severity of the losses occurring. The implementation of these measures should be monitored and be taken into account for future alternative risk management strategies development (Al-Bahar and Crandall, 1990). By improving the poorly defined scope elements and thus lowering the PDRI score, the project team is able to increase the probability of better project performance. The PDRI score evaluation also serves as a good measure for monitoring the effectiveness of risk control techniques implemented. The following sections will discuss the PDRI in more detail in terms of risk management and the affect of scope definition on project outcomes.

4. DATA COLLECTION AND ANALYSIS

In the initial development of the PDRI for building projects, a questionnaire survey was conducted to collect data from 33 building projects (CII, 1999). In addition to these 33 projects, 45 building projects from an institutional organization (which prefers to remain anonymous) were surveyed for this research. The questionnaire used in PDRI-Buildings research was modified toward the organization's specific need for this data collection effort. However, it should be noted that only the element description part of the PDRI questionnaire was modified while the sections, categories, elements, and weights remained unchanged. Information concerning PDRI evaluation score, project characteristics, project performance, and user satisfaction was obtained through the survey. A total of 78 building projects representing $1.1 billion (USD) in construction cost were studied and analyzed. It is important to note that the sample selection for the study is based on organizations volunteering projects for the study and not on a random sample of a known population. The survey data did not provide enough information for a PDRI analysis based on contract delivery methods such as design-build, design-bid-build, and construction manager at risk.

The 78 sample projects varied in project size from a final cost of $0.7 million to $200 million with an average of $14.3 million. Among the 78 projects, three projects were provided by one contractor (design-builder), three projects were provided by a consulting company with owner input, and the remaining 72 projects were provided by 14 different owner organizations. As the majority of the projects were from owner organizations or by consultants and contractors that were developing the scope in conjunction with the owner, the research results represent the analysis from the owner perspective. These projects include projects such as schools, churches, research labs, offices, warehouses, performance houses, border stations, shopping centers, court houses and fire stations. Both domestic and international (Mexico, Canada, and Australia) projects were surveyed and the average size of building was approximately 150 thousand square feet. Nine out of the 78 projects were renovation projects and the rest were new construction projects.

In the PDRI survey questionnaires, specific questions were intended to obtain historical and "after the fact" project information. The questionnaires included question regarding project basics (location, type, budget and schedule), operating information, and evaluation using an unweighted PDRI score sheet. Survey participants were asked to think back at a point just prior to Construction Document development when they filled out the PDRI evaluation score sheet. The total scores were then calculated based on pre-assigned element weights after the questionnaires were returned. Refer to CII (1999) for detail development of PDRI element weights. Figure 3 shows the wide spread of PDRI scores among the sample projects.

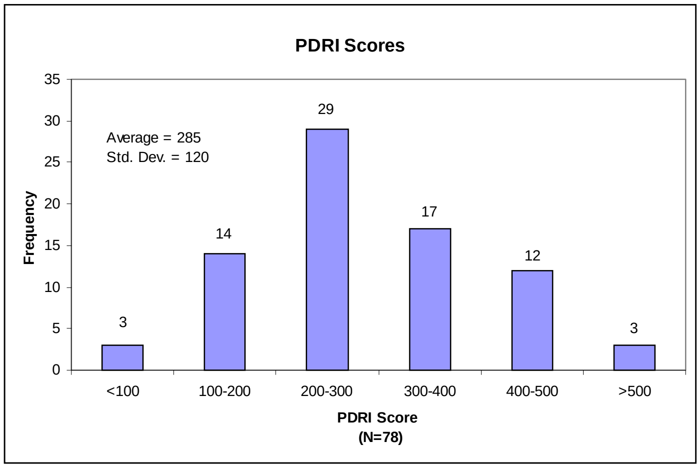


Figure 2: PDRI Scores

In the survey, respondents were also asked to provide estimated costs at the start of construction document development as well as the actual costs after construction completion. Total cost growth measures total project cost growth as a percentage of the initial predicted project cost. Cost performance was measured by project cost growth metric obtained as follow:

$$\frac{\textit{Actual Total Project Cost} - \textit{Initial Predicted Project Cost}}{\textit{Initial Predicted Project Cost}}$$

The total project duration used to calculate project schedule growth was measured from the start date of construction documents development to the date of substantial completion in months. The following equation was used for computing project schedule performance:

$$\frac{\textit{Actual Total Project Schedule} - \textit{Initial Predicted Project Schedule}}{\textit{Initial Predicted Project Schedule}}$$

Project cost/schedule growth measures overall percent cost/schedule growth for many reasons, and therefore is a good overall measure of owner-contractor team performance (CII, 1998). One of the objectives for this research is to identify the relationship between project success and PDRI. Gibson and Hamilton (1994) proposed a Project Success Index rating system as a measurement of project success. The procedures were adopted for this research study, with some changes, as a measure of project success for the 78 building projects. This adjusted measure of project success, Project Success Index, was calculated by combining cost and schedule performance. In some cases, continuous data can become difficult to detect patterns and discover significant relationship. Therefore, it may be necessary to group the data into categories (Abdul-Raheem, 1994). For this research, the large range of continuous cost and schedule performance variables were grouped by percentiles and recoded into nominal values ranging from one to five. The values for the cost and schedule achievement were converted using the criteria show in Table 1. Since only two variables were considered in the success index, for simplicity a weight of 50% for each variables was used to represent the importance of these two factors in the success index (even though this may not be indicative of relative value for some projects). A project success index was then calculated by averaging the two variables (budget and schedule achievement).

$$\textit{Project Success Index} = (0.5 \times \textit{Budget Achievement}) + (0.5 \times \textit{Schedule Achievement})$$

Using the PDRI score as an independent variable and project success index for each project as a dependent variable, a linear regression analysis can be performed to examine the relationship between the independent variable (PDRI score) and dependent variable (project success index). First, a scatter plot was constructed and a best fit line was then calculated and plotted on the scatter plot. The linear regression analysis is performed using Microsoft Excel® 2000. The ANOVA results showed that Significant F equals to 7.5E-08, which is less than 0.05 and indicates the linear relationship is statistically significant. The coefficient of determination, R^2, records the proportion of variation in the dependent variable (project success index) explained or accounted for by variation in the independent variable (PDRI score). In this case, an R^2 equals 0.32 indicates that 32% of the variation in project success can be explained by the variation in PDRI scores. The analysis results show that the linear relation between PDRI score and project is statistically significant and PDRI score (level of scope definition) can be used to explain a certain proportion of project success. Figure 4 shows the scatter plot and regression results. It should be noted that many factors may influence the project after pre-project planning and therefore, can contribute to cost overruns and schedule slippage such as poor contract documents, unforeseen conditions, market conditions, strikes, and Acts of God, and so on.

Table 2: Scoring Criteria for the Project Success Variables

Variable	Range	Value	No. of Project
Budget Achievement (Measured by cost performance)	< 1.6%	5	16
	1.6% ~ 5.6%	4	15
	5.6% ~ 9.5%	3	16
	9.5% ~ 16.7%	2	15
	> 16.7%	1	16
Schedule Achievement (Measured by Schedule performance)	< 0%	5	20
	0% ~ 6.3%	4	11
	6.3% ~ 13.9%	3	16
	13.9% ~ 31.8%	2	15
	> 31.8%	1	16

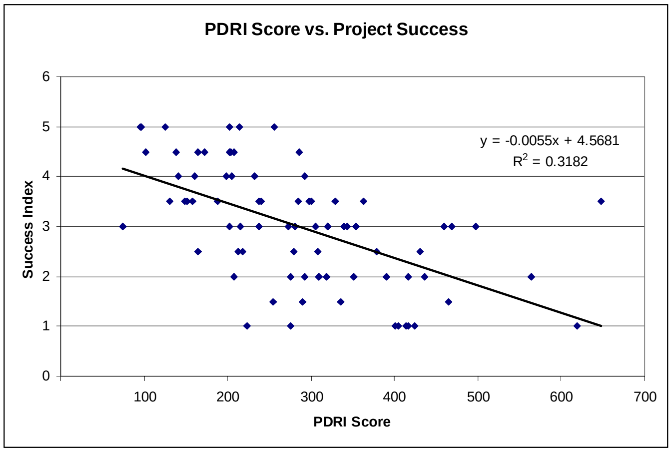
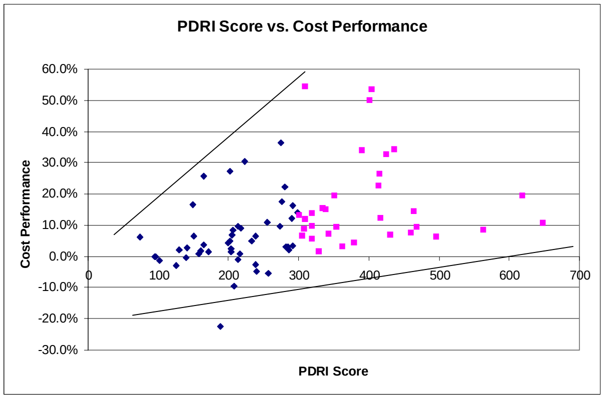


Figure 3: Project Success Index vs. PDRI Score

5. APPLYING PDRI IN RISK MANAGEMENT

As stated earlier, risk identification is the process involving the investigation of all possible potential sources of project risks and their potential consequences. AL-Bahar and Crandall (1990) suggested starting the risk identification process from a preliminary checklist of potential project risks. The weighted checklist provided in the PDRI for evaluating project scope definition serves as an excellent risk identification checklist. The PDRI evaluation performed by the project team will assess project scope definitions and identify poorly defined scopes (potential project risk factors). After the identification of these risk factors, the magnitude of risk impact and its probability should be taken into account for evaluating project risks. The PDRI evaluation process also leads to PDRI scores which may be an indicator of the completeness of the level of project scope definition and risk exposure as well.

Risk quantification is needed to determine the potential quantitative risk impact. Figures 5 and 6 can be used to visualize the potential risk impact for a given project's PDRI score. Scatter plots for cost/schedule performance and PDRI scores were developed based on the sample data (78 projects). It is shown clearly that when a PDRI score is larger (more poorly defined), there tends to be larger variation in cost/schedule performance. Two lines were drawn manually on the scatter plot to address this trend. From an overall project perspective, these two graphs reveal the potential risk impact on project cost or schedule performance in terms of percentage increase or decrease (actual/budget).



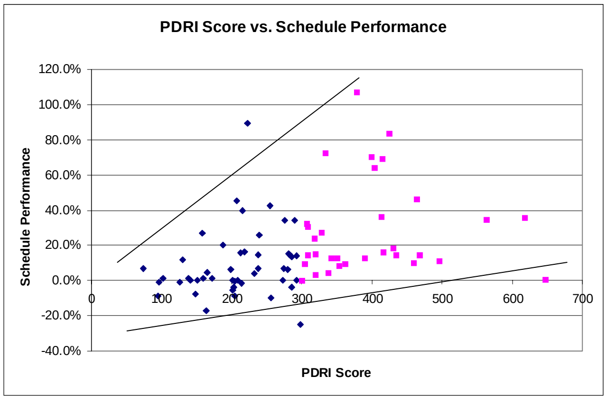


Figure 4: PDRI Score vs. Cost Performance **Figure 5: PDRI Score vs. Schedule Performance**

As previously described, risk control involves measures aimed at avoiding or reducing the probability and/or potential severity of the losses occurring. The implementation of these measures should be monitored and be taken into account for future alternative risk management strategies development (Al-Bahar and Crandall, 1990). Risk control measures include risk avoidance, risk reduction, risk sharing, risk transfer, insurance, risk acceptance by establishment of contingency accounts, risk acceptance without any contingency and risk containment (CII, 1989). Measures should be taken to improve the poorly defined project scopes and thus reduce the risk exposure. The PDRI score not only represents the completeness of project definition at a point in time but also can be used to visualize the potential risk impact on cost and schedule performance. The risks identified in the pre-project planning process should be addressed following pre-project planning and through the project execution phase. By improving the poorly defined scope elements using risk control elements and thus lowering the PDRI score, the project team can reduce the variation of potential project performance and thus have a better control of project outcome (Wang, 2002).

The risk management process is a continuous cycle that consists of risk analysis, strategy implementation, and monitoring (Minato and Ashley, 1998). The above proposed systematic risk management approach using the PDRI can be implemented by the project team in the pre-projecting planning phase of a project to increase the probability of a successful project. Performing the analysis several times during this phase will help the team improve its risk control measures.

6. CONCLUSIONS AND RECOMMENDATIONS

Unresolved scope issues contribute greatly to construction project risk. Projects with good scope definition, including effective risk management, have better outcomes. Developed as a project scope definition tool, PDRI is also an effective tool for addressing risk issues, estimating potential risk impacts, and assisting in risk control. The systematic risk management approach of applying the PDRI in risk identification, risk quantification, and risk control can help the project team address the risk issues in the pre-project planning stage of a project life-cycle and thus, more successful projects can be expected by implementing this approach.

It is important to note that the sample selection for the study is based on organizations volunteering projects for the study and not on a random sample of a known population. Therefore, caution should be taken when making the inferences beyond this sample. It is recommended that organizations should establish their own database from historical projects.

The objective of this paper was to propose a generic risk management approach using the PDRI and thus extend the usage of PDRI as a project risk management tool. A predictive model using second moment Bayesian method is currently under development at the University of Texas at Austin to provide a better mechanism for performance prediction.

7. REFERENCES

Abdul-Raheem, N. (1994). “The Relationship between Perceived Leadership Behavior of Construction Superintendents, Situational Factors, and Job Satisfaction of their Foreman”. Ph.D. thesis, University of Texas at Austin, Austin, TX

Al-Bahar, J. F. (1988). “Risk Management in Construction Project: A Systematic Analytical Approach for Contractors”. Ph.D. thesis, University of California at Berkeley, California, U.S.A.

Al-Bahar, J. F., and Crandall K. C. (1990). “Systematic Risk Management Approach for Construction Projects”. *Journal of Construction Engineering and Management*, Vol. 116, No. 3, pp. 533-546

Ashley, D. B., Stokes, S. L., and Perng, Y.-H. (1988). “Combining Multiple Expert Assessments for Construction Risk Identification”. Proc. 7th International Conference on Offshore Mechanics and Artic Engineering, Vol. VI: Computer Technology, American Society of Mechanical Engineers, New York, pp. 183-192

Broaddus, J. A. (1995). *Managing Inputs to Design for Project Success: Participant Handbook – CII Education Module EM-9*, Construction Industry Institute, The University of Texas at Austin, Austin, TX.

The Business Roundtable (1982). *Modern Management Systems*, Report A-6

Cho, C. S. (2000). “Development of the Project Definition Rating Index (PDRI) for Building Projects”. Ph.D. thesis, University of Texas at Austin, Austin, TX.

Cho, C. S. and Gibson, G. E. (2001). “Building Project Scope Definition Using Project Definition Rating Index”. *Journal of Architectural Engineering*, Vol. 7, No. 4, pp. 115-125

The Construction Industry Institute (1998). *Planning for Startup: Overview of Research – Research Summary 121-1*, Austin, TX.

The Construction Industry Institute (1999). *Project Definition Rating Index (PDRI), Building Projects,* Implementation Resource 155-2, Austin, TX.

Gibson, G. E., Kaczmarowski, J. H., & Lore, H. E. (1993). *Modeling Pre-Project Planning for the Construction of Capital Facilities* – Source Document 94, Construction Industry Institute, Austin, TX

Gibson, G. E. and Hamilton, M. R. (1994). *Analysis of Pre-Project Planning Effort and Success Variables for Capital Facility Projects*, a report to the Construction Industry Institute, The University of Texas at Austin, Source Document 105

Gibson, G. E., Kaczmarowski, J. H. and Lore, H. E. (1995). “Pre-Project Planning Process for Capital Facilities”. *Journal of Construction Engineering and Management*, Vol. 121, No. 3, pp. 312-318

Gibson, G. E. and Dumont, P.R. (1996). *Project Definition Rating Index (PDRI)*, a report to the Construction Industry Institute, The University of Texas at Austin, Research Report 113-11, June

Kangari, R. (1995). “Risk Management Protection and Trends of U.S. Construction”. *Journal of Construction Engineering and Management*, Vol. 121, No. 4, pp. 422-429

Merrow, E. W., Philips, K. E., & Myers, C. W. (1981). *Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants*, R-2569-DOE, RAND Corporation: Santa Monica, CA.

Merrow, E. W. (1988). *Understanding the Outcomes of Megaprojects: A Quantitative Analysis of Very Large Civilian Projects*, R-3560-PSSP, RAND Corporation: Santa Monica, CA.

Minato, T. and Ashley, D. B. (1998). “Data-Driven Analysis of ‘Corporate Risk’ Using Historical Cost-Control Data”. *Journal of Construction Engineering and Management*, Vol. 124, No. 1, pp. 42-47

Myers, C. W., & Shangraw, R. F. (1986). *Understanding Process Plant Schedule Slippage and Startup Costs*, R-3215-PSSP/RC, RAND Corporation: Santa Monica, CA

O’Connor, J. T., & Vickroy, C. G. (1986). *Control of Construction Project Scope* – Source Document 6, Construction Industry Institute, The University of Texas at Austin, Austin , TX

Pre-Peoject Planning Handbook (1995). Special Publication 39-2, Construction Industry Institute, Austin, TX.

Project Management Institute (2000). *Project Management Body of Knowledge*, Newtown Square, PA

Rao, Guru N. Grobler, Francois. and Liu, Liang Y. (1994). “Managing Uncertainty in Project Planning and Execution: Introduction and Overview.” Computing in Civil Engineering Conference Proceeding, ASCE New York, pp. 33-40

Smith, M. A. & Tucker, R.a L. (1983). *An Assessment of the Potential Problems Occurring in the Engineering Phase of an Industrial Project,* a report to Texaco, Inc., The University of Texas at Austin, Austin TX.

Smith, G. R. and Bohn, C. M. (1999). “Small to Medium Contractor Contingency and Assumption of Risk”. *Journal of Construction Engineering and Management*, Vol. 125, No. 2, pp. 101-108

Wang, Y. (2002), “Project Risk Management Using Project Definition Rating Index (PDRI)”, Ph.D. thesis, University of Texas at Austin, Austin, TX.